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2009 Proceedings

Adapting to Change

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Note: These proceedings are not a peer-reviewed publication. The research presented herein is a compilation of the technical papers and posters selected for presentation at the 2009 International Conference on Ecology and Transportation. Presentations were selected by the ICOET 2009 Program Committee based on a set of criteria that included relevance to the conference theme and applicability of research results. Presentations included in this document may be in full paper or abstract format. Contact information for the authors is provided where possible to encourage further networking among conference participants and other professionals about current research applications and best practices in the transportation/ecology field.

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Message from the Conference Chair

Paul J. Wagner, Washington State Department of Transportation

On behalf of the ICOET Steering Committee, I'm pleased to present the proceedings of the 2009 International Conference on Ecology and Transportation, held September 13-17, 2009 in Duluth, Minnesota. This was the fifth biennial ICOET bringing together world experts to share the most current knowledge and best practices at the intersection of transportation and the ecological sciences. Attended by more than 400 professionals, ICOET 2009 featured over 120 presentations from 16 countries in its technical program and poster sessions.

'Adapting to Change' was our 2009 conference theme, and it certainly reflects the times. We face environmental change and are learning what climate change means for us, just as we feel the effects of political change and tremendous economic change from the current recession. The environmental challenges that come with addressing transportation needs seem more urgent and more complex, requiring innovation and adaptation. The participation at ICOET by hundreds of transportation and environmental professionals, and their research contributions to the proceedings, are an important part of finding and sharing those successful adaptations.

Each ICOET brings new and exciting elements to the conference program thanks to the many organizations that participate, and this year was no exception. Some of the highlights at ICOET 2009 included:

- Presentations from 16 countries – Australia, Brazil, Canada, France, India, Ireland, Israel, Mexico, the Netherlands, the People's Republic of China, Portugal, Sweden, Switzerland, Taiwan, Wales, and the United States – were accepted this year, including several countries new to ICOET. Another first for the conference was a tribal presentation by Native American participants from Minnesota's Fond du Lac Band of Lake Superior Chippewa. Participation from the international community at ICOET greatly enriches the body of research presented at the conference, and provides a vital global perspective on both the state of the art and state of the practice in addressing ecological issues associated with transportation infrastructure.
- Rick Ridgeway, noted adventurer, author, filmmaker, and Vice President of Environmental Initiatives for Patagonia Inc., provided an exceptional keynote address on *Freedom to Roam*, a campaign and coalition founded by Patagonia to protect wildlife corridors that connect crucial animal habitats. His remarks are available for view on the conference Web site at www.icoet.net. We thank Rick for his inspiring words and generous donation of his time to attend and support ICOET.
- The 2009 Federal Highway Administration Environmental Excellence Awards ceremony was hosted for the second consecutive year at ICOET. Award winners from 12 environmental categories were recognized at the September 14 luncheon. FHWA sponsors this biennial awards program to honor state and local partners, projects, and processes that excel in meeting growing transportation needs while protecting and enhancing the environment. Details on the 2009 winners are included in the "Special Session" section of the proceedings.
- Our host agency, the Minnesota Department of Transportation, planned two excellent field trips, including one demonstrating their progressive work in reconstruction along the ecologically sensitive North Shore of Lake Superior. Mn/DOT's North Shore Scenic Byway initiatives were honored by FHWA with a 2009 Environmental Excellence Award presented at ICOET.

The port city of Duluth on Lake Superior was an ideal venue for ICOET 2009, at the intersection of land and water, striking natural beauty amid transportation corridors. We were delighted to visit this engaging location, and are sincerely grateful for the hospitality shown by Mayor Don Ness and the citizens of Duluth, by the Duluth Entertainment Convention Center, and by our Mn/DOT co-hosts who provided outstanding services to the conference.

Numerous sponsors – governmental, non-profit, and private – also deserve thanks for their contributions to bring us together at ICOET 2009. You'll find these groups listed on the back cover of the proceedings. I wish to thank personally the many volunteer members of the ICOET 2009 committees and subcommittees who worked tirelessly to plan, organize, and generate an outstanding program. I hope that you will use these proceedings to continue to advance your efforts to protect and enhance our environment when planning and implementing transportation programs.

It is not too early to begin planning for the next ICOET. The 2011 conference will be hosted by the Washington State Department of Transportation. We hope to see you there!

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Posters

Moving Toward Sustainability – Case Studies in Integrating Land Use, Conservation, Transportation, and Community Planning

INTEGRATING CONSERVATION AND LONG-RANGE TRANSPORTATION PLANNING USING A STRATEGIC ASSESSMENT FRAMEWORK

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Abstract

The Pikes Peak Area Council of Governments *Moving Forward* metropolitan transportation planning process introduced a Strategic assessment planning framework to the Pikes Peak region. This framework was selected because it integrates multi-disciplinary qualitative and quantitative information from technical experts and regional stakeholders to determine and weight objectives and indicators within the evaluation process. In order to implement this framework the regional modeling system was updated and several new technical tools added; including Natureserve's *Vista* for habitat conservation, and Placeways' *CommunityViz* for community impact evaluation. PPACG received funding from the FHWA to investigate integration and initial application of these planning tools at the regional level.

Both the biological impacts of potential transportation investments and potential locations of regional mitigation sites were determined by integrating conservation planning concepts, planned land uses, and transportation planning concepts using *Vista* software. A matrix was created to describe the compatibility of each conservation species (selected to represent a larger conservation objective) with each land use class. The analyses found that, given current urban development, there should already be serious concerns about the long-term viability of some species and that some rare and imperiled species face significant threats from planned developments. The initial output was reviewed and refined by Colorado Natural Heritage Program ecologists in order to map ecologically relevant areas of conservation importance. This information was then incorporated in the *CommunityViz* growth scenarios. Several future socio-economic scenarios and their respective conditions were developed.

The analyses in *CommunityViz* showed two key factors in the growth and development pattern of the study area. First, it showed that increasing density to support an increased transit system can concentrate growth around transportation corridors meeting or approaching transportation, social and economic goals from public input within the timeframe of the long-range plan. It also showed that a conservation plan could be applied in conjunction with this transit-oriented development to achieve publicly stated conservation goals. Combining transportation and conservation planning could successfully focus development around city centers while relieving development pressure on land that is necessary to meet conservation goals.

The best scoring alternative was not adopted by the elected leaders in the region due to its dependence on changed land uses. The reason for this is that land uses are outside the purview of MPO. However, several smaller projects resulted from the enhanced communication, including the CDOT and the Colorado Springs Stormwater Enterprise each moving water quality mitigation project locations to co-locate with a developer's project. This mitigation effort will create more total ecological benefit and an additional cultural amenity.

The primary outcome of the PPACG process is that both citizens and decision-makers are better informed regarding the tradeoffs between transportation investment decisions and other planning and development decisions that were previously made in isolation.

Introduction

Several trends are currently changing the nature of planning in the U.S. Both federal policies and requirements and input from local citizens and elected officials reflect these trends (Dietz, 2008), which include:

1. Integrating issues from traditionally separate fields, such as conservation and transportation, when making decisions;
2. Increasing public input and consider the needs and desires of all potentially affected interests in plans;
3. Increasing the use of enhanced technical planning tools to improve the performance of investments.

To increase confidence in the planning process, planners need a decision-making framework for complex multi-criteria problems that can accommodate both qualitative and quantitative information from disparate sources and of different resolutions and formats. A solution explored by the Pikes Peak Area Council of Governments (PPACG) is using a strategic assessment planning framework that is a cross between traditional NEPA analysis and integrated regional planning. This process incorporates multi-criteria analysis (MCA) that is typically used in conservation planning (Mendoza, 2004). A precautionary note: the MCA process rarely results in community consensus due to broadly perceived needs, priorities and impact distribution. It can, and in PPACG's case did, lead to informed consent for the decisions that were made. The difference between consensus and consent is that groups that were involved in the process, but did not agree with the outcomes, did agree to not actively work against implementation of the recommendations.

Inherent in this framework is the need for technical tools that provide more and better information to decision-makers on the needs, deficiencies, and trade-offs between alternative programs, projects, and service investments within a region. While many tools can do similar functions, for this effort the PPACG and the Colorado Natural Heritage Program (CNHP) used NatureServe's decision-support software, *Vista*, to conduct initial conservation planning iteratively with growth and development scenarios created via Placeways' community planning software, *CommunityViz*.

Vista integrates conservation information with land-use patterns and policies, enabling users to create plans and policies and assess their impacts on natural resource goals. With the use of its ArcGIS extension software, *CommunityViz*, stakeholders, government agencies, and community members can better communicate and understand the outcomes of a proposed project or future growth and development in a region. These tools also have the advantage that they have history of being able to communicate and work iteratively with each other.

Planning Framework

While a well-designed and executed planning framework may not eliminate conflicts, it can enhance collaboration and pinpoint areas of and reasons for conflict between different planning efforts (transportation, land-use, conservation, economic development, etc.) to further shape and refine alternatives and relationships. In order to accomplish this, procedures were undertaken to ensure the transportation planning framework was:

1. Legitimate: The process actively reached out and was accessible to all potentially affected interests.
2. Rigorous: The process did not allow those who voiced their concerns most loudly, most often, or most articulately to wield disproportionate influence. Instead, the impacts and alternatives were evaluated using scientific standards for data and analysis so that competing claims were assessed fairly.
3. Timely: The complexity of decision-making can lead to very lengthy deliberative processes. There was a need to expedite decision-making and avoid 'analysis paralysis.'

In the current planning climate, with complex and often contradictory goals prioritized by the public, decisions need to consider useful scientifically based analysis of the social, economic, and ecological consequences of investments. Confusion and suspicion can arise if a logical and well-structured decision-making process is not used to analyze and rank projects with these considerations (Dietz, 2008). This makes technical analysis more than a backroom exercise; it is inseparable from the decision-making process and must be transparent and accessible. The PPACG transportation team refined the standard transportation planning framework and used a strategic assessment framework based upon soliciting and synthesizing data and input from both citizens and technical experts from multiple disciplines to determine considerations that can inform decision-making (Mendoza, 2004).

In situations such as transportation planning, where the analysis and decisions made may be subject to later legal challenge, the ability to communicate and document how the decisions were reached is as important as the decisions themselves. A rigorous strategic assessment separates the decision elements and communicates both how the decision-making process evolved and what the result was, making it ideally suited to regional decision-making. Proper documentation of both the technical and public communication processes, the information used, and the results of each step ensure that information developed and decisions made during planning are useful and useable during NEPA studies and can be carried into the NEPA process.

When the term "decision-making" is used in planning, it generally refers to the final approval of a policy or plan. However, in the strategic assessment framework used by PPACG, both public and agency input is included in making the small decisions on which assumptions and information will be based to develop the larger analyses that are then provided to decision-makers. This process ensures that there is opportunity for the public and agencies to remain in step with the regional transportation planning process (Mendoza 2004).

Steps of the PPACG Framework

The following steps are generally listed in the order in which they occur. However, most steps are iterative as the planning process progresses.

Step 1: Establish the Foundation for Decision Making

The following transportation planning principles adopted by PPACG reflect the region's goals for its transportation system (in no particular order):

1. Preserve the existing transportation system.
2. Provide efficient transportation for people and goods.
3. Develop a multi-modal transportation system that provides access to employment, services, military installations, and other destinations.
4. Fully integrate connections within and between modes for people and for freight.
5. Increase the safety of motorized and non-motorized travel.
6. Increase the security of the multi-modal transportation system.
7. Support the economic vitality of the Pikes Peak area.
8. Improve mobility of people and goods.
9. Protect and enhance the environment by implementing transportation solutions that are sensitive to natural and human contexts.

Step 2: Determine Public and Agency Concerns and Desires

In order to continue to provide transportation customers with a system that they are willing to purchase, it is necessary to identify and incorporate their desires into investments in the system. An added regional and national goal is to consider how transportation fits within the surrounding natural and human contexts. The issues, measures, and opportunities that make up the regional context should be identified early in the planning process. This regional context encompasses transportation-related social, economic, and ecological values and issues, and the role of non-transportation agencies in the transportation planning process. Most importantly, the process requires the involvement of citizens who have a stake in the transportation system as customers, investors, and those whose quality of life will be impacted by the decisions made. The development and prioritization of issue areas was made with awareness of legal requirements and the social, economic, and ecological goals, policies, and plans of other agencies that can impact or be impacted by transportation investments.

PPACG utilized several public involvement techniques to provide a development process that is open and promotes transparency and accountability, along with establishing a solid foundation for subsequent stages of development and refinement. The specific techniques include:

1. PPACG Advisory Committees: The regular meetings of these committees and the PPACG Board are open to the public.
2. PPACG Public Participation Working Group: Supplemented the advisory committee structure and facilitated two-way communication with key stakeholders and agencies in the region.
3. Speaker's Bureau: An active outreach effort that targeted civic and community organizations, including economic development groups and homeowners associations.
4. Focus Groups: An interactive method conducted at critical milestones to gain understanding of perceptions, concerns, and knowledge about key issues. The three focus groups used by PPACG were statistically valid representations of the region based on race, income, sex, age, and geography.
5. Elected Official Briefings: Offered information on the status of the process so that the officials are able to answer questions from their constituency. These briefings occurred during PPACG Board of Directors' meetings and at the member entity council, commission or board meetings.

6. Public Fairs/Special Events: Information was provided to the public during various community events, such as farmers markets, street fairs, home and garden shows, and during community celebrations. A “traveling display” was assembled. A rating and ranking activity and short survey forms that individuals can complete quickly were administered / used.
7. Facilitated Workshops: Provided education and solicited input through facilitated sessions. As with the focus groups, they provide a mechanism for a higher level of participation in the planning process. PPACG conducted two Regional Transportation Roundtables that included a “game” where participants invested fiscally constrained funds using lifecycle cost effectiveness by specific project mode and location.
8. Open House Meetings: This format for general public meetings offers another means to enhance two-way communication by talking with citizens one-on-one and soliciting their input on the planning process. Information stations with displays and other supporting materials can be used and comment forms made available.
9. Final Public Hearing: Formally presented the recommended plan to the public in its entirety (following recommendations by the appropriate PPACG Committees and public input).

Step 3: Develop and Prioritize Decision-Relevant Measures of Effectiveness

Developing and prioritizing principles of and determining how to measure progress or impact requires the participation of many stakeholders fulfilling their roles as technical experts, policy analysts, and decision-makers. This step also provides additional opportunities for public and agency participation. At this stage the public can identify key issues and information needs that they hope or are concerned will be changed by transportation investments. Providing an open process also promotes transparency and accountability. Coordination with other planning agencies highlighted additional considerations that are traditionally considered during the project implementation process but could benefit by inclusion in the long-range transportation planning process, such as location of species or water quality issues. By weighting the principles, the region determined the relative importance of one issue against another in order to develop a regionally customized approach to balancing issues and concerns (Casper, 2006).

PPACG used a simple three-step methodology to determine the analysis that will be utilized during the long-range transportation plan development:

1. Compiled a “long list” of all concerns expressed either from data or from information provided by agencies and the community. Concerns were not excluded or pre-judged as to their relevance, value, or validity.
2. Presented the comments to PPACG’s Board of Directors who created the following “short list” of key issues:
    a. Pavement Condition
    b. Bridge Condition
    c. Efficient (Uncongested) Intersections
    d. Increased Travel Choices
    e. Safer Travel
    f. Reduced Social Impacts
    g. Reduced Natural Impacts
    h. Reduced Pollutant Emission
    i. Effective Freight Movement
3. Classified and ordered the key issues into “impact categories” for inclusion in the decision-making process.

Step 4: Gather Baseline Conditions

Effective evaluation of the severity, extent, duration, and likelihood of impacts from transportation investments requires reliable information on the current state of the social, economic, and ecological environments. Baseline information plays an important role in informing planners, decision-makers, and the public about the nature and scale of current issues. It provides an essential reference point against which to predict and monitor the outcomes of different transportation investments. However, gathering baseline information is time-consuming and expensive, particularly if field monitoring is necessary to acquire new data. The PPACG transportation team obtained data from agencies or from previous feasibility and/or environmental studies of various projects around the region.

Based on an on-going appraisal of data availability and quality, future efforts may be needed to collect new or additional data for the evaluation process based on evolving knowledge of impacts and the likelihood of impact occurrence. This adaptive effort was and will be guided by previous studies and local knowledge to identify data deficiencies and needs.

Step 5: Forecast Potential Development Futures

A well-executed analysis of options is vital to the outcome of the process. This requires development of several regional modeling systems that can provide useful forecast and evaluation of identified issues from Steps 2 and 3. PPACG utilized Natureserve's *Vista* and Placeways' *CommunityViz* for the bulk of this step, developing two initial scenarios: "Business as Usual" and "Enhanced Transportation", which is an in-fill-focused scenario.

A major issue with this step was educating transportation and other agency technical staff, decision-makers, and the public on the analytical limitations of the various models and evaluation systems and convincing them that a solution to uncertainty is use of scenarios. Prediction and evaluation methods often involve a degree of uncertainty, particularly where information is limited and environmental impacts are difficult to predict. A good technical process will include uncertainty and adopt a precautionary approach to decision-making while still enabling consideration of the broader and more complex issues and interactions such as land use and environmental (social, economic, and ecological) protection.

The complexity of the land development process, evolving travel decisions, rapidly changing forms of industry and commerce, a swiftly shifting population structure, changing lifestyles, increasing motor vehicle fuel costs, and alteration in the value of time, means that even a perfect set of forecasting models will not eliminate uncertainty. As a result, it was necessary to achieve some level of agreement on what constitutes useful measures of effectiveness and evaluation. The PPACG transportation team chose to combine input from committees and other interested parties to develop several scenarios instead of trying achieve a single perfectly accurate forecast. Awareness of what the purpose of each scenario was allowed erring on the side of caution and better bracketing of the analyses.

> *The point is not so much to have one scenario that 'gets it right', as to have a set of scenarios that illuminate the major forces driving the system, their interrelationships and the critical uncertainties.*
>
> Peter Wack *(1985)*

Step 6: Create Transportation Investment Scenarios

PPACG began to develop five general transportation investment philosophies, listed below, that would then be consolidated into idealized future systems based on coherent philosophies relayed during the public and agency involvement process. Total costs and effectiveness of the different systems were to be evaluated. Ideally, the combination of these scenarios would have painted a picture of the total regional transportation vision and needs. Additionally, from these vision systems, a fiscally constrained subset of transportation system improvements would be derived to include in the Regional Transportation Plan. The lengthened time of the analyses and public discontent with some concepts interrupted these planned processes.

1. Provide Maintenance Only: What is the cost to maintain the current conditions or achieve desired conditions? This analysis showed approximately $2 billion in existing backlog of maintenance needs increasing to $7 billion in maintenance needs by Year 2035.
2. Management and Operational Improvements Only: What effect could be realized with transportation system management strategies, including advanced technological improvements and coordination, and at what cost? This concept was only generally explored during this plan update.
3. Free Flowing Roads: What is the total cost to not have any roads with a volume-to-capacity (V/C) ratio over 1.0? After showing the public examples of four-lane roads that needed to be expanded to ten lanes and two-lanes that needed to be increased to six, this option was abandoned.
4. High Quality Public Transportation: What transit system can be implemented for the same cost as free-flow roads and what is its effectiveness? This analysis showed that we could quadruple bus service and implement four bus rapid transit routes and commuter rail along the Front Range.
5. Non-motorized Dominant: What is the cost to fully implement a trails and "complete streets"-type system? The greatest disparity between planned/needed facilities and available funding was for non-motorized system improvements. Funding would need to increase by an order of magnitude to make measureable progress in implementing this system.

The three transportation investment scenarios that were developed and evaluated were:

1. Strategic System Investment: A continuation of existing road-centric investment practices.
2. Environmentally Least Damaging: Maintenance of existing roads and bridges, improving operational characteristics of the roads, and construction of transit and non-motorized facilities.
3. Balanced Investment: Seeks a middle ground between the other scenarios.

Step 7: Evaluate and Refine Scenarios

The 2035 Regional Transportation Plan used Multi-Criteria Analysis (MCA) to analyze projects and scenarios. MCA is an analysis tool developed for complex multi-criteria problems that include both qualitative and quantitative information in the decision-making process. MCA is based upon obtaining input from both experts and stakeholders. These inputs are solicited and synthesized to arrive at a collective decision, or choice, regarding the selection and use of a weighted set of criteria based upon known objectives and indicators. During this step both transportation and development scenarios identified in Steps 5 and 6 were iteratively refined to increase benefits and decrease negative impacts. This step focused on whether or not to implement projects. It worked very closely with the following Step 8.

Step 8: Identify methods to Minimize and Mitigate Unavoidable Impacts

PPACG transportation planning Principle 9 states that the transportation solutions that are selected should be sensitive to the natural and human contexts. SAFETEA-LU requires a transportation plan to discuss mitigation measures that protect, enhance, and restore social, economic, and ecological functions that are the unavoidable result of transportation projects. The desired outcome of this step was to identify and avoid, minimize, mitigate, or remediate negative impacts. This analysis focused on changes within projects that could increase benefit or decrease negative impacts of individual projects. This information was then used to further refine scenarios identified in Steps 5, 6, and 7. Overall policies for different impact categories were also identified.

Step 9: On-going Monitoring / Adaptive Planning

A Continuing, Cooperative and Comprehensive (3-C) planning process requires that policies, programs, plans, and projects integrate and adapt to changes in design, management, and monitoring techniques in order to systematically assess and improve the effectiveness of the planning process and technical analysis. Appraisal techniques themselves must be evaluated and their effectiveness in predicting the outcomes of particular decisions put to the test. Monitoring plays an essential role in providing information on whether a strategy or plan is delivering its desired outcomes. It also assists in the early identification of unintended environmental impacts and provides information to update and fill gaps in baseline data necessary to inform future strategy development.

Integrated Analysis / New Tools and Techniques

Two evaluation tools not previously a part of PPACG transportation planning were used during Steps 2, 3, 4, 5, 7, and 8: Natureserve's *Vista* and Placeways' *CommunityViz*.

Overview of NatureServe Vista

NatureServe *Vista* is a relatively new decision-support tool for land use and conservation evaluation and planning that operates as an extension to the Environmental Systems Research Institute, Inc. (ESRI) software ArcGIS version 9.x. Its primary purposes are to identify high-priority areas for conservation, evaluate competing land-use plans, identify uses that conflict with conservation goals, and compare different stakeholder values and visions in order to highlight areas of agreement or conflict (NatureServe, 2006).

There are two main outputs from NatureServe *Vista*: Conservation Value Summaries and Scenario Evaluations. Conservation Value Summaries (CVS) are straightforward accounts of species richness in a particular area, or they can be used to summarize the overall conservation value of an area by integrating occurrence viability, data confidence, and any number of subjective weights and filters based on special considerations or objectives. For this project, two weighted CVS's, one based on legal protection and management of target species, the other based on CNHP conservation priorities, were run to identify the relative conservation value (low to high) of different areas in the region. Scenario Evaluations indicate areas with compatible land use and adequate protection policies to meet target conservation goals (NatureServe, 2006).

Overview of CommunityViz

CommunityViz is designed to help stakeholders, government agencies, and community members develop, analyze, visualize, and communicate the outcomes of a proposed project or future growth and development. *CommunityViz* produces both dynamic custom outcome analyses and a visual representation of each future scenario to facilitate comparison between scenarios. *CommunityViz* is an extension of ESRI's software ArcGIS version 9.x (Placeways, 2007).

As with all computer modeling and analysis tools, the outputs generated by these tools are only as good as the input data. Ecological and human systems are complex, and comprehensive data is sorely lacking. *CommunityViz* and *Vista* are only support tools. They cannot and should not make decisions for the users; their use should be limited to highlighting areas of perceived importance for further consideration and research. Additionally, *Vista* does not take into account seasonality, either in regard to a species' use of an area or to fluctuating recreational or traffic volumes.

Initial Issue

For analysis purposes it was important to develop a common land-use classification system for the study area. The Colorado Natural Heritage Program (CNHP) worked with PPPCG and Placeways to produce a single land-use classification scheme that would meet analysis needs for multiple tools. The system categorized each zoning code into a major and a minor category. For Vista, additional information on protected public and private lands was added from the Colorado Ownership Management and Protection (COMaP) layer (CNHP, 2008).

Vista Set-up

Biological Conservation Target Selection

A total of 59 conservation targets were chosen for the project: 23 plants, 2 amphibians, 3 reptiles, 12 mammals, 9 birds, 3 fish, 5 insects, and 1 mollusk, plus CNHP-designated Potential Conservation Areas (PCAs). Most targets were chosen based on their previous use in one or more other conservation planning efforts, such as The Nature Conservancy's ecoregional plans or the Colorado Department of Transportation's Shortgrass Prairie Initiative. Several targets, such as the six big-game species, were included at the request of stakeholders. The PCAs were used in lieu of good data on quality wetlands. A PCA is defined by CNHP to be the best estimate of the area necessary to support long-term (100+ years) survival of populations of target species or natural communities. A PCA may require management or restoration to ensure their long-term persistence and functionality, but they do not necessarily preclude other human activities within the area (CNHP, 2007a).

<table>
<tr><th>Major Category</th><th>Minor Category</th></tr>
<tr><td rowspan="2">Government</td><td>Large Military Installations</td></tr>
<tr><td>Other Government</td></tr>
<tr><td rowspan="6">General Urbanization</td><td>Commercial</td></tr>
<tr><td>Industrial</td></tr>
<tr><td>Mixed Use</td></tr>
<tr><td>Office</td></tr>
<tr><td>Community/ Public Buildings</td></tr>
<tr><td>Infrastructure/General Urbanization</td></tr>
<tr><td rowspan="7">Residential</td><td>High-Density Urban</td></tr>
<tr><td>Medium-Density Urban</td></tr>
<tr><td>Low-Density Urban</td></tr>
<tr><td>Suburban to Exurban</td></tr>
<tr><td>Exurban to Rural</td></tr>
<tr><td>Residential Mixed Use</td></tr>
<tr><td>Undeveloped Private</td></tr>
<tr><td rowspan="2">Parks, Recreation, Greenbelt</td><td>Park/Greenbelt</td></tr>
<tr><td>Protected Open Space</td></tr>
<tr><td>Agriculture*</td><td></td></tr>
<tr><td>Unknown or Road</td><td></td></tr>
</table>

Figure 1. Land-use classification scheme.
***Due to limitations of the source data, "Agriculture" is assumed to include both cultivated land and open rangeland.**

Most of the data used to represent target occurrences and viability were derived from CNHP's Biodiversity Tracking and Conservation System (BIOTICS) Element Occurrence, Observation, and Potential Conservation Area datasets (CNHP, 2007b). Big-game data and some supplemental raptor data came from the Colorado Division of Wildlife's Wildlife Resource Information System (WRIS) (CDOW, 2006). Additional fish locations were provided from the Fountain Creek

Watershed Study (URS, 2006). Data that were considered historic or of poor precision were not used. Precise location polygons were used when available. When only point data were available, the points were buffered by 1/10 mile (160 m) in accordance with standard CNHP natural heritage methodology. CNHP data are precise locations, whereas WRIS data for the most part represent broader seasonal distributions of species. WRIS distributions that blanketed the entire study area were not included, because they did not contribute information as to the critical areas to conserve within the two counties. The remaining distributions were combined in an additive manner, resulting in a single layer with ranked areas of importance to each big game species.

Target Integrity and Data Confidence Scores

In addition to species distribution, NatureServe *Vista* also accommodates information on the quality of location and confidence in data used. These scores are ranked from 0 to 1 and are incorporated in *Vista's* Conservation Value Summaries. Each target polygon was ranked as to its quality and level of data confidence. Observation data quality was ranked according to Use Class, big-game data were ranked based on the number of overlapping WRIS distributions and PCAs were ranked based on their Biodiversity Ranking. The fish locations from the Fountain Creek Watershed study were given a single, medium rank of quality due to lack of information. Data confidence ranks were based on mapping precision of Element Occurrence (EO) and Observations, mapping status for PCAs, and single values for WRIS and Fountain Creek Watershed Study data as general indicators of perceived data accuracy.

Land Use Compatibility Designations

Literature review and expert opinion were used to create the compatibility matrix that describes the compatibility of each conservation target with different land uses. NatureServe *Vista* analyzes land use as either compatible or incompatible with each species, existence. The dichotomy of having to designate all land uses as either compatible or incompatible to the persistence of a species or landscape is extremely limiting, especially because not all relevant land uses could be reliably mapped over the project area. A primary example of this is the difference between rangeland and agriculture. Many species are compatible with open rangeland, and very few are compatible with active cultivation of cropland. However, these two land uses could not be reliably distinguished with the available data and so were lumped into one “Agriculture” category.

Conservation Goals and Risk

Conservation goals were based on the Natural Heritage Network Ranking System, taking into account both Global (G-rank) and Subnational (S-Rank) ranks, and using three levels of risk for effectively conserving target species (NatureServe 2002). The low-risk goal set provides the best chance of conserving the species, the high-risk the worst. In evaluating the various scenarios, NatureServe found a clear tipping point between high- and moderate-risk goal sets, but no real difference in evaluation results between moderate- and low-risk goal sets. Because of this finding and the project's time constraints, NatureServe concentrated on evaluating just the Moderate risk goal set against the three scenarios. However, all three goal sets are included in the electronic deliverable for future use. It is important to note that these are broadly applied goals based on a simplified ranking system. Effective conservation of any specific population in a specific area cannot be guaranteed through the use of these goal sets. On-the-ground inventory and monitoring is the only way to assure the effectiveness of conservation efforts for any particular species (CNHP, 2008).

For the legal concern and management summary, each target was ranked based on its level of legal protection, if any, or other level of government-mandated management concern. The U.S. Endangered Species Act takes precedence, followed by the Colorado Endangered Species List, then the Migratory Bird Treaty Act, then USFS & BLM Sensitive Species Lists, and finally management of game species. These ranks are not cumulative. If a species is protected under more than one mandate, then it was assigned the highest weight it could receive. Because PCAs do not receive any legal protection, they were given a weight of zero, which effectively removes them from the summary evaluation. All insects, the one mollusk species, and about half of the plant species on the target list also have no protection and so did not contribute to this summary (CNHP, 2008).

For the CNHP conservation priority summary, each target was ranked by its assigned S-Rank, except for PCAs, which do not have an S-Rank. These areas are already identified as important to conservation of rare and imperiled species and natural communities and were therefore given the highest weight possible. NatureServe *Vista* analysis is based on values ranging from 0 to 1; the highest possible rank is a 1.0. This information was given to Placeways, who utilized in the CommunityViz growth models (CNHP, 2008).

The output of a Conservation Value Summary in Vista is a floating-point grid that ranges in value from zero (0) to a maximum that depends on the number of overlapping targets, each multiplied by their weights, viability scores, and data confidence scores (if used). The results are difficult to interpret, so the raw output of each CVS was reviewed and refined by CNHP ecologists in order to create discrete polygons representing ecologically relevant areas of conservation importance. Each raw CVS grid was classified into discrete levels of conservation importance (Figure 2). Figure 2 shows that the two analysis summaries, “CNHP High Value” and “Legal Concern,” are two different ways of viewing the same data. The value thresholds for these categories were based on relating each combination of target weight and viability score back to CNHP’s own ranking methodologies (CNHP, 2008).

Polygons were then manually drawn around all areas of extreme importance while trying to include as many areas of "regular" importance as possible. These delineated polygons may be larger or smaller than the actual "hotspot" areas shown by the CVS grid. All of the areas represented in these two datasets are considered important to conserving either rare and imperiled species (CNHP High Value) or legally protected species (Legal Concern). However, as shown in Figure 3, the polygons have been further subdivided into "tiers." Tier 1 polygons are those of critical importance; Tier 2 polygons are not critical, but are nevertheless important and should not be disregarded. Zonal statistics were run on the final polygons using the original CVS grid as the value layer. The results were appended to the attribute table of the polygon layers. Those polygons that fell within the top 20% of the Zonal Sum value were attributed as Tier 1 polygons with the remainder assigned to Tier 2 (CNHP, 2008).

Reasonable effort was made to represent areas that are both ecologically meaningful and practical for conservation planning, but no guarantee is made that these areas fully meet either condition. Element occurrence and observation data (on which the CVS grid is largely based) are precise locations and do not necessarily reflect the full area required for a population or dependent community to persist. These areas are based on best professional judgment given the time and information available, but are not guaranteed to represent either necessary or sufficient habitat for functioning populations of the target species.

Legal Category	Weight		S-Rank	Weight
USESA			S1	1.00
Endangered	1.00		S2	0.95
Threatened	1.00		S3	0.80
Candidate	0.70		S4	0.66
State Listing			S5	0.10
Endangered	1.00		SU	0.50
Threatened	1.00		SNR	0.50
Candidate	0.70		SNA	0
Migratory Birds	0.80		SX	0
Sensitive Species Lists			SH	0
BLM/USFS	0.60		PCAs	1.00
BLM	0.50			
USFS	0.50			
Big Game	0.125			

Figure 2. Priority weights.

CNHP High Value CVS	Legal Concern CVS	Category
0 to <0.6	0 to <0.6	not of immediate conservation importance
0.6 to <1.0	0.6 to <0.8	important for conservation
1.0 and greater	0.8 and greater	extremely important for conservation

Figure 3. Conversion of summarized conservation value into discrete categories.

Conservation Analyses

Existing Conditions

An Existing Conditions Scenario was created to represent current land use. This land-use layer was input into

NatureServe *Vista* using the *Override* functionality. This functionality creates a single raster layer that describes only one land use present in any one cell. In cases where overlapping land uses exist, a system of precedence is used to determine the dominant land use. The data used to develop Vista's initial Baseline Scenario is very important. These data determine the resolution and accuracy of all future Scenario Evaluations. Therefore, it is very important that Baseline Scenario input data are as robust and accurate as possible.

When NatureServe completed the Existing Conditions Scenario comparison against the moderate-risk goal set, only 39 out of 59 (66%) of the conservation targets met the moderate-risk conservation goals. What this means is that a full one-third of identified species have a moderate risk to their continued survival in the Pikes Peak area, including the three federally listed species that occur in the study area. This is only to be expected, because if they were not threatened by human activities they would not be federally listed. This analysis also points out all of the other species whose long-term viability is threatened and are not yet listed. Of particular note are four species that no longer have lands compatible with their long-term viability remaining in the region. These are the Colorado blue butterfly (*Euphilotes rita coloradensis*), the hog-nosed skunk (*Conepatus leuconotus*), the Front Range alum-root (*Heuchera hallii*), and the Pikes Peak spring parsley (*Oreoxis humilis*).

After the Existing Conditions Scenario was generated, this raster layer was then passed to Placeways for use in growth modeling in *CommunityViz*, which was used to generate two Year 2035 growth scenarios: a "Business As Usual" scenario and an "Enhanced Transportation" scenario. Protected lands, steep slopes, and the proposed Fort Carson conservation buffer were considered during this process.

Creation of Development Scenarios

Scenario Development requires three main inputs: a desirability map, land suitable for development, and the projected population increase from 2005 to 2035. First, a desirability map was created to calculate each polygon's attractiveness to growth and development given no natural, zoning, or capacity constraints. This map gives a desirability score to each polygon based on a number of inputs. The inputs are factors that influence growth and can be weighted in relation to one another.

Next, the buildable land was determined by eliminating water, protected lands, military installations, and roads from the area in which populations could be placed. This input acts as a mask, preventing growth from occurring in these areas. The zoned capacity of the remaining land area was then calculated based on the acreage and allowed dwelling units per acre.

The final step was to allocate the expected population increase to the land-use polygons based on the desirability map. The population is allocated so that the most desirable places fill up first and so that population cannot exceed the zoned capacity.

The analysis evaluated three different growth and development models: Business As Usual, Enhanced Transportation, and Conservation. The Business as Usual model is the default or base model, which assumes that the Colorado Springs region continues to develop in the same pattern, density, and speed that it currently demonstrates. The Enhanced Transportation and Conservation models were created by making alterations to this base model. For the Enhanced Transportation model, bus rapid transit and commuter rail routes and stations were added to the analysis. The zoned density around these areas was increased to allow for more population to be placed near public transportation. For the Conservation model, the land determined by CNHP to be areas of high conservation value were rezoned to "Conservation," thus preventing development in these areas during the allocation process.

After the initial growth models were set up, it was important to collect local knowledge that might not be reflected in other input data. Placeways met with local agency staff to discuss and gather relevant knowledge that could be utilized to further refine the analyses. Local knowledge included natural, social, and political determinants of development, mixed use zoning densities, enhanced transit routes and station locations, and overall development potential. The information was applied to each relevant growth model. Three scenarios were developed and evaluated: Business as Usual, Enhanced Transportation, and Conservation of Critical Lands.

Business As Usual Scenario

The Business As Usual model, adopted by the PPACG Board of Directors as the official forecast for air quality conformity purposes, continues policies that have produced the current regional growth pattern. This forecast was originally conducted using TELUM in order to begin to incorporate travel conditions into location of growth forecasts. The results were then paralleled in *Communityviz* by changing attraction and repulsion levels until the two results mirrored each other. The resulting scenario predicts that development will continue to grow outward from the core of Colorado Springs. When NatureServe evaluated the Business as Usual land development scenarios less than half (29 out of 59 or 49%) of the conservation targets met the moderate-risk conservation goals and six additional (a total of 10) species did not have any occurrences of compatible lands remaining. Those newly identified species are the roadside skipper (*Amblyscirtes simius*), Gunnison's prairie dog (*Cynomys gunnisoni*), Townsend's big-eared bat (*Plecotus townsendii pallescens*), Front Range milkvetch (*Astragalus sparsiflorus*), Front Range alum-root (*Heuchera hallii*), and Porter feathergrass (*Ptilagrostis porteri*). Figure 4 shows the location of growth in the Business as Usual scenario.

Enhanced Transportation Scenario

This scenario utilized existing zoning policies, applied in ways that differ slightly from current implementation. Specifically, this scenario included the installation of a bus rapid-transportation system in Colorado Springs as well as a commuter rail line along the Front Range. These new transit facilities served to focus regional growth using existing mixed-use zoning policies within ¼ mile of the transit facilities. The corridors for Colorado Springs' four bus rapid-transit lines were obtained from the Colorado Springs Rapid Transit Feasibility Study and System Master Plan and were enhanced with input from the local staff. The station stops for the commuter rail route were located along the Burlington Northern Santa Fe based on current intersections of transportation networks, downtowns, and population centers. Figure 5 shows the location of growth in the Enhanced Transportation Scenario. The size of the Transportation Analysis Zones masks much of the detail associated with the implementation of transit corridors.

The Enhanced Transportation Model demonstrated a growth pattern that was more compact with mixed uses compared to Business As Usual. Densification appears most notably around the nodes and corridors of the bus rapid-transit systems. When NatureServe evaluated the Enhanced Transportation Scenario, 28 out of 59 (47%) of the conservation targets met the moderate-risk conservation goals (Table 11). Differences between this scenario and the Business As Usual scenario are the greatly increased densities along the transit corridors, which creates more incompatibilities in these areas. The one additional target that did not meet goals in this scenario compared to Business as Usual is the Ferruginous Hawk (*Buteo regalis*), which went from 4 occurrences (121% of goal) on compatible land uses to 3 (91%).

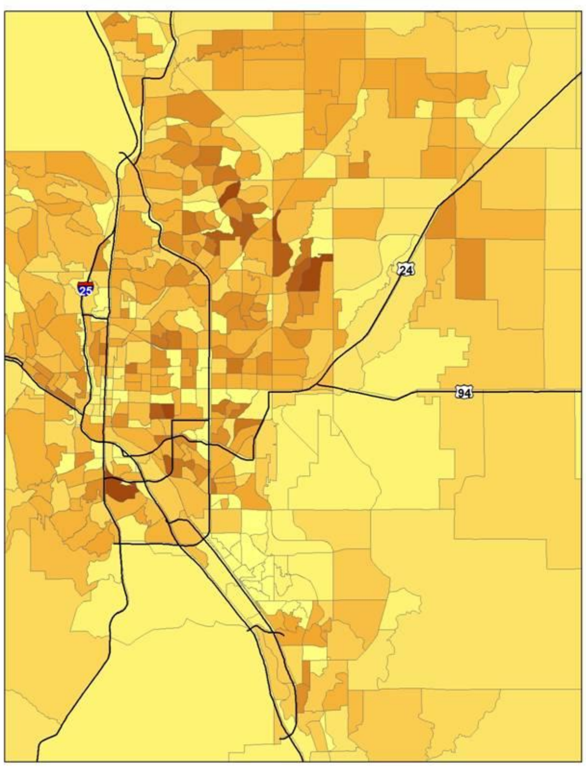

Figure 4. Location of regional growth under Business As Usual. Darker indicates more growth.

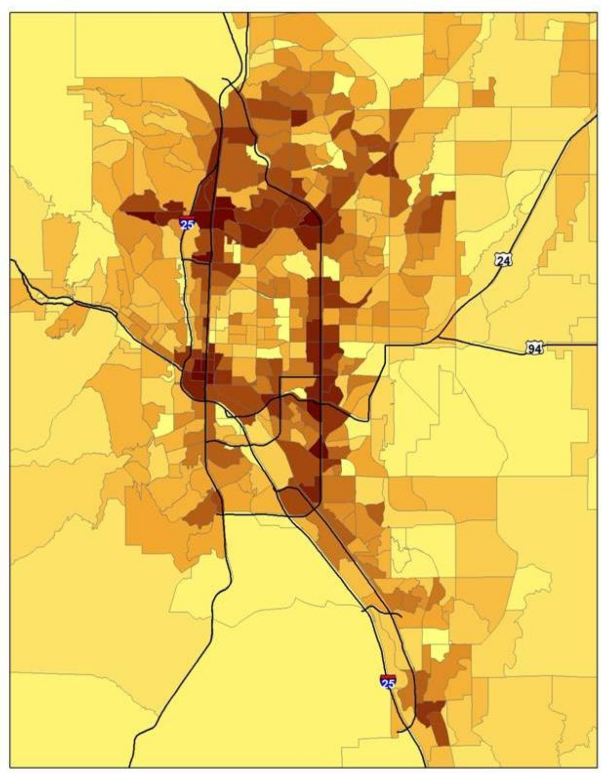

Figure 5. Location of regional growth under Enhanced Transportation. Darker indicates more growth.

Conservation of Critical Lands

Vista's Site Explorer tool is an interactive conservation planning tool that allows users to point-and-click on land-use parcels within the project area and view the presence and condition of conservation targets within the parcel(s). Parcel units are determined by designating the spatial layer to use on the Scenario Evaluation form. After identifying the properties of conservation targets within the parcels, users can develop mitigations by changing the land use in a parcel to a use that supports the health and persistence of that target (i.e., a land use that has been designated as "compatible"). These land-use changes, or mitigations, can be exported as shapefiles and incorporated into Communityviz scenarios.

This exercise created an example Conservation of Critical Lands Scenario and evaluated it against the other scenarios. NatureServe staff selected parcels with high concentrations of conservation targets and changed them to various compatible land uses. When this example scenario was evaluated using the Business As Usual growth model, the number of conservation targets that met the conservation goals increased from 29 to 30. The Conservation model produced a scenario similar to the Business As Usual model, with the growth pattern appearing like an extension to the current growth pattern. What changed most dramatically was that the location of development occurred further from the urban core, creating a "leap-frog" effect.

Summary

Areas of greatest conservation value and regulatory concern were initially identified in *Vista*, refined by ecologists and then entered into *CommunityViz* growth models as areas where new or continued growth is undesirable. The growth models produced future development scenarios, which were then passed back into *Vista* for evaluation against conservation goals. These growth scenarios were iteratively input into the travel demand model to evaluate traffic conditions.

The *Vista* analyses highlight species that are threatened, either by existing or potentially planned development, including those that are not yet federally listed under the Endangered Species Act. This information can help planners be proactive in their development plans and reassure regulatory entities that conservation values are being taken seriously and incorporated early in the process. Both the Business As Usual and Enhanced Transportation scenarios created undesirable impacts on conservation targets, and further study showed that there are some species that cannot successfully be protected within the Pikes Peak region given forecast levels of growth.

The analyses in *CommunityViz* showed two key factors in the growth and development pattern of the study area. First, it showed that a bus rapid-transit system does have the potential to concentrate growth around city centers. It also showed that a conservation plan, applied in conjunction with a transportation plan, is more effective than either done separately. In the Conservation scenario, development was shown to leap-frog land that was removed from development for conservation purposes, thus producing little change from the Business As Usual scenario. A combined transportation and conservation plan has the potential to focus development around city centers while relieving development pressure on land that can help to meet conservation goals.

The authors of this report would like to emphasize that all results given here and in the accompanying electronic data are preliminary and based entirely on available spatial data, which may not accurately reflect conditions on the ground. Consultation with appropriate state and federal regulatory agencies is always necessary, and planners are urged to conduct on-the-ground biological and reconnaissance surveys, and to solicit public comment before finalizing any plans. More detailed or up-to-date data may significantly change the results of these initial growth models and scenario evaluations.

This project's greatest value can only be realized by using the databases, methods, and expert knowledge hand-in-hand. The general trends identified in this project are predictable: a loss of conservation targets due to increased growth. However, the spatial analyses in this project provide probable causes and locations for the loss of specific target species. With this precious information planners can identify problem spots and focus attention on those areas containing the species of greatest concern. As land-use changes are made, planners can then reevaluate the status of conservation targets, getting quantitative feedback about the impact of their decisions. The first and most productive initial step may be simply to identify those locations where species are incompatible with the land use, and local knowledge suggests that there is an opportunity to modify that land use.

Mitigation

An important point to note is that conservation goals were not met for a full third of the targets in the Existing Conditions scenario. This indicates that planners should already be concerned about the long-term viability of a number of rare and imperiled species in El Paso County, and that continued urban development will worsen the situation, even with proactive action. These analyses and discussions with resource agencies have led to PPACG considering using off-site and out-of-kind compensatory mitigation to proactively protect key species in the Pikes Peak region.

Off-site out-of-kind mitigation could increase conservation benefits by proactively protecting a large resource or a complex of habitats that would accomplish other goals and avoid discontinuous mitigation sites that are surrounded by urban features that will suffer increasing pressures. By focusing on species most heavily impacted by the growth projections that can be protected in the region, and using conservation principles for those species out-of-kind out-of-region, efficient and cost-effective gains can be made for conservation targets.

Two specific species that could benefit from this approach are the Townsend's big-eared bat, which is a candidate species for state listing and is considered imperiled in the state of Colorado (S2), and the Porter feathergrass, which occurs only in Colorado and is also considered imperiled. Neither of these species is currently threatened within El Paso County (as modeled by the Baseline scenario), but both become highly threatened in all of the future scenarios considered. Several other species and the Potential Conservation Areas follow this same pattern, which is also a concern, but the Townsend's big-eared bat and Porter feathergrass are the most vulnerable of these targets in the state.

While the Mitigation scenario produced during the study is only one example, it demonstrates how *Vista* can take scenarios generated by *CommunityViz* growth models and manually protect some individual parcels to refine planning objectives to best meet conservation goals. Combining local knowledge with the predictions of goal achievement for target species can yield results that are informed by ecologic and economic models, as well as an *in situ* understanding of realistic pressures and opportunities across the project area.

Conclusions and Recommendations

The primary outcomes of the PPACG process are better informed citizens, while decision-makers have more understanding of the relative priorities of citizens and impact tradeoffs between transportation investment decisions and other planning and development decisions. This planning framework depicts the decision-making process in a way that makes it ideally suited to communicate the basis of each decision. This communication is rigorous enough that it is likely to produce documentation and analysis that can be carried into the NEPA project development process. Another discovery by the study team is that a technical process that produces results that are expected/desired by elected leaders is considered much more accurate than one that produces something unexpected. Further refinement of the process and tools to generate a more complete accounting of the direct, indirect, and cumulative impacts of policies and investments is warranted.

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Looking to the Future with Retrofit Options from Lessons Learned

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Abstract

A statewide inventory and evaluation is in process for existing structures having potential for being modified for usage by wildlife. Using lessons learned from our research involving wildlife connectivity and related reduction of wildlife/ vehicle collisions, we would apply effective retrofit options in areas that may not be slated for immediate extensive upgrades. Many of these solutions are inexpensive and simple. On a segment of roadway that has a high number of recorded road kill, a targeted retrofit can provide huge safety benefits without a large financial commitment. Several of these cost saving remedies will be discussed. For example, a simple low cost alternative to removing existing right of way fencing and replacing it with traditional elk proof fencing involves the use of fence extensions. By way of another example, utilizing the topography in an area to create slope jump-outs for elk eliminates the necessity of building an actual structure. In times of budgetary constraints, such practices offer an inexpensive means of increasing safety and promoting environmental stewardship.

Introduction

Arizona is rapidly reaching a crossroads where development is colliding with the ecological and natural resources of Arizona. If not addressed, this issue will ultimately affect the quality of life of all residents and visitors. The projected increase in population and subsequent demand for movement of goods, services, and people in Arizona increase the impacts of highways on Arizona's wildlife and environment. Vehicle mobility and biodiversity are State priorities, but one option does not have to come at the expense of the other.

Arizona is experiencing a serious economic down turn along with many other states. The Arizona Department of Transportation (ADOT) has incurred substantial budget cuts during the current as well as the last fiscal year. In order to continue to reduce wildlife vehicle collisions statewide, retrofit options are being considered as many of the larger highway upgrade construction projects are being put on hold. These retrofit options will allow site-specific solutions that will have immediate benefits rather than waiting for the funding for the overall upgrade of the area. Reducing the risk of collisions between the motoring public and wildlife will mean fewer human injuries and fatalities, less money spent on vehicle repair, reduced insurance costs, and reduced mortality in wildlife populations.

Over the last decade, the State of Arizona has constructed numerous wildlife passage structures, fencing and associated structures that provide for highway safety and increase wildlife permeability allowing large mammals such as elk, deer, coyote, bear and javelina to pass beneath certain roadways. In conjunction with this, a variety of ungulate-proof fencing methods have been utilized to funnel wildlife through these structures. Research continues to evaluate the effectiveness of these measures. ADOT is using monitoring and research data to improve wildlife vehicle collision mitigation measures.

Discussion

Sections of roadway that are not currently scheduled for major roadway improvements that have a relatively high occurrence of road kill can be considered for retrofit options. The area is cross-referenced against the *Arizona's Wildlife Linkages Assessment* to determine if the area falls within an identified potential linkage zone providing additional information for the area. Existing structures within the segment are investigated with respect to several criteria. One of these is the size to determine the openness ratio present to determine adequacy for the identified species. The evaluation of the structures also includes surrounding land ownership, land use, terrain, and distance to additional structures, obstructions/deficiencies, as well as additional threats such as off-road vehicle usage.

Because road kill data is crucial to wildlife connectivity planning, ADOT and the Arizona Game and Fish Department (AGFD) signed a Memo of Understanding (MOU) in February 2008 to work cooperatively to collect wildlife vehicle collision data that includes a shared database. Prior to this, numerous databases existed statewide that had limited access and differing reporting methodology. This MOU has brought all of these disconnected databases together and has attempted to standardize the information. The amount of available data is augmented through this collaborative approach. In addition, the quality of the data is increased through the use of a standardized wildlife vehicle collision reporting form by both agencies that ensure consistency. Location accuracy is understood to be necessary to determine spatial patterns of collisions (Sielecki 2001). This has greatly increased our ability to focus on particular areas of concern where wildlife and highway operations are most severe. The collection of road kill data goes beyond just the large mammals, which have been the primary focus of accident reporting of wildlife vehicle collisions. Analysis of road kill data to determine priority areas aids in the efficient use of limited funding.

Utilizing the results from research conducted through the Arizona Transportation Research Center (ATRC) as well as surveying research nationally and internationally, improvements to keep wildlife off the roadway can be made. The studies on SR 260 have made it abundantly clear that fencing and the height of the fence is a critical component. Fencing should be considered as an integral component of wildlife mitigation measures, since permeability in concert with effective passage structures, should extend outward from passages at a distance that sufficiently funnels animals, intercepts peak crossing zones, and prevent at-grade crossings. Looking at the pre-fencing and post-fencing data, a clear safety benefit can be achieved (Dodd et al. 2007). The addition of fencing to an existing structure that is large enough to accommodate wildlife is an inexpensive means that will rapidly address safety issues in an area. Fencing combined with underpasses and overpasses, as appropriate, is a broadly accepted method that is theoretically sound and proven to be effective in the reduction of wildlife vehicle collisions (Hedlund et al. 2004). The use of ungulate proof fencing commonly increases elk use of underpasses or overpasses by 80% or more (Ruediger et al. 2005).

Fencing height and type will differ for different species, which makes road kill identification a key component in determining retrofit options. Some species such as elk and bighorn sheep require eight-foot tall fencing in order to keep them off the roadway while a species such as the desert tortoise requires shorter, dense fencing. Another study on SR 260 is looking at different types of fencing and their associated costs. These include ElectroBraid fencing, right-of-way extension, and elk riprap.

Elk riprap consists of closely spaced large boulders, two feet and greater in diameter (Figure 1). Research has shown that is necessary to have all gaps filled order to effective. This is a point is crucial. The boulders are laid in a swath that is approximately eight-feet wide. This option also has the added benefit that, in the long term, little or no maintenance will be required. One drawback is the slightly higher initial investment. Overall, this is designed to work in the same manner as the elk proof fencing. It deters the movement of elk across the highway and aids in funneling wildlife to an underpass thereby increasing permeability. One measure that has proven to be ineffective as a means to discourage elk from entering the roadway is the use of cut-slopes. Elk have been shown to be able to traverse 60 degree and greater slopes.

In conjunction with fencing, escape ramps are a necessity. In the event an animal manages to get onto the roadway is trapped within the exclusion fencing, a means to get off the road is provided. Originally, large escape ramps have been constructed on SR 260 and US 93. AGFD designed an escape ramp that ADOT has incorporated into the right-of-way fence that is dependent on the area's slope in order to forego the need for the construction of a ramp. An opening is left in the fencing. An animal is able to jump down, but it will be unable to return to the roadway. Utilizing these slope-jumps reduces the expense of building the structure.

It is not only the larger wildlife that requires fencing for funneling through wildlife crossing structures. Wildlife such as desert tortoise, skunks, fox, coyote, etc. need specialized fencing to prevent animal/vehicle collisions. All road kill has the potential to cause more road kill. Scavenging species such as eagles, hawks, coyotes, etc, are likely to be hit by passing vehicles leaving them dead or maimed. Eagles in particular are susceptible to such threats. Also, the type of fence should not create a situation where it becomes a hazard to the wildlife rather than a benefit.

In some cases, fencing is not enough. ADOT is going beyond just standard tortoise fencing to help the desert tortoise. On the Gonzales pass segment of US 60 outside of the town of Superior, some culverts are getting tortoise ramps. These culverts experience high water flow events. Because of these flows, large riprap was utilized to help dissipate the water force. Unfortunately, this size of riprap is not conducive to desert tortoise movement. In particular, there is a great risk to juvenile tortoises due to the spacing between the rocks in uniformly gradated rock mulch since there is a greater danger of them getting stuck and unable to get out. In response to this, ADOT has added a concrete tortoise ramp to an otherwise "normal" culvert that allows tortoise passage through the riprap (Figure 2). One of the pathways also required the construction of an incline to assist the tortoise in accessing the culvert (Figure 3).

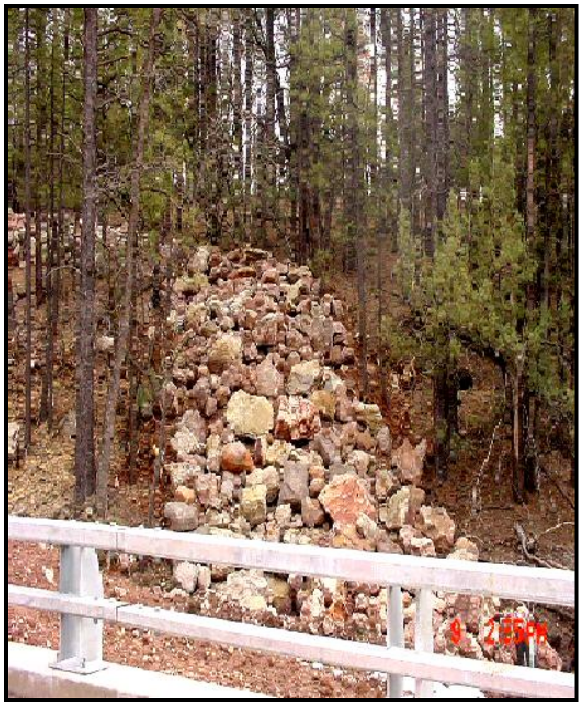

Figure 1. Elk Riprap (Photo by ADOT).

Figure 2. Tortoise Ramp (Photo by ADOT/USDA Forest Service).

Figure 3. Desert Tortoise Going up Incline to enter Culvert (Photo by ADOT/USDA Forest Service).

Another low-cost retrofit option is helping to protect and increase bat roosts and habitat under bridges. ADOT can contribute to bat recovery at little or no extra cost through practical and easily constructed measures. There are numerous bat species in Arizona that are considered threatened and endangered or are species of special concern. Research has shown that bat colonies, even large ones, do not damage highway structures. Nationally, the use of bat boxes under highway structures has been shown to be an extremely effective way to address bat concerns.

Another species that has unique considerations is the Mount (Mt.) Graham red squirrel, *Tamiasciurus hudsonicus grahamensis*. The Mt. Graham red squirrel is a federally listed endangered tree squirrel with less than 250 individuals remaining in the wild. Their only known habitat is in southeastern Arizona and SR 366, a scenic highway known as the Swift Trail, bisects it. As an arboreal species, these animals tend to move through the tree canopy. In order to keep these animals from becoming road kill and increase the connectivity within this region, an adaptation of inexpensive rope tunnel canopy bridges (often used in Australia) is being considered. Rope ladders are combined to form a four-sided tunnel that is strung 7-8 meters above the road and anchored on to the trunks of mature trees. Where roads carry low traffic loads, attaching rope tunnels to trees has been proven successful, especially in Australia, and will help reduce costs and compliance requirements. In cases of large canopy gaps, strengthening with wire cables may be necessary (Goosem et al. 2008).

ADOT is cooperatively working with other state and federal agencies and non-government conservation organizations to utilize data gathered from the most current and ongoing highway/wildlife research. In addition, best management practices, GIS wildlife linkage and habitat maps, road kill databases, and other resources are being used to ensure future conservation of wildlife species and their habitats.

Biographical Sketch

Bruce D. Eilerts holds a B.S. in Zoology and is currently the Program Manager of the Arizona Department of Transportation's (ADOTs) Office of Environmental Services, Natural Resources Management Group. During the past twenty-six plus years, he has worked for ADOT, the Center for BioDiversity; environmental consultants, the U.S. Air Force, U.S. Navy, and U.S. Fish and Wildlife Service in Arizona, Hawaii, and the Pacific Islands.

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Long Point World Biosphere Reserve Causeway Improvement Plan, Port Rowan Ontario: Benefits For Wildlife Movement, Species At Risk, Traffic And Pedestrian Safety

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Abstract

The Long Point World Biosphere Reserve (LPBR), located on the north shore of Lake Erie in the Province of Ontario, is one of Canada's most significant regions for herpetofauna.

The Big Creek National Wildlife Area, within the LPBR, is a wetland refuge for animals in a fragmented landscape. The wetlands provide habitat for Species at Risk in Canada including the endangered Spotted Turtle (*Clemmys guttata*), and the Threatened Blanding's Turtle (*Emydoidea blandingii*) and Eastern Fox Snake (*Elaphe vulpina gloydi*), and federally and provincially designated Species of Concern such as the Map Turtle (*Graptemys geographica geographica*) and Eastern Milk Snake (*Lampropeltis triangulum triangulum*).

The Long Point causeway is a vital community and recreational link that connects the mainland to the cottage community on Long Point. Constructed in 1927, the causeway disrupted natural hydrological processes and impeded wildlife movement between the wetlands and Long Point Inner Bay. The causeway is rated one of the fifth highest turtle mortality zones in the world, and has been responsible for over 10,000 wildlife mortalities in one year (including amphibians).

The Long Point World Biosphere Reserve Foundation leads a multi-agency and NGO Steering Committee with the objectives of reducing wildlife road mortality, restoring hydrological connections, providing for safe wildlife movement between Big Creek Marsh and Inner Bay, and providing improved traffic and pedestrian safety.

Ecoplans Limited, a Canadian Environmental consulting company with expertise in road ecology, was contracted to develop practical short and long term solutions to address the above-noted objectives.

Ecoplans Limited worked closely with the Steering Committee to assess existing research on target wildlife species and movements, solicit public and stakeholder feedback, and prepare a recommended Causeway Improvement Plan that was presented to the public in 2008 (see www.longpointcauseway.com).

The Causeway Improvement Plan embodies the following key elements: 1) provide an ecopassage system (culverts/bridges and funnel walls) to provide safe wildlife movement across the causeway; 2) re-establish the hydrological connection between the marsh and the Inner Bay; 3) provide supplementary turtle nesting habitat; 4) provide a safer roadway cross-section (and trail opportunities) for both local residents and visitors to the wetland; 5) provide signage to raise public awareness; 6) calm traffic; 7) provide temporary measures; and 8) monitoring.

Temporary measures were implemented in 2008 until funding is available to implement the remaining stages of the project (Class Environmental Assessment, Detailed Design, and Construction). These included installation of temporary silt fencing to restrict the movement of animals onto the road and an associated monitoring program, turtle habitat enhancement work, and a vigorous public awareness campaign including mobile/active road signage and display boards. Preliminary road mortality monitoring results indicate a decrease in the number of animals killed on the causeway in summer/fall 2008. The results from current monitoring of wildlife activity associated with the silt fencing will be utilized in the permanent mitigation strategy.

Public interest in the recommended Improvement Plan has been strong to date. Once the causeway upgrading is completed, monitoring of the mitigation measures will be a key benefit to ongoing road ecology research throughout the world.

Introduction

Study Area and Context

The Long Point causeway (a road that is raised above surrounding wetland) connects Highway 59 (a Norfolk County road) and Port Rowan to the cottage community on Long Point at the head of Long Point Inner Bay on Lake Erie, in Norfolk County, Ontario, Canada. The causeway forms the east edge of the Big Creek Marsh, a 1200 ha wetland located at the mouth of Big Creek at the head of Inner Bay (Figure 1).

The significance of Long Point, Big Creek Marsh and their associated habitat and wildlife is recognized worldwide. Long Point is designated as a *World Biosphere Reserve* (designated by UNESCO in 1986) and is included in the *International Ramsar Convention on Wetlands*, a treaty developed to conserve globally significant wetlands. Long Point is also considered a *Canadian Important Bird Area* and the east half of Big Creek Marsh is a *National Wildlife Area*. The site is one of the most important areas for reptiles and birds in Canada, acting as a refuge for Species at Risk in an area of southwestern Ontario otherwise fragmented by agriculture and development.

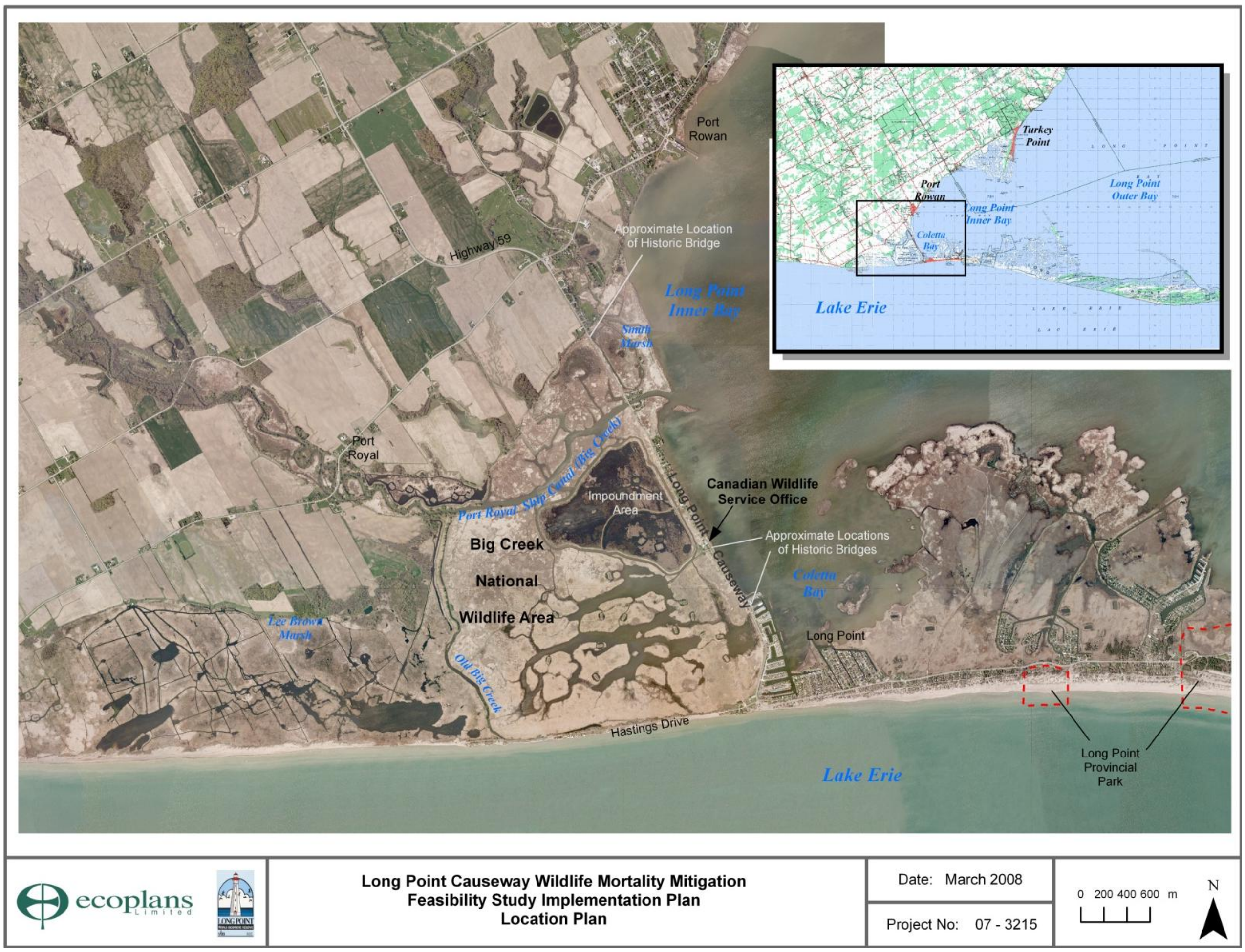

Figure 1. Location Plan.

The causeway is a vital community and recreational link to Long Point. However, it has isolated the Big Creek Marsh habitat from the shoreline and nearshore habitat of Inner Bay, hindering wildlife movement opportunities, fish passage, causing significant wildlife road mortality and reducing open water connections and associated flow that provides nutrient circulation and exchange.

The major effects of roads on wildlife include removal and fragmentation of habitat, population isolation, interference with life cycle activities, and direct road mortality, and are reviewed in detail in Forman et al. 2003 and Cramer 2007.

Road mortality research on the causeway between Port Rowan and Long Point has documented over 10,000 wildlife mortalities each year, including federally and provincially designated Species at Risk (Ashley and Robinson 1996). The causeway has been deemed the fifth deadliest road in the world for turtles (Ashley 2006).

Roads built through or adjacent to wetlands are often a significant cause of reptile and amphibian mortality, population fluctuations, isolation, decline and extirpation or even extinction (Jackson and Tyning 1989; Aresco 2004; Puky 2005, Forman et al. 2003; Ecoplans Limited 2006; Cramer 2007; LesBarerres 2007). Turtle populations are particularly at risk of decline from road mortality because turtles take many years to reach sexual maturity and have naturally low annual recruitment due to high rates of egg and juvenile mortality. The loss or depletion of reptile and amphibian populations can have far reaching, detrimental effects in both terrestrial and aquatic communities.

To date, wildlife crossing signs installed at Long Point have had little effect on reducing incidences of vehicle-wildlife collisions. While public education programs are on-going, a more intensive approach needs to be developed to address the extremely high wildlife mortality rates on the causeway as well as mortality of Species at Risk.

Project Purpose

Accordingly, the Long Point World Biosphere Reserve Foundation (LPWBRF) formed a ratepayer and multi-agency Steering Committee to lead a Long Point Causeway Improvement Project Feasibility Study. The Steering Committee included representatives from Federal and Provincial natural resource and conservation agencies, Ontario Ministry of Transportation, Norfolk County staff, Chamber of Commerce, local ratepayers associations, local field naturalist club, and the Toronto Zoo.

The LPWBRF retained a team of Ecologists, Environmental Planners, Water Resources and Civil Engineers from Ecoplans Limited and McCormick Rankin Corporation to undertake the Feasibility Study and prepare a Plan to guide future improvements, including short and long term recommendations. The intent is to implement the LPWBRF vision for the causeway that: *substantially reduces wildlife mortality and improves the hydrological connectivity of the Big Creek Marsh and Long Point Inner Bay. The improved causeway should provide ancillary social benefits including improved road safety and enhanced recreational opportunities, while maintaining the rural character of the Long Point countryside* (see Figure 2 photos).

Figure 2. Causeway Setting. Photos: Ecoplans Limited (2007/2008).

<u>Feasibility Study – Developing The Plan</u>

The Improvement Plan was developed in the following three (3) phases:

Phase 1 developed the Project Implementation Plan.

This entailed a review of wildlife mortality data and road ecology research, and understanding traffic and safety issues on the roadway (through questionnaire survey) in the context of developing mitigation solutions. Key findings from attendance at the 2007 Toronto Zoo Ecopassages Forum were also considered as were successes and failures from other case studies dealing with road mortality and ecopassage design.

Phase 2 developed and presented Mitigation Options.

The long list and proposed short list of options was evaluated during meetings with the Steering Committee in 2008. Based on that review, the short list of mitigation options was finalized and further developed into the Plan.

Phase 3 identified Management Actions and Developed the Improvement Plan.

The short list of mitigation options, approved by the Steering Committee, was used to develop specific management actions and formulate the Improvement Plan (herein referred to as the Plan). In the formal report, the Plan recommendations were presented as a series of enhancement themes and plates, with technical details presented as fact sheets in the appendices.

Improvement Plan Recommendations

The Plan recommendations are:

- Create an Ecopassage System
- Restore Hydraulic Connectivity
- Enhance Wildlife Habitat
- Enhance the Recreational Experience
- Sign for Awareness
- Calm Traffic
- Provide Temporary Measures
- Monitor

Photo: Ecoplans Limited.

The recommendations are based on solutions developed, implemented and monitored by Ecoplans on similar projects, research into solutions being developed in other jurisdictions, and consultation with the Steering Committee to determine what potential solutions are acceptable to the local community.

Create an Ecopassage and Funnel Wall System

A permanent *ecopassage system* is the cornerstone of the recommended mitigation strategy. The ecopassage system will increase road permeability for wildlife and reconnect habitat east and west of the causeway.

The *ecopassage system* consists of two elements:

1. A series of passages (culverts and/or bridges) designed to facilitate safe movement of wildlife under the roadway; and
2. A continuous funnel system (wall or fence) that prevents wildlife from entering the roadway and directs wildlife toward the passages.

Proposed ecopassage culverts have been sized to maximize the overall “see-throughness” of the culvert (openness ratio) and minimize thermal differences between the culvert and surroundings, to facilitate reptile and amphibian use. Openness ratio (OR) is the ratio of the cross-section area of the structure opening (in m^2) divided by the distance of wildlife travel through the structure (in m). A target OR of 0.25 m (about 0.8 ft) was identified. Square or rectangular box culverts are being considered, with a maximum height of 1.7 m to provide reasonable openness while avoiding major changes in the existing road profile.

A total of 11 ecopassages have been recommended to increase likelihood of use by the target species and decrease out of way travel. A target distance of 100 m to 300 m spacing has been used to guide culvert placement because reptiles are slow moving, have relatively small home ranges, and may become susceptible to predation if moving long distances. Structure placement was also guided by a review of the detailed road mortality data (which showed some spatial variation) and by input from a SAR biologist, Scott Gillingwater, who has extensive local research experience on turtles and snakes in the area.

The final selection of funnel wall material will be made in the design stage, when additional geotechnical and soils information is collected and confirmed. Armourstone, sheet pile and concrete (pre-cast or cast-in-place) are options under consideration. Although preliminary costing has been based on armourstone wall treatment, sheet pile may be a suitable and less expensive option. The funnel wall material should be durable and able to withstand temperature extremes, erosion, water, winter road maintenance activities and ice build-up, particularly along the east side of the causeway. Wall material should also be relatively smooth to inhibit climbing by certain species.

A funnel wall height of at least 1 m is recommended to prevent Leopard Frogs from jumping over. A ‘lip’ or ‘cap’ will help reduce the ability of some species, such as Fox Snakes, from scaling the wall and moving onto the causeway. The wall terminus should ideally curl back in a 120 degree curve away from the roadway rather than end abruptly to reduce ‘end runs’.

Regular maintenance should be implemented to limit the growth of vegetation, especially cattails, near the base of the wall. Vegetation growing close to the wall may provide wildlife with an opportunity to climb over the wall and access the causeway. A barrier such as landscape fabric can be buried in the ground to discourage plant growth.

Figure 3 provides a photo rendering of what one version of a funnel wall might look like on a section of the causeway.

Figure 3. Possible Funnel Wall concept (Wall and structure rendering courtesy of Dwight Forsyth, FDOT).

Restore Hydraulic Connectivity

The wetland system historically received water, nutrients and re-circulation through flows when Big Creek flooded the delta, as well as from Lake Erie and Inner Bay water moving back into the marsh during storms and wind set-up.

As the area was settled, access to Long Point was obtained along the sand spit or by boat, until the causeway was constructed in 1927. Initially the causeway had minor impacts on the marsh as the profile was low and subject to frequent flooding. In addition, four bridges were constructed along the causeway to retain the natural hydrological links between the bay and the wetland. The most southerly bridge (nearly 220 feet in length) spanned the original mouth of Big Creek and a spillway structure for controlling water levels in the wetland for muskrat ranching.

However, in the 1950s, three of the four outlets, including the mouth of Big Creek, were closed off with fill when the bridges and spillway fell into disrepair. The level of the causeway was also raised to reduce seasonal flooding. Today, the only outlet to Inner Bay is the main channel of Big Creek. An impoundment in the western portion of the marsh (see Figure 4) was constructed to manage the marsh ecosystem. The water levels in the impoundment are maintained by pumping.

Figure 4. Big Creek outlet under causeway, with impoundment area in right central part of photo and Lake Erie at top of photo (Photo courtesy of Scott Gillingwater).

The Plan recommendation is to re-establish historical openings at two locations under the causeway that will re-establish exchange of bay water with the marsh. Providing a larger culvert structure at one of the sites can enhance water movement as well as provide aquatic and terrestrial wildlife passage. The upstream sediment load to the marsh would not be changed, so that over time, the circulation pattern in the marsh would adjust to the new openings, with associated changes in sediment distribution patterns.

Wildlife Habitat Enhancement

The creation and/or enhancement of turtle nesting habitat can play an indirect role in reducing turtle road mortality. Turtles (including SAR) cross the Long Point causeway through random wandering (particularly with Blanding's Turtles), as well as direct, intentional movement either towards critical habitat (nesting, foraging or over-wintering habitat) or in search of a mate. Turtles are attracted to the loose, gravelly substrates and open canopy conditions of the road shoulder for nesting. This puts both nesting females and emerging hatchlings at risk of road mortality.

By creating new nesting sites within the Big Creek Marsh, turtle species will gain safe access to a greater variety of habitat conditions not fragmented by the causeway. The *key criteria* that are important in creating suitable turtle nesting habitat are: 1) substrate type; 2) moisture content; 3) temperature (sun exposure and canopy cover); 4) ground cover; and 5) nesting depth and risk of predation (wire enclosure protection).

A long-term monitoring and maintenance program is an important consideration that should be incorporated in the habitat construction plan.

Figure 5. Example of turtle nest site creation – Ontario (Photos courtesy of Scott Gillingwater).

Turtle nesting sites were installed by the LPWBRF, as recommended, in the spring of 2008. Initial results are promising, with Snapping Turtles utilizing sites soon after completion.

Enhance the Recreational Experience

The causeway has been identified in municipal plans and policy as a candidate trail route and a potential on-road cycling route. It is likely that the potential future trail system would be located along the west side of the causeway. Roadway improvement works required to implement the ecopassage system present an excellent opportunity to consider the potential for a multi-use trail system along the west side of the causeway (See Figure 6) that could be accommodated within the existing County road allowance.

The causeway currently functions as a travel corridor as well as a destination, with several nodes or points of interest providing recreational opportunities. These include the Big Creek Marsh observation deck, the Inner Bay observation deck (just north of the marina) and the Big Creek bridge. Commercial fishing and recreational hunting are traditional uses on the east side of the causeway and some hunting also occurs on the west side of the causeway.

The Plan also recommends addition of viewing platforms to enhance the recreational experience. Figure 7 provides a possible viewing platform layout. Potential viewing platform locations have been identified based on current use patterns observed along the causeway.

Figure 6. Photo renderings of possible future multi-use trail with native species plantings, or on-road cycling trail, superimposed on the existing Causeway (Ecoplans Limited).

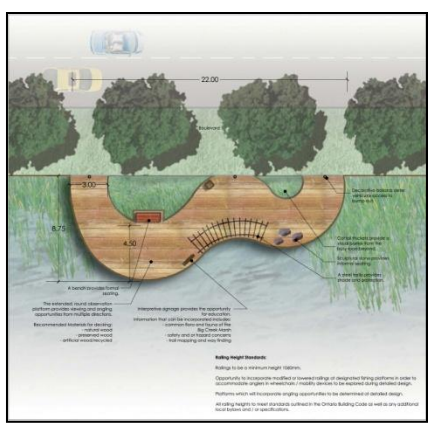

Figure 7. Possible viewing platform layout. (Ecoplans Limited).

Linkages between viewing platforms and the cycling route and/or multi-use trail system can be provided through a series of strategically located pedestrian crosswalks. Additional linkages between the multi-use trail or cycling route and the Big Creek Marsh berm could be considered in the future.

Formal parking areas for causeway users currently exist at three locations along the causeway. The intent is to maintain existing parking facilities but encourage causeway use through a cycle route or multi-use trail. Parking trends should be monitored on the causeway and opportunities for future parking at the south end of the causeway should be examined.

Signs and Education

Signs are recommended to raise **driver awareness** about the potential for wildlife on the road. To reduce driver habituation to static signs, mobile signs with digital messages are recommended at the causeway during key periods of wildlife movement: April to October. Messages should be short, direct and command based. Signs can be more effective when combined with a mechanism that slows traffic or attracts driver attention, such as rumble strips (Ecoplans 2006). Figure 8 shows a mobile message sign that has been erected at the causeway as part of the study recommendations.

Figure 8. Seasonal mobile sign installed at the Long Point Causeway in 2008 (Long Point Causeway Steering Committee).

Gateway Signs

Gateway Signs are recommended at both ends of the causeway. These signs would indicate the driver is now entering the Long Point portion of the World Biosphere Reserve drawing attention to the significance of the area as well as specific conservation efforts and programs.

Interpretative signage

Interpretative signage is recommended at recreational nodes along the causeway to **educate** users about the marsh and wildlife ecosystem, the trail network, and wildlife protection. In fact, a large weather-proof interpretative panel showing the causeway and Recommended Improvements has already been installed at the Big Creek Marsh Interpretive area on the west side of the causeway, Education and outreach will continue to be an important part of the mandate of the LPWBRF.

Calm Traffic

Wildlife mortality studies in Point Pelee National Park and Rondeau Provincial Park in Ontario Canada found that speed limit (which may be closely related to traffic volume) was consistently, positively and strongly correlated with road mortality for all wildlife species and in both parks (Farmer and Brooks, 2007).

A reduction in the speed limit along the causeway, either permanent or seasonal (during spring and summer), was an option explored during the Feasibility Study. This recommendation was implemented by the County in 2008. The previous 70 km/hr limit has been reduced to 60 km/hr south of the Big Creek bridge where several homes and cottages are located and continues southward to the first marina, where the speed limit drops to 50 km/hr. Other measures such as digital speed signs and carefully placed rumble strips have also been recommended as part of this study, and are under consideration by the County.

Temporary Wildlife Protection Measures

This study recommended installation of temporary silt fencing along higher risk portions of the causeway as an interim measure to reduce wildlife mortality and to collect additional information that can assist in future wildlife structure design and placement. The LPWBRF implemented this recommendation in June 2008, and continued road mortality work and fence monitoring from July to November 2008 (Figure 9). Initial results of this monitoring found a marked reduction in amphibian road mortality along temporarily fenced sections. Additional temporary fencing and turtle nest mounds were installed and a more extensive monitoring program was implemented in the summer of 2009.

Figure 9. Temporary Fencing installed in 2008, and working quickly (Eastern Foxsnake capture).

Wildlife Structure Monitoring

Multi-year monitoring of mitigation measures and wildlife ecopassage use is recommended. Monitoring surveys should be carried out both prior to construction and following construction to determine true impacts and success of mitigation measures. Road mortality monitoring at the causeway was undertaken from 1996 to 2006 and provides an excellent baseline of mortality information.

The core monitoring program should incorporate amphibian call surveys, and walking road mortality counts, following the protocol used by Canadian Wildlife Service and remote camera monitoring at selected wildlife structures (see Figure 10).

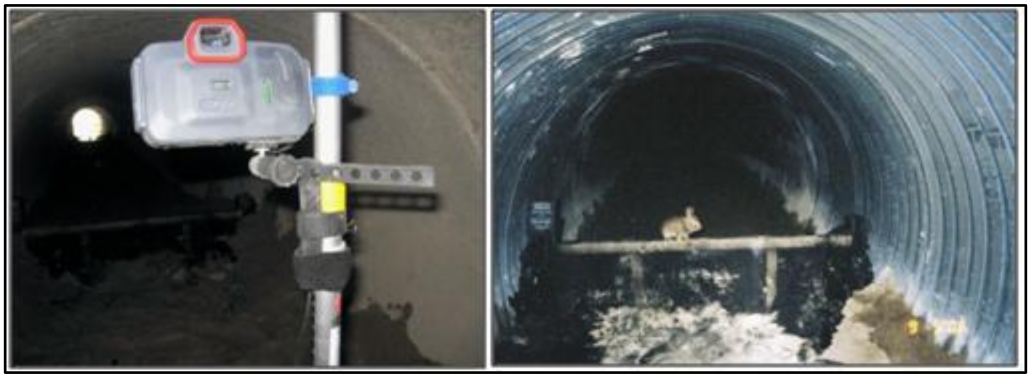

Figure 10. Example of remote camera monitoring – wildlife structure in York Region, Ontario (Ecoplans Limited).

Use of sand substrates to record animal tracks, and inspection of cover objects placed along fences for animals or signs of animals may be used to augment the core monitoring program.

Establishing a partnership with a local environmental group/naturalist club, College or University is a cost effective way to implement a monitoring program. While volunteers can be integrated into the overall monitoring program, the program is best overseen by wildlife experts who can provide guidance and interpretation.

The success of the Plan can be evaluated quantitatively in various ways. The most important measure will be in the reduction of wildlife road mortality. Based on mortality rates, species and distribution patterns along the causeway, areas that remain vulnerable to wildlife kills, even after the installation of the ecopassage system, can easily be identified and addressed through design additions or enhancements.

New open water connections through culverts must also be monitored for sedimentation. Clean out measures should be developed in consultation with the Long Point Region Conservation Authority, Ministry of Natural Resources and Fisheries and Oceans Canada.

The Plan – Summary Along The Causeway

The attached plates provide an overview of the recommended Improvement Plan at selected causeway sections, as well as various future road cross-section options, and preliminary costing for all improvements (See Table 1 - subject to change/revision during detailed design). The reader is referred to www.longpointcauseway.com to review the full report and plates or contact Ecoplans Limited (Geoff Gartshore) for further details.

If this project is advanced, the next steps would be to: 1) Undertake a Class Environmental Assessment and preliminary design of the proposed undertaking; 2) Following approval of the Class EA, undertake detail design work; and 3) Implement the improvements through construction. Unfortunately at the time of writing, a determined group of local opponents have challenged the need for the improvements. It is our hope that completion of these improvements will be realized, resulting in a causeway that “re-connects” the human and natural ecosystem, protects wildlife Species at Risk, and enhances the recreational experience for residents and visitors alike.

Biographical Sketch

Geoff Gartshore (B.Sc., M.Sc.) is a senior Ecologist and Partner with Ecoplans Limited, the independent environmental division of McCormick Rankin Corporation and the MMM Group. He has been working as an Ecologist since 1980, and has been with Ecoplans Limited since 1984.

Mr. Gartshore has been a key participant in a wide range of environmental projects encompassing terrestrial and aquatic resource assessments for many public and private sector clients throughout Ontario. His expertise has been applied to highway and utility corridor studies, resource management studies and plans, urban development impact studies, as well as rehabilitation and restoration projects.

Mr. Gartshore's special interest is in wildlife and transportation mitigation strategies for highways and urban developments. He helped prepare the *Environmental Management Plan* (EMP) for a major highway in New Brunswick that received an Environmental Achievement Award from the Transportation Association of Canada (TAC). Mr. Gartshore also prepared the *Wildlife Guide for the Oak Ridges Moraine* in 2006 that addresses wildlife and transportation interactions and solutions for the Ontario Ministry of Transportation.

He has presented various research and case study papers before bodies such as the International Road Federation, Environment Canada, Ontario Good Roads Association, Municipal Engineers Association, the University of Windsor, the International Conference on Ecology and Transportation (ICOET- San Diego 2005), Toronto Zoo Massasauga Rattlesnake Symposium (Road Panel), and the International Association for Great Lakes Research. He has participated in additional projects that received awards from the Consulting Engineers of Canada (Bayview Avenue Extension – Ontario Canada) and the Transportation Association of Canada (Highway 17, Sault Ste. Marie, Ontario, Canada).

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	Minimum Road Cross-Section		Typical Road Cross-Section		Enhanced Road Cross-Section	
	Ecopassage System (culverts and funnel wall)	Road Improvements	Ecopassage System (culverts and funnel wall)	Road Improvements	Ecopassage System (culverts and funnel wall)	Road Improvements
Zone 1	$1, 800, 000	$506, 250	$1, 880, 000	$592, 500	$1, 910, 000	$723, 750
Zone 2	$3, 875, 000	$1, 012, 500	$4, 075, 000	$1, 185, 000	$4, 150, 000	$1, 447, 500
Zone 3	$2, 470, 000	$877,500	$2, 575, 000	$1, 027, 000	$2, 635, 000	$1, 254, 500
Subtotal	$8, 145, 000	$2, 396, 250	$8, 530, 000	$2, 804, 500	$8, 695, 000	$3, 425, 750
Combined Subtotal	$10, 541, 250		$11, 334, 500		$12, 120, 750	
Engineering (15%)	$1, 581, 188		$1, 700, 175		$1, 818, 113	
Contingency (20%)	$ 2, 108, 250		$2, 266, 900		$2, 424, 150	
Top layer paving	$150,000		$150,000		$150,000	
Total	**$14, 380, 688**		**$15, 451, 575**		**$16, 513, 013**	
Rounded Grand Total	**$14, 400, 000**		**$15, 500, 000**		**$16, 600, 000**	

Table 1 - Preliminary Cost Estimates (2008 Canadian Dollars)
(Subject to change as design advances)

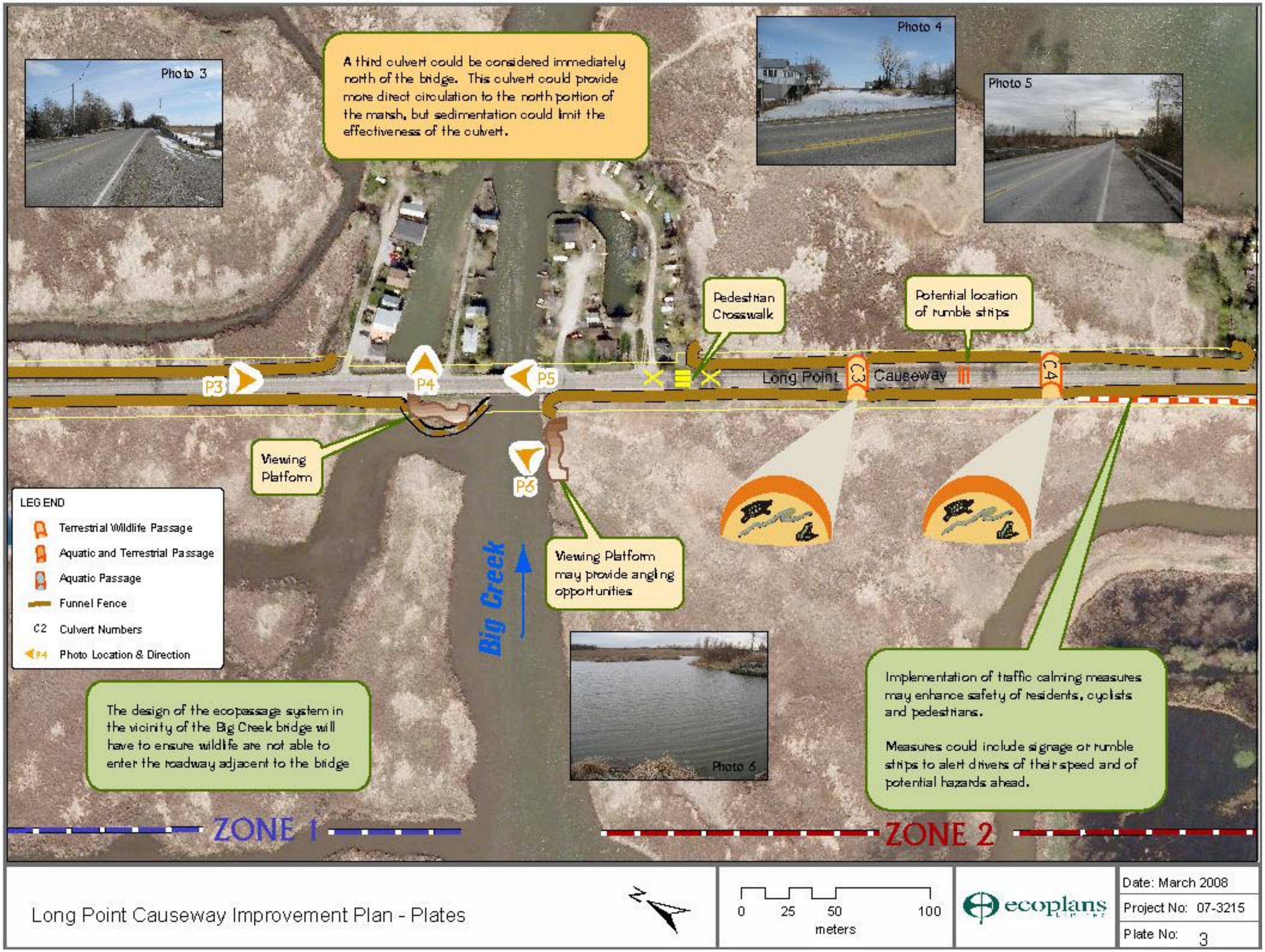


Photo 3
A third culvert could be considered immediately north of the bridge. This culvert could provide more direct circulation to the north portion of the marsh, but sedimentation could limit the effectiveness of the culvert.
Photo 4
Photo 5
Pedestrian Crosswalk
Potential location of rumble strips
P3
P4
P5
P6
Long Point
C3
Causeway
C4
Viewing Platform
Viewing Platform may provide angling opportunities
Big Creek
LEGEND
Terrestrial Wildlife Passage
Aquatic and Terrestrial Passage
Aquatic Passage
Funnel Fence
C2 Culvert Numbers
P4 Photo Location & Direction
The design of the ecopassage system in the vicinity of the Big Creek bridge will have to ensure wildlife are not able to enter the roadway adjacent to the bridge
Photo 6
Implementation of traffic calming measures may enhance safety of residents, cyclists and pedestrians.
Measures could include signage or rumble strips to alert drivers of their speed and of potential hazards ahead.
ZONE 1
ZONE 2
Long Point Causeway Improvement Plan - Plates
N
0 25 50 100
meters
ecoplans
Date: March 2008
Project No: 07-3215
Plate No: 3

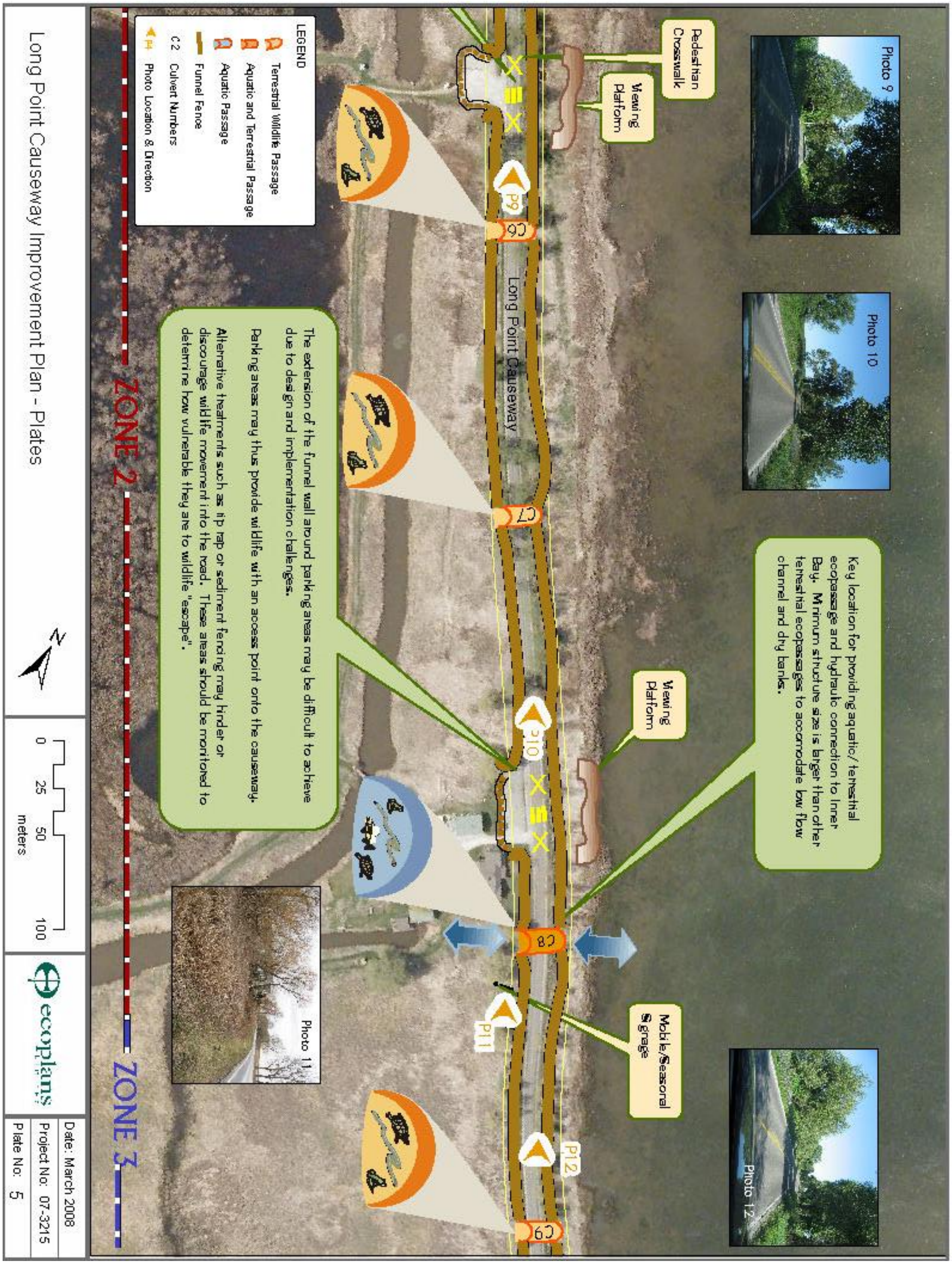


Photo 9
Photo 10
Photo 12
Photo 11
Pedestrian Crosswalk
Viewing Platform
Viewing Platform
Mobile/Seasonal Signage
Key location for providing aquatic/terrestrial ecopassage and hydraulic connection to Inner Bay. Minimum structure size is larger than other terrestrial ecopassages to accomodate low flow channel and dry banks.
Long Point Causeway
The extension of the funnel wall around parking areas may be difficult to achieve due to design and implementation challenges.
Parking areas may thus provide wildlife with an access point onto the causeway.
Alternative treatments such as rip rap or sediment fencing may hinder or discourage wildlife movement into the road. These areas should be monitored to determine how vulnerable they are to wildlife "escape".
P9
P10
P11
P12
C6
C7
C8
C9
ZONE 2
ZONE 3
LEGEND
Terrestrial Wildlife Passage
Aquatic and Terrestrial Passage
Aquatic Passage
Funnel Fence
C2 Culvert Numbers
Photo Location & Direction
N
0 25 50 100
meters
Long Point Causeway Improvement Plan - Plates
ecoplans
Date: March 2008
Project No: 07-3215
Plate No: 5

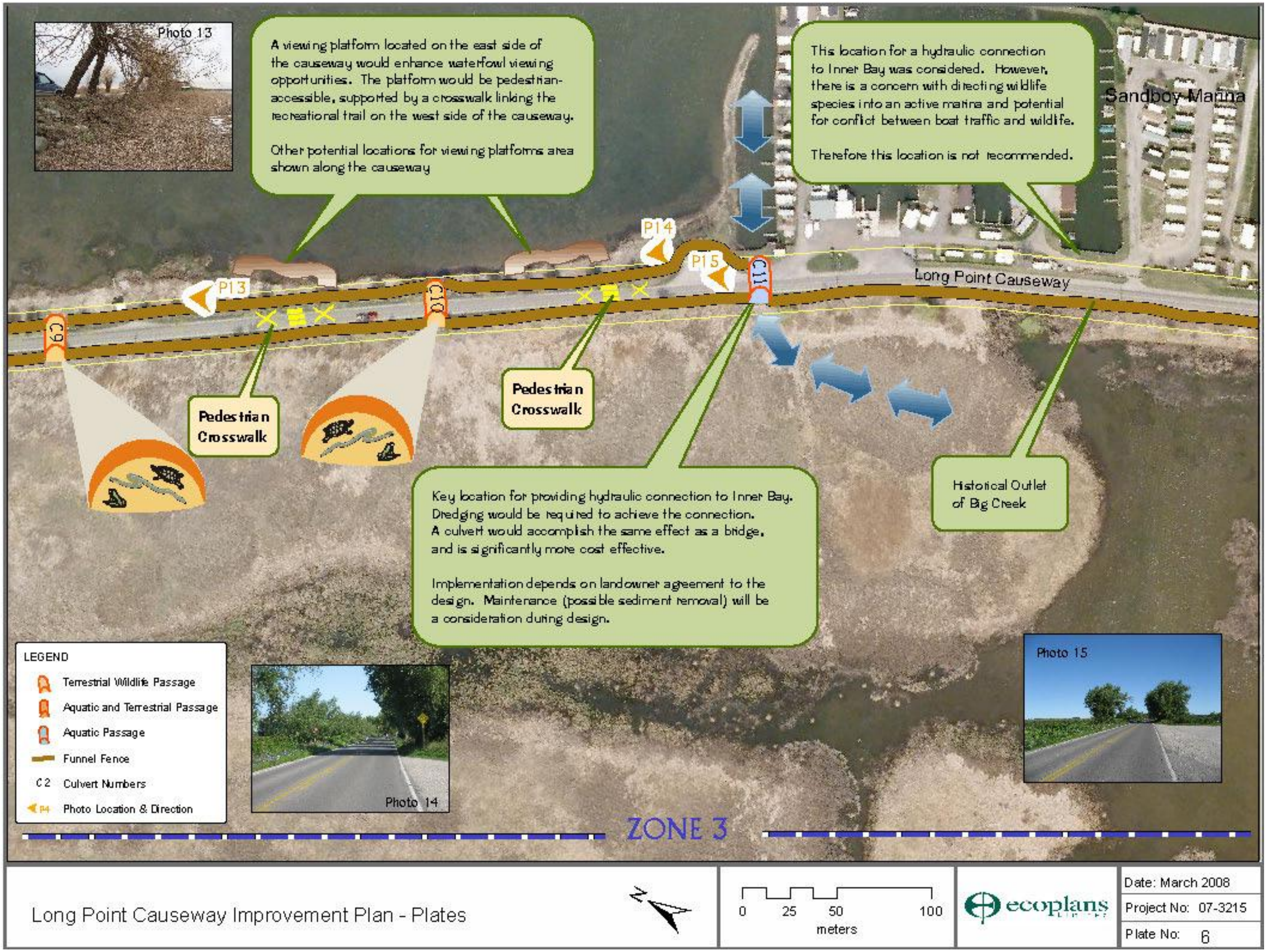


Photo 13
A viewing platform located on the east side of the causeway would enhance waterfowl viewing opportunities. The platform would be pedestrian-accessible, supported by a crosswalk linking the recreational trail on the west side of the causeway.
Other potential locations for viewing platforms area shown along the causeway
This location for a hydraulic connection to Inner Bay was considered. However, there is a concern with directing wildlife species into an active marina and potential for conflict between boat traffic and wildlife.
Therefore this location is not recommended.
Sandboy Marina
P14
P15
P13
C9
C10
C11
Long Point Causeway
Pedestrian Crosswalk
Pedestrian Crosswalk
Key location for providing hydraulic connection to Inner Bay. Dredging would be required to achieve the connection. A culvert would accomplish the same effect as a bridge, and is significantly more cost effective.
Implementation depends on landowner agreement to the design. Maintenance (possible sediment removal) will be a consideration during design.
Historical Outlet of Big Creek
LEGEND
Terrestrial Wildlife Passage
Aquatic and Terrestrial Passage
Aquatic Passage
Funnel Fence
C2 Culvert Numbers
Photo Location & Direction
Photo 14
Photo 15
ZONE 3
Long Point Causeway Improvement Plan - Plates
N
0 25 50 100
meters
ecoplans
Date: March 2008
Project No: 07-3215
Plate No: 6

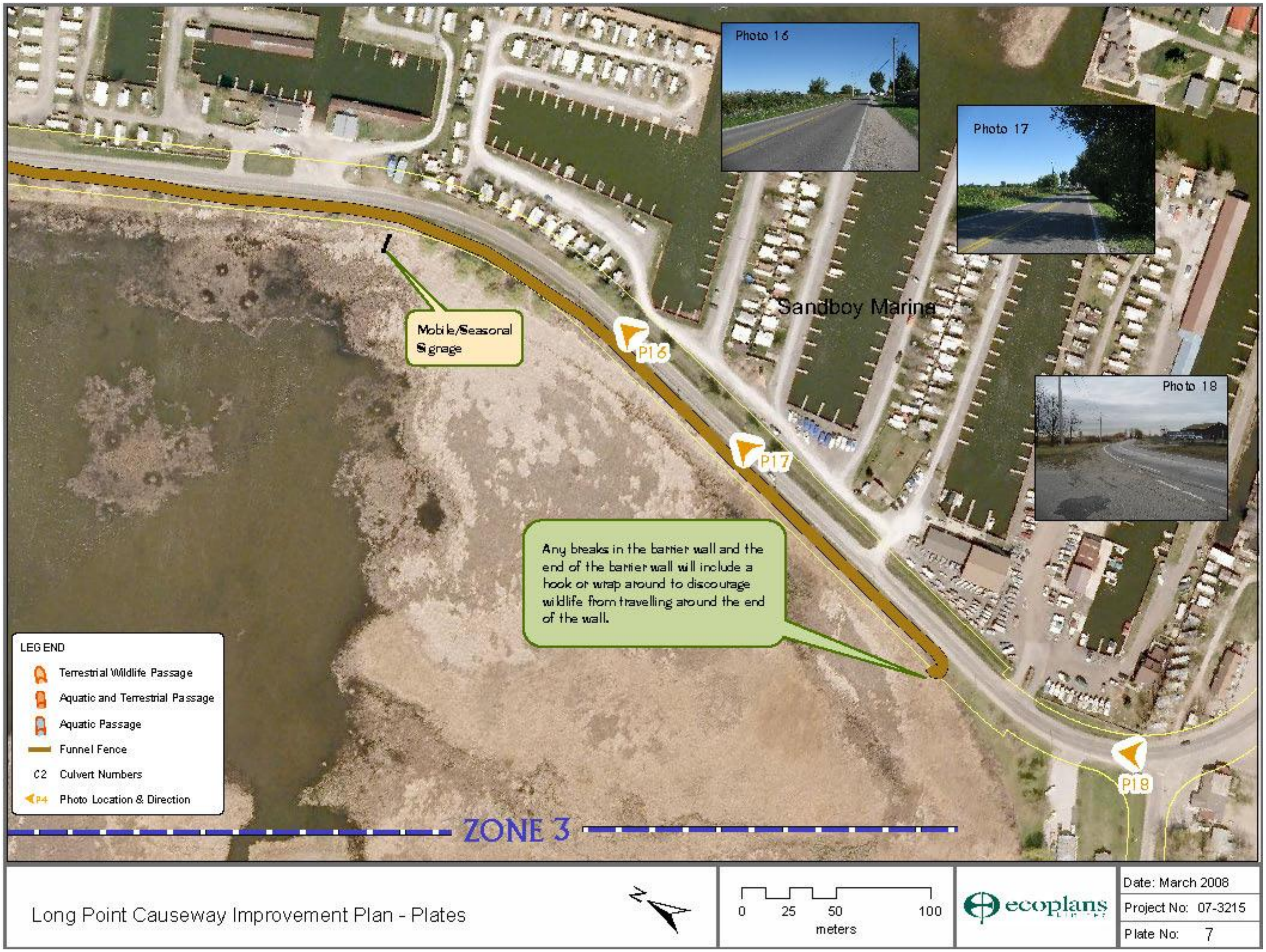
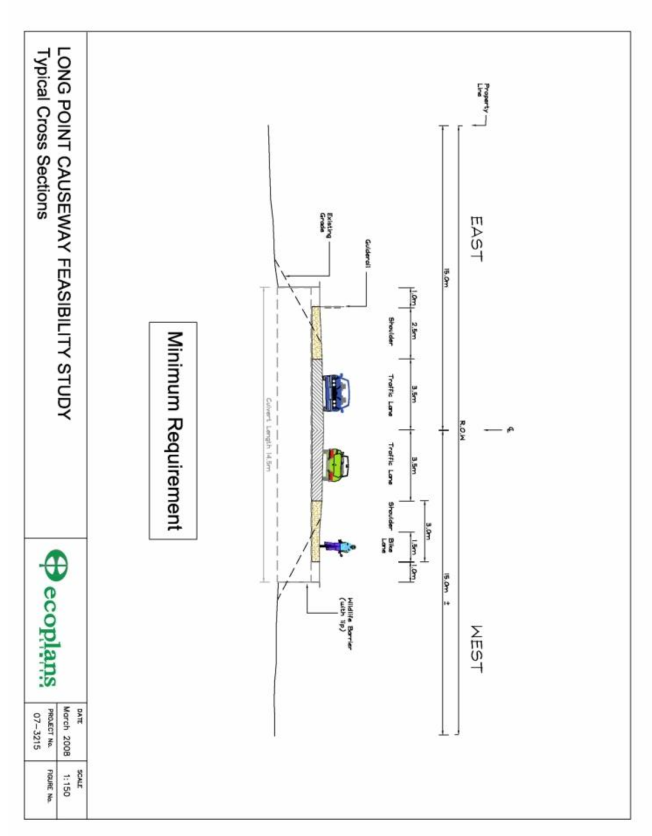
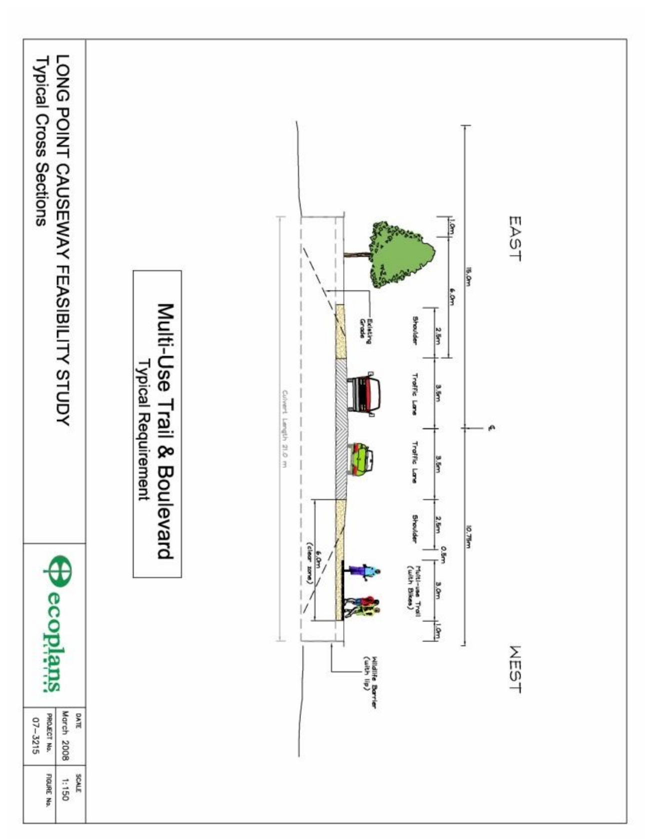
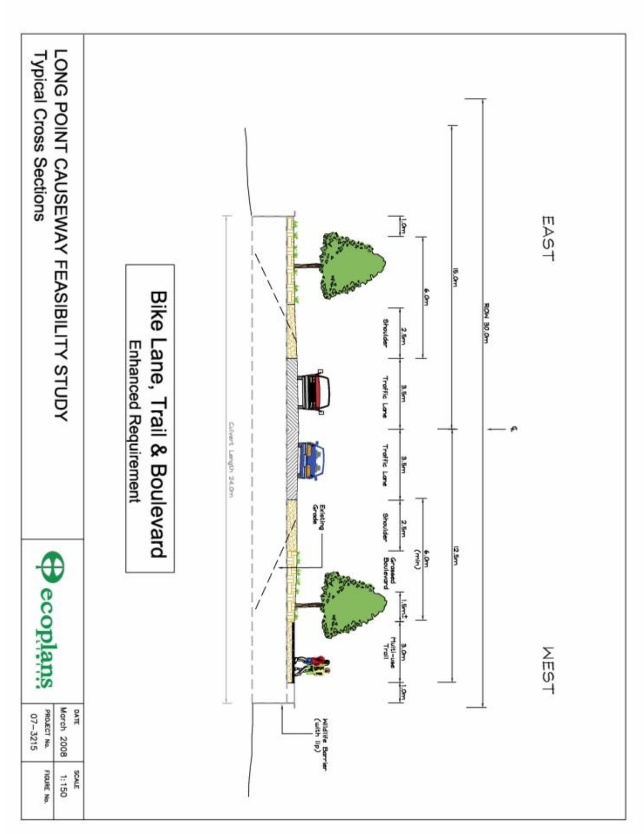


Photo 16
Photo 17
Photo 18
Sandboy Marina
Mobile/Seasonal Signage
P16
P17
P18
Any breaks in the barrier wall and the end of the barrier wall will include a hook or wrap around to discourage wildlife from travelling around the end of the wall.
LEGEND
Terrestrial Wildlife Passage
Aquatic and Terrestrial Passage
Aquatic Passage
Funnel Fence
C2 Culvert Numbers
P4 Photo Location & Direction
ZONE 3
Long Point Causeway Improvement Plan - Plates
N
0 25 50 100
meters
ecoplans
Date: March 2008
Project No: 07-3215
Plate No: 7


LONG POINT CAUSEWAY FEASIBILITY STUDY
Typical Cross Sections
Minimum Requirement
EAST
WEST
ecoplans
March 2008
1:150
07-3215


LONG POINT CAUSEWAY FEASIBILITY STUDY
Typical Cross Sections
Multi-Use Trail & Boulevard
Typical Requirement
EAST
WEST
ecoplans
March 2008
1:150
07-3215


LONG POINT CAUSEWAY FEASIBILITY STUDY
Typical Cross Sections
Bike Lane, Trail & Boulevard
Enhanced Requirement
EAST
WEST
ecoplans
March 2008
1:150
07-3215

Climate Change – Understanding the Impacts and Developing Mitigation Strategies

How Will Climate Change Affect the Design and Management of the Highways Agency Soft Estate? Preliminary Study: An Examination of Species Richness of the Habitat Areas on the Soft Estate

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Abstract

The Highways Agency (HA) soft estate comprises the land adjacent to the Strategic Road Network (SRN) which lies within the highway boundary but is not part of the road carriageway. Originally created to buffer the environmental impacts associated with construction and operation of the active highway environment the land has proven to be exceptionally valuable in terms of ecological habitat and biodiversity with 42% of UKBAP (United Kingdom Biodiversity Action Plan) species and 53% of the UKBAP priority habitats either known to occur or are considered likely to occur within the soft estate.

This study is part of a Ph.D. the main author is undertaking on how climate change will affect the design and management of the soft estate. It is chosen to provide baseline information on species richness of the habitat areas within the soft estate environment.

This study analyzes the relationship between area size and species diversity using data collected on the Area 7 MAC (Managing Agent Contractor), an area situated in the east midlands of England comprising Leicestershire, Nottinghamshire, Derbyshire and Lincolnshire.

Ordinary linear regression shows a significant relationship between area size and species richness on all the roads examined and further establishes that maintaining large contiguous areas is beneficial to species diversity overall. Despite a standard planting mix being used on all the roads the habitat areas diversify over time until a species saturation point is reached. A number of other factors are highlighted as well which need further study: the effect of management regimes on species diversity, spatial location (in terms of the geographical spread of habitats across the UK), effects of invasive or domineering species, and age of the soft estate.

To ensure that the soft estate continues to be a viable ecological asset, active management needs to occur but the question remains as to what is the most appropriate form of management regime to adopt in light of the predicted scenarios of climate change. It is intended that this investigation will be expanded upon in the next phase of the Ph.D. to focus more closely on indicator species as a gauge of habitat type and how these will respond to the alteration of environmental cues (such as temperature and precipitation) resultant of climate change. Once an understanding has been reached on how indicator species and therefore habitats will shift in response to climate change we can begin to examine management protocols in order to gain an understanding of how we can manage climate induced habitat change.

Introduction

Background

This study is conducted in response to growing concerns regarding the effects of climate change on important habitats within the UK. Climate is a strong influencing factor on habitat occurrence, species behaviour (such as breeding patterns), distribution and abundance. The effects that climate change have upon habitat and species of importance in the UK is already being observed and there are increasing concerns that these effects will only become more profound over time (Hopkins et al 2007).

Originally established in 1994 the Highways Agency (HA) is an executive agency for the Department for Transport (DfT) managing the Strategic Road Network (SRN) in England on behalf of the Secretary of State (SoS) for transport. The HA is responsible for the design, management, maintenance, upgrade and operation of the SRN and included within their aims and objectives for undertaking the above is a requirement to minimise environmental impact (Highway Agency, 2007a).

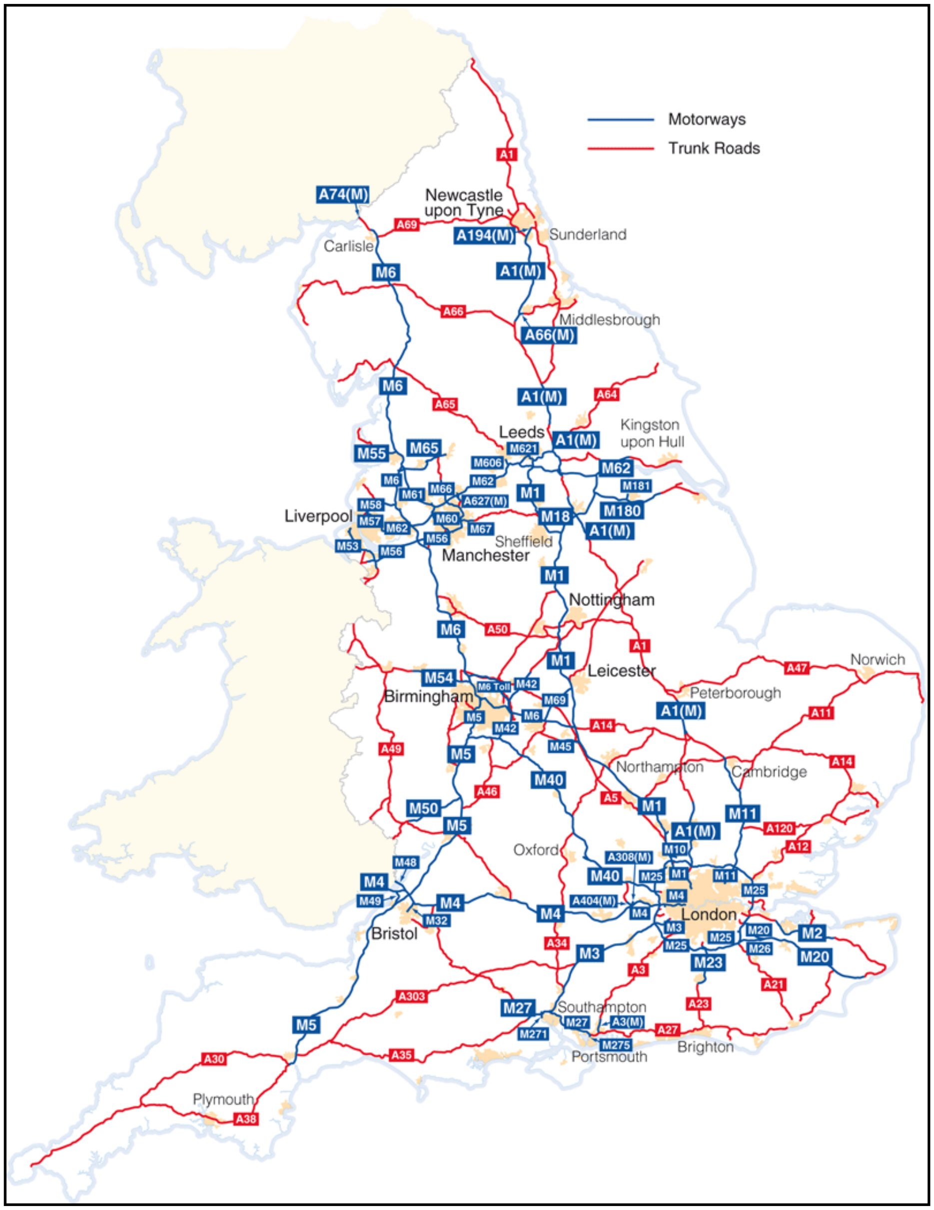

Figure 1: The Highways Agency Strategic Road Network (Highways Agency, 2007c)

Within the SRN there is at present approximately 30,000 hectares of soft estate defined as:

"Land owned by the Highways Agency between the highway fences, but not occupied by the road carriageway" (Highways Agency, 2007b).

Original design of the soft estate focused on mitigation of the visual and landscape impacts associated with the building of a road, but since the late 1970's it has been used to address ecological issues. In 1998 the Government published a white paper entitled “A new deal for transport: better for everyone”, which set out the approach that would be taken with transport policy throughout the UK. The focus of this particular white paper was how the UK intended to meet international targets and standards including those outlined in the Kyoto Protocol and those agreed at the Convention on Biodiversity in 1992.

A new deal for transport identified that although transport has enriched our lives it has done so at a cost and within the UK carbon dioxide emissions from road transport are the fastest growing contributor to climate change (Highways Agency, 1998c). In terms of environment the paper sets a number of objectives and included within these are frameworks to:

- Respond to the challenge of climate change, and
- Minimise transports demand for land, protect habitats and maintain the variety of wildlife.

In response to the white paper the HA created a report on how they would “green” their operations and set out the specific aims and objectives that the HA would work towards in order to have a significant beneficial impact upon the environment. One of the main outcomes of the Green Report was the production of a strategic report, “Towards a balance with nature – Highways Agency environmental strategic plan” in which the Highways Agency stated their intention to develop a series of Biodiversity Action Plans (BAPs). Between 1999 and 2001 the HA commissioned all their Areas to compile a complete inventory of the soft estate in order to understand its potential value as an environmental resource. The results were quite astonishing, indicating that 42% of the UKBAP (United Kingdom Biodiversity Action Plan) species and 53% of the UKBAP priority habitats are either known or are likely to occur in the soft estate. In 2002 the HABAP (Highways Agency Biodiversity Action Plan) was issued containing a total of 20 priority Species Action Plans (SAPs) and five priority Habitat Action Plans (HAPs).

Between 2005 and 2006 the HA commissioned a series of research projects to examine the effects of climate change on the SRN. These projects predominantly looked at effects on the hard landscape such as the pavement surface and bridge integrity but amongst these projects was one undertaken by the MET Office to examine how climate may change over the next 80 years. In 2007 the HA held its first climate change conference and a presentation was given on each of the research projects commissioned, the results gave cause for grave concern.

The climate projections made by the MET office for the end of this century show a clear trend towards a further increase in the average UK temperature and also depict a higher likelihood of the occurrence of extreme weather events (storms, droughts and torrential rain). The majority of the SRN was built over 30 years ago and was constructed to a set of specifications such as temperature range and runoff capabilities, which although more than adequate 30 years ago have now been exceeded more frequently than anticipated and MET Office research indicates that this will not only continue but will become more profound over time.

To date the majority of the research has focused on the hard landscape features of the SRN. This is quite rightly so due to the public safety and economic aspects involved in keeping the SRN running, however the respective environmental advisors of the HA are concerned that the biodiversity improvements they have worked so hard to achieve could be negated due to the change in climate. Following discussions with the HA it was decided that research into this area would not look at specific species or habitats but holistically at the soft estate and what the effects could be in order to help refine management techniques for the future and define further areas for research.

What are the issues?

The HA is one of the biggest landowners in the UK and in order for the UK to meet the biodiversity targets agreed during the 1992 Biodiversity Convention this land needs to be under active biodiversity management, hence the release of the HABAP in 2002. Since 2002 a substantial amount of money has be spent on the ecological improvement of the HA soft estate particularly in the areas of habitat creation, enhancement and improving connectivity.

Climate change is not considered in management of the soft estate so far although the effects of climate change upon the soft estate are already being witnessed (Viles & Rossier, 2001). Growing seasons have changed, spring is starting 2 – 4 weeks earlier compared to the 1960’s (Menzel and Fabian, 1999) which is already causing management implications in terms of the standard safety requirements for visibility splays and sign clearance; Breeding seasons have also altered which has had an effect on translocation activities for new roads as well as biodiversity management on existing roads.

Although the general public often associates roads with the negative aspects of environmental impact, the nature of the soft estate, in that it is a relatively unmanaged expanse of land where people rarely go, means that it has become a haven for wildlife. This is the reason why so many of the UK priority species and habitats occur within it. Road verges can vary greatly in composition and size. Some are a mere 1m wide and mainly comprise a linear strip of grass with adjacent hedge, whereas others can be 100m in width and composed of woodland edge, hedgerows, shrubs and grassland.

In addition to this land are a number of areas that were bought when the original purchase orders were issued to build the road. These areas are often the remnants of farmland which was included in the purchase due to their small size making it unfeasible for the farmer to continue using them. Often forgotten about and rarely subject to management these areas form pockets of untouched habitat along the road network. As such both these areas and the soft estate verges provide a valuable ecological resource in intensively farmed areas or urban environments where suitable habitat may be scarce.

Current Soft Estate Management Techniques

Current guidance on soft estate design and management rests within the Design Manual for Roads and Bridges (DMRB) Volume 10, (The Highways Agency, 2009d), the Routine Winter Service Code (RWSC), (The Highways Agency, 2004e) and Network Maintenance Manual (NMM) (The Highways Agency, 2008f). Within these documents, particularly the NMM and RWSC, routine maintenance of the soft estate is driven by public safety to ensure that vegetation does not become a hazard to road users. All trees and shrubs which are within falling distance of the road or constitute a fire or visibility hazard have to be inspected and managed accordingly. Although soft estate management and improvement for biodiversity and landscape is a part of routine maintenance there is often little budget to allow effective management regimes to be undertaken.

DMRB Volume 10 is the Highways Agency guidance document on environmental management of the soft estate. It comprises a series of advice notes and handbooks detailing everything from landscape management through to translocation of protected species.

Section 0 of DMRB Volume 10 consists of advice on the correct creation and maintenance of the Area Environmental Information System (EnvIS) upon which strategies and management plans for the maintenance of the soft estate should be based. The databases themselves vary in content and detail between areas however as a minimum the soft estate is mapped according to habitat type and a management programme created.

Sections 1 and 2 of the DMRB Volume 10 provide guidance on the creation of new roads or upgrades to the existing road network, in particular where environmental; landscape or ecological improvements can and should be made. However Sections 3 and 4 provide landscape, habitat and species specific guidance on achieving the best integration, mitigation and habitat from the limited resources available.

The Following Chapters

This paper has been set out as follows:

1. Data – A discussion of data collection, sampling strategy, safeguards for consistency of collection protocols and limitations.
2. Analysis – The methodology of the statistical analysis used and presentation of the results.
3. Discussion – An examination of the results in relation to other research projects undertaken and review of salient points of the analysis.
4. Conclusions – Summary of the project findings and presentation of recommendations in relation to future studies.

Data

Data Collection

For ease of management the SRN is split into 14 ‘Areas’ run by a means of a joint venture between a Managing Agent and Contractor known as a MAC. See Figure 2.

Under the Area MAC contracts there is a requirement to populate an Environmental Database which is fed into the HA Environmental Information System (EnvIS) on a biannual basis. Environmental data is gathered in accordance with the specification in DMRB Volume 10 Section 0 Parts 1 – 6 and inputted into a Geographic Information System (GIS) with attached database stating the landscape, design and environmental functions and objectives of each area mapped.

For the purpose of this study four HA Areas have provided a copy of their Environmental Database, Area's 1, 4, 7 and 13. Areas 1 and were targeted for two reasons:

1. They are situated on a climatic gradient (maritime climate through to a more continental climate) and thus would make suitable study areas; and
2. They have used similar data collection methodologies, thus there is consistency in the data.

Areas 4 and 13 were chosen due to their geographical location, in that they run along a line perpendicular to the climatic gradient which runs through Areas 1 and 7.

It was considered that in order to get a suitable overview of the habitats, their distribution and climatic effects, these four areas would form a suitable survey group. Data has been recorded within the four Areas using two different methodologies. The first method of data recording is via the use of a palm held GIS data capture unit with attached Global Positioning System (GPS). For example in Area 7 data was captured using a Trimble GEOXT ruggardised palm held computer with an inbuilt GPS accurate to under a metre. On return to the office the device would automatically download and update the Environmental Database on connection to the computer.

The second method of data collection was a simple hand entry onto paper maps of the road, which would then be copied onto the office based GIS system by a GIS administrator. Of the two methodologies the use of the GIS data collection system is more accurate, quicker and because of this more detailed data can be collected.

Figure 2: The SRN Area's in England

Data Format

Habitats were mapped using the equipment and a table of information populated whilst on site. Once mapped, a habitat is attributed a Primary and Secondary Function Code. The principle purpose of the code is to ensure that management of this habitat is undertaken in accordance with the government's environmental objectives. There are a total of 8 codes (EFA – EFH) to define the primary and secondary purpose of the habitat, for example an area of woodland may have a Primary Function of EFB which defines it as a Landscape Integration feature. However due to the nature of the woodland it may have a Secondary Function of EFD which indicates that the habitat has an important Nature Conservation and Biodiversity aspect.

The habitat is then subdivided further into features and each feature given a Landscape, Environmental or Planning and Policy Element Code. Environmental Codes refer to those features which are relevant to achieving non-landscape objectives and are usually attributed to hard environmental measures, such as noise fencing or sediment catchers. Planning and Policy codes are attributed in accordance with the local, regional and national environmental protection status of the feature. Habitats, species or certain landscape features may be protected under ecological, heritage or landscape legislation or alternatively be highlighted as a government target area in a local, regional or national policy document, an example of this would be a SINC (Site of Interest to Nature Conservation).

Landscape codes cover the majority of the habitat's and features on the soft estate and are divided into broad classification types; woodland, grassland, boundary features etc. These classifications are then subdivided again, for example Grassland (LE1) is further subdivided into LE1.1 Amenity Grassland, LE1.2 Grassland with Bulbs, LE1.3 Species Rich Grassland, and so on. These further subdivisions allow quite detailed information on habitat features to be collected and appropriate management regimes implemented.

Each feature logged onto the database is given a unique reference code for that area and date of inspection and mapping. If the feature has been mapped as a polygon, for example an area of grassland, the area of the feature in m^2 must be collected. Similarly for linear features such as hedgerows and streams, the length of the feature must be recorded, and for individual points, such as a protected species, the number identified logged.

A regime for works, monitoring and re-survey of the area needs to be logged and built into the environmental management plan for the area. Basic information on the area, such as issues with management and species present should be entered and if there is insufficient space for the detail required a pathway provided to where this information is held.

To ensure consistency in data collection within Area 7 all surveyors needed to have a minimum first degree in an environmental, ecological or biological subject and were given an exam on interview to confirm their ability to use a key to identify species.

Following acceptance of their role they were given two weeks of training on correct identification of the Environmental Features and Elements within the DMRB and use of the equipment. In addition to this they were all sent on the Identification of Flowers and Grasses courses given by the Field Studies Council (FSC) a sub group of Oxford University. Finally data collected was audited by a senior ecologist to ensure that plant and habitat identification was being undertaken correctly.

Shortcomings of the data

Despite the best efforts of the HA, the data collected by the respective Managing Agents is not consistent across the SRN with a variety of GIS packages having been used and varying levels of data collected. This is mainly due to the information available when the decision was originally made to collect the data in 1998, as over the course of time the specification of the environmental database has evolved into something very different from the original remit. Unwilling to completely write off the original work collected many Managing Agents have attempted to remould their existing database into one appropriate to the HA's requirements and thus the diversity of data collected is quite profound.

Data has also been collected by a variety of surveyors, some Managing Agents have used ecologists to collect data and others environmental generalists. In this particular investigation, and due to time constraints, only data from Area 7 has been used to do the analysis due to the detailed methodology of data collection and quality assurance measures which were in place.

Results

The aim of the analysis was to discover if there is a relationship between species richness and area size of habitat. In accordance with standard ecological practice the data was log transformed prior to regression analysis using the species-area relationship equation which improves the distribution of errors (Arrhenius, 1921):

$$\log(S) = \log c + z \log(A)$$

The coefficients log c and z were estimated with ordinary least squares. A t-test was applied to test the significance of the coefficients (see Table 1 for details, R Development Core Team, 2008); all slopes were significant at $p< 0.05$. All intercepts, with the exception of the A1 analysis, were significant at $p< 0.01$. No systematic variations in the distribution of errors appear in Figures 3 to 6. A visual inspection of the figures revealed several outliers (numbered points on Figures 3 – 6).

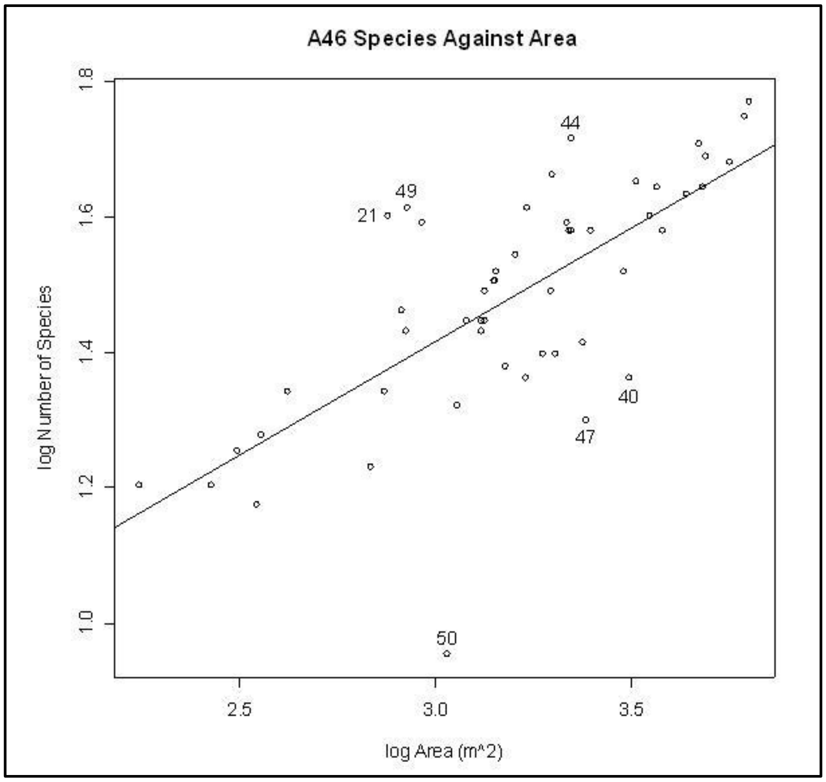

Figure 3: Log Number of Species (log S) against log Area Size (log A). Outliers have been identified and are numbered.

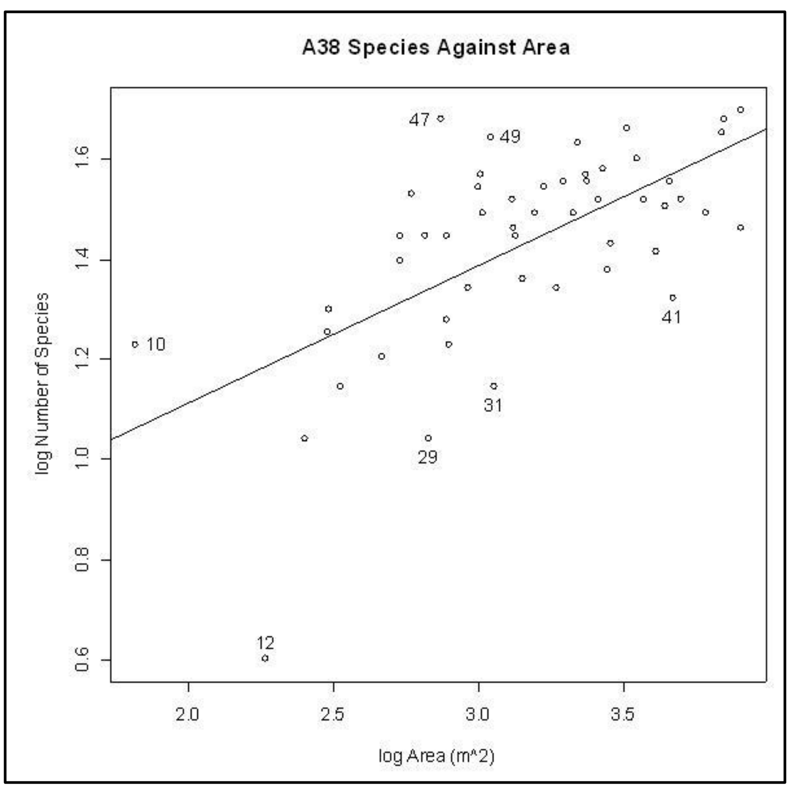

Figure 4: Log Number of Species (log S) against log Area Size (log A). Outliers have been identified and are numbered.

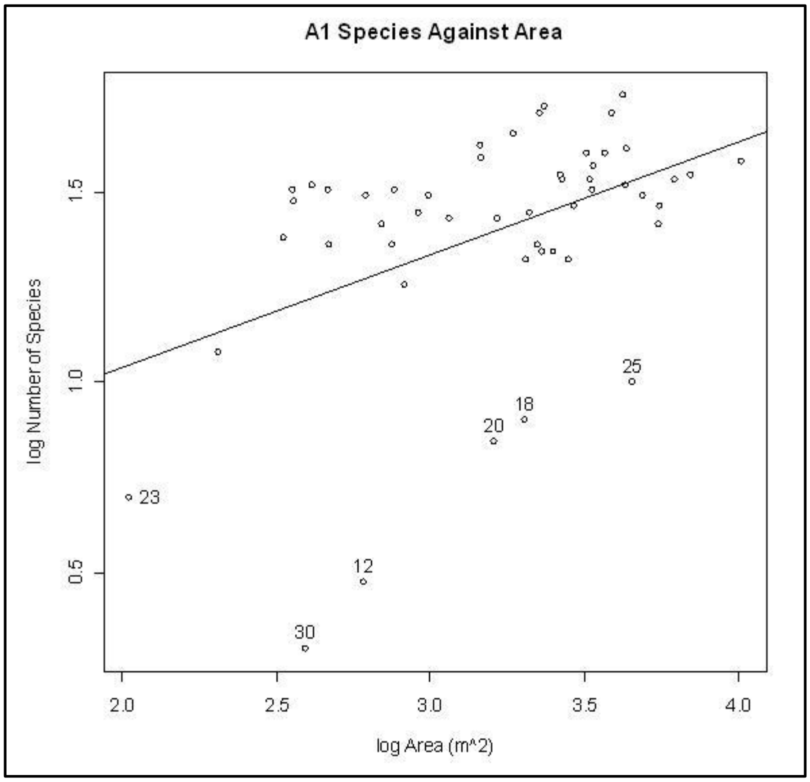

Figure 5: Log Number of Species (log S) against log Area Size (log A). Outliers have been identified and are numbered.

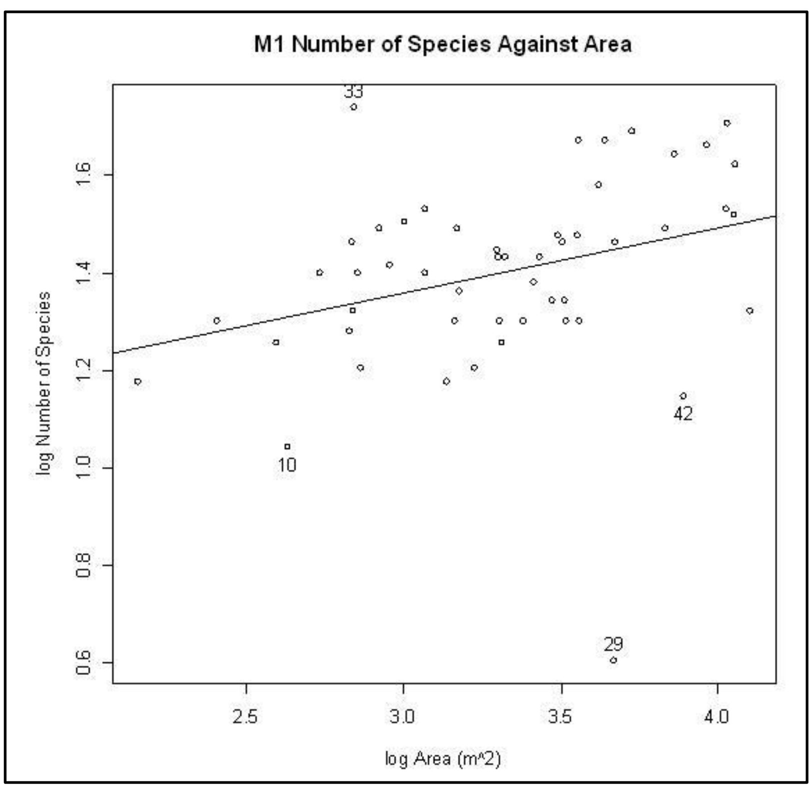

Figure 6: Log Number of Species (log S) against log Area Size (log A). Outliers have been identified and are numbered.

	Road	Estimate Std.	Error	t value	Pr(>|t|)
Intercept	A46	0.41221	0.14873	2.772	0.00786 **
c(log10)N.Area)	A46	0.33472	0.04618	7.248	2.74e-09 ***
Intercept	A38	0.56277	0.15382	3.659	0.00062 ***
c(log10)N.Area)	A38	0.2751	0.04823	5.704	6.67e-07 ***
Intercept	A1	0.44719	0.2788	1.604	0.11514
c(log10)N.Area)	A1	0.29596	0.08601	3.441	0.00119 ***
Intercept	M1	0.95484	0.19432	4.914	1.04e-05 ***
c(log10)N.Area)	M1	0.13427	0.05792	2.318	0.0247 *

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 1: Results of the t test of the ordinary linear regressions for all roads

Discussion

Results Overview

Following the analysis of all four roads in terms of size of habitat area and number of species a number of salient points can be drawn from the results. Over all of the roads the majority of the mapped habitat areas are under 4000m^2 (around 90% of habitat areas analysed) and the range of sizes of habitat area corresponds with carriageway width with the single carriageway A46 having the smallest habitat areas and narrowest soft estate (no areas over 7000m^2) and the M1 Motorway having the largest habitat areas and widest carriageway width comprising three lanes, the largest M1 area assessed was just over 14,000 m^2.

The A46 and A38 are the oldest roads opened in 1923 and 1922 respectively, however since this time both roads have undergone a series of upgrades mainly undertaken between 1950 and 1975. The A1, (built in a number of stages between 1927 and 1971, with the area of interest built in the 1950's) is a combination of dual and three lane carriageway, and has larger habitat areas with the maximum size of areas examined not exceeding 12,000 m^2. Finally the M1, the youngest of the four roads, comprises of three lane motorway and was opened in 1968. Within the analysis areas which have been upgraded as part of the strategic highway improvement process have not been included.

The linear regression analysis for both the A46 and A38 showed the greatest level of significance, followed by the A1 and finally the M1. This is shown clearly on Figure 7 below which has plotted all the roads on one graph and demonstrates the difference between log S and log A for each of the roads in comparison with each other. Significance of the relationship between log S and log A clearly demonstrates the impact of road age with the oldest roads having the most significant relationship between log S and log A and the youngest having the least.

Although the oldest road has the most significant relationship between log A and log S there will be a saturation point where species diversity and concentration will not increase further. Due to the difference of the ages between the A46, A38 and A1 but the similarity of their regression lines it could be hypothesised that this point has been almost reached by these roads, which is why they are so close together It could be further hypothesised that as the youngest road the linear regression of the M1 will change over the next 30 years and become more significant as the soft estate matures and more species colonise. Eventually the relationship between log S and log A for the M1 should reflect the other 3 roads.

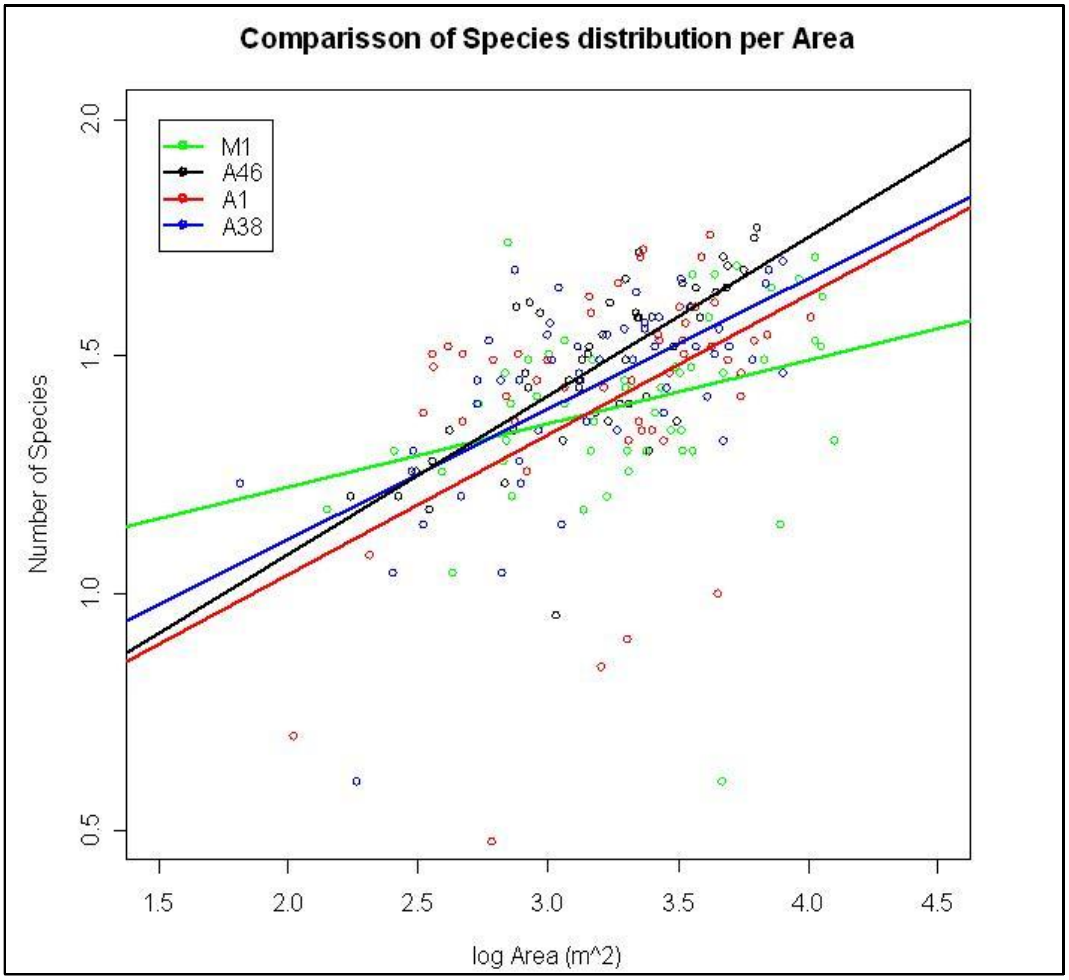

Figure 7: Comparison of Species distribution per Area for all 4 roads. The A46 built in 1923, the A38 built in 1922, the A1 built in the 1950's and the M1 built in 1968.

Area Size

The difference in habitat area size between the roads and the relationship between road size and area size, and road age and area size is unsurprising. Larger roads need a greater buffer zone (soft estate) to mitigate the impacts of air quality, noise and visual intrusion and thus larger habitat areas were created within the soft estate. As the environmental impacts of roads have been given a greater level of importance so too has the size of the buffer zone increased so much so that on very new roads, like the Bexhill to Hastings Link Road which is planned to be built in 2010, an extra 32 hectares of land has been purchased for ecological and landscape mitigation. Incorporated into this mitigation is provision of a new wildlife area which will be created as a receptor site for all the species translocation that will need to take place as a result of this scheme.

Species Saturation

The relationship between species diversity and ecosystem size is one of the few constants in ecology although it can be influenced by a number of other variables such as geographical location, management regimes, speciation rates and disturbance (Fukami, 2004). The analysis of all four roads demonstrates a significant relationship between area size and number of species, in that as area size increases so too does the number of species observed.

The term 'species diversity' does not just encompass species richness but also how evenly the populations are distributed across the habitat and how this relates to the wider ecosystem, thus, mechanistic explanations of the relationship between the size of a habitat or ecosystem and the diversity of species within that area are still very much a central topic for debate among the ecological community (Fukami, 2004).

The data on the roads indicates that the habitat areas along the soft estate appear to reach a saturation point. Although there is a distinct age gap between the oldest and youngest roads, the linear regression of the A46, A38 and A1 are all very close together and follow a very similar line. This indicates that despite the age gap between the roads there is an end point to the amount of species which can colonise an area and it can be hypothesised that over time the linear regression of the M1 will change to reflect those of the A46, A38 and A1.

Outliers

There were a number of plots on all the graphs produced which were situated significantly away from the line of linear regression. Inspection of the outliers for each of the four roads indicates that:

1. Grassland outliers with a below average species richness tend to comprise of areas dominated by a high population of one particular species which inhibits the growth of others such as Gorse or Bramble (for example outlier 41 on Figure 4 is dominated by the highly competitive species of Bramble, Nettle and Bracken)
2. Outliers with a below average species richness which are woodland environments tend to be dominated by Sycamore (for example outlier 12 on Figure 5 is a dense woodland dominated by Sycamore).
3. Areas with an above average species richness tend to be most prolific on the older roads and can comprise both woodland and grassland habitats (for example outlier 44 on Figure 3 which has a very diverse grassland habitat)

There are a number of reasons for why the outliers may have occurred such as the habitat area lying adjacent to an existing wildlife area which may have acted as a source for colonisation by a variety of desirable species. In some instances the original landscaping undertaken when the road was originally built may have had an impact through use of infected topsoil or choice of planting; this is particularly noticeable on the M1 where a lot of Sycamore, a quick growing and shade tolerant species, was planted when the road was built in the late 1960's.

There is also the possibility that the habitat area has been damaged by an adjacent road maintenance activity allowing invasive disturbed ground species such as nettle, thistle and bramble to colonise and inhibit the growth of more desirable species. This could also be true of adjacent land uses such as intensively farmed areas allowing Ragwort colonisation. However the majority of the reasons for the areas with a low number of species per area on all the roads are due to management.

The value of the road environment as a biodiversity resource is mainly due to the lack of management that has been undertaken upon the soft estate, but this has not been without consequence. Succession is defined by Primack (2000) as:

"The gradual process of change in species composition, community structure, and physical characteristics that occurs following natural or human-caused disturbance to a biological community"

Much of the original landscaping on the road environment comprised grassland areas and at the very beginning these were mown in their entirety. In the past 30 years budgetary constraints have resulted in a loss of funding for this type of management and mowing has been reduced to the bare minimum required to satisfy health and safety, the swathe and visibility splay cuts. The natural succession state of grassland is to develop into a woodland environment and the reduction in mowing has allowed encroachment by gorse, bramble, sycamore and ash, all opportunistic species which will spread if left unchecked. The HA acknowledges that they have lost a large amount of their original grasslands to woodland succession, a natural occurrence but nevertheless an unwanted one due to the loss of valuable grassland habitat.

In addition to this, woodland management has also suffered from the reduction in funding 30 years ago and standard thinning and coppicing has not been undertaken. The result is that many woodlands have limited ground flora and under storey due to density of the canopy, and the original planting is under threat from Sycamore. The trees overall are tall and thin, and densely packed together with barely anything of the original two tiered woodland systems created remaining.

Despite the issues with the lack of management of the soft estate, succession and the increase in homogenous habitats the soft estate is an incredibly valuable resource. A survey by Bellamy et al (2000) examined small mammal populations upon the soft estate and found that despite the dangers of living adjacent to a live carriageway the soft estate supports a wide diversity of small mammals including bank voles, field voles and wood mice. The rodents caught were of a variety of ages, from breeding adult to juvenile, which suggest that not only is the road verge suitable habitat for foraging it actually supports a breeding population (Bellamy et al, 2000).

Within his study Bellamy identified a number of "key verge characteristics related to rodent abundance". Grass verges with large hedgerows had the highest populations of bank voles and wood mice. In particular managed verges with short grass and improved line of sight for rodents seemed to be preferred, possibly due to the advantages of foraging in short grass as opposed to long grass. The study concluded that overall road verges in arable areas support a greater density of small mammals populations than hedgerows situated within arable land (Bellamy et al, 2000).

In recent decades the concept of ecological corridors which can be used to connect larger areas of habitat and allow movement of species between habitats has become an intrinsic principle in ecological conservation. Although many scientists firmly believe that the creation of corridors to allow migration and movement of species between habitats is essential to promote genetic health and allow populations to grow and fulfill their lifecycle the drive to create wildlife corridors often meets with significant political opposition (Van Der Windt & Swart, 2008).

The main objections are focused on the costs associated with producing these corridors which include purchase of land, habitat creation and maintenance of the finished product. However there is another concern which the study does not mention, which surrounds the implications of allowing protected species into new areas which may inhibit development of those areas in the future should they be required. This is a particularly significant issue for the HA which is focusing on rapid widening using soft estate areas to enhance the existing road network as opposed to design and build of an entirely new road (Van Der Windt & Swart, 2008).

The main arguments for ecological corridors surround the equilibrium theory of island biogeography and meta-population theory. Both theories focus on the problem of isolation. An isolated population in an unconnected or fragmented habitat is at a higher risk of extinction than a population split into a series on interconnecting sub populations situated within a series of adjoining habitats. This is because of a number of factors such as:

- Ability of a population to move to an alternative habitat if food sources are temporarily unavailable; and
- Increased genetic variation and sexual competition ensuring a genetically healthy population (Van Der Windt & Swart, 2008).

Overall the study concludes that within the Netherlands ecological corridors have been a success, however there is an important aspect to this success which is worth mentioning, which is 'one size does not fit all'. Different species require different things from a green corridor and the bigger the corridor the more species it can be adapted for and the greater chance there is of overall success (Van Der Windt & Swart, 2008).

In 2001 Viles and Rossier published an article examining the use of roads in creation of greenways, also known as 'wildlife corridors' or 'green corridors'. One of the biggest issues with wildlife corridors is that if habitats are dispersed over a wide area how do you convince the private landowners in between to allow a wildlife corridor across their land. This is particularly problematic in intensively farmed areas where there are seasonal and yearly changes to the environment (Viles & Rossier, 2001).

Traditional ecological practice in New Zealand advocated ecological preservation of select unconnected areas without recognition of the linkages within the surrounding landscape. Although this is not necessarily an incorrect form of conservation, smaller reserves may not have a full representation of the regions biota and in effect these smaller reserves can become islands of wilderness with unviable populations of species (Viles & Rossier, 2001).

Wildlife corridors link patches of the surrounding landscape together making the most of the small isolated areas of unconnected habitat and linking them together to form a habitat matrix across the landscape. These can then be linked in to protected areas to facilitate movement of species to and from areas and promote colonization (Viles & Rossier, 2001).

Figure 8 below shows the working theory of Viles and Rossier by connecting 3 habitats (in green) and 3 unconnected pockets of wild area in yellow:

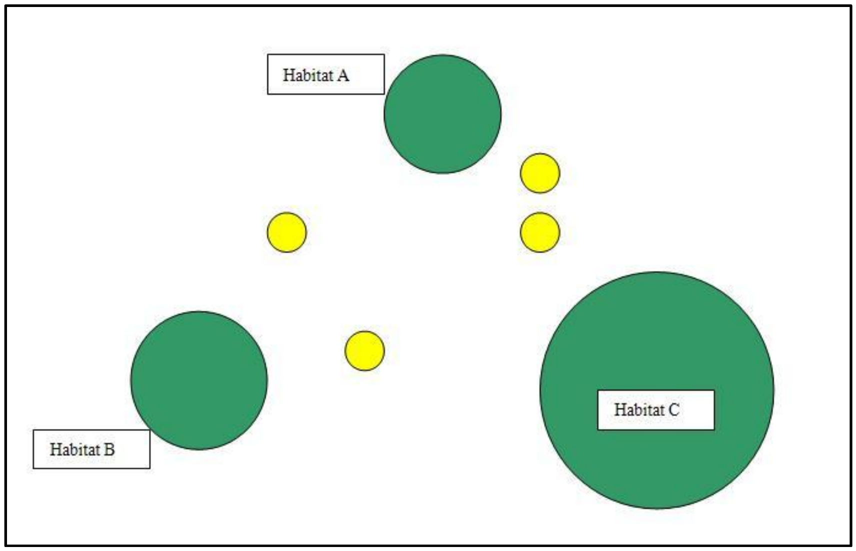

Figure 8

Figure 9 shows how corridors (light green) are both habitat and connectors, and that by connecting habitats A, B and C together you can also connect pockets of unutilized wild area to create more habitat. In addition to increasing the amount of habitat available to wildlife the connections also make the existing habitat more stable by allowing movement between habitats. If one habitat is compromised then species can migrate through the network of wildlife corridors to other areas.

Criticisms against greenways are mainly focused around the connectivity that is so widely regarded as the main strength that they bring to conservation. Connectivity of habitats leaves them open to invasion by undesirable species of plant and animal. In particular where greenways are manufactured disturbed ground can often be quickly colonized by injurious or invasive weeds (Viles & Rossier, 2001).

In addition to this are concerns about the spread of disease both from undesirable species and by allowing a free flow between habitat areas and their indigenous populations. In certain areas of the world fire is a great cause for concern as greenways allow a dispersal route by which fire can pass from one habitat to another. All these concerns are valid however with careful planning and appropriate management they can be mitigated against (Viles & Rossier, 2001).

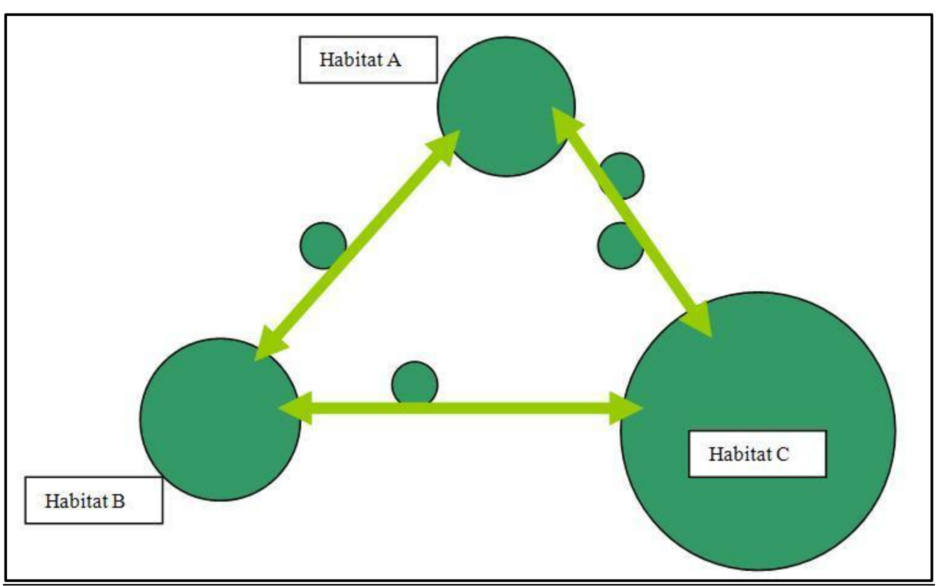

Figure 9

In terms of the HA soft estate their value as habitat is secondary only to their value as green corridors. Van Der Windt & Swart's 2008 study advocates the importance of green corridors to facilitate species redistribution resultant of changes in climatic parameters and it could be that the true value of the soft estate is yet to be recognized.

Directions for Future Research

This study has been undertaken to provide a baseline for the question of how to accommodate management for climate change within the HA soft estate. This study has been important in identifying how the roads have changed from their original landscape design, and the results clearly demonstrate that even when seeded or planted with a standard mix the majority of habitats created will naturally increase in diversity until a saturation point is reached.

The outliers have provided valuable information on the issues which can develop from lack of management if opportunistic and invasive species are allowed to grow unchecked and it is clear that management is a key aspect to the ensuring that the soft estate continues to be a useful ecological resource.

The main importance of the soft estate for climate change is not just provision of habitat it is the network of corridors it provides between habitats allowing populations to migrate into more suitable areas as both the climate and microclimates change. Species of both flora and fauna are incredibly sensitive to changes in climatic conditions and Palaeo-ecological studies have demonstrated that the eventual response of all species to climate change is a re-distribution of the population to areas where the climate is more suitable (Dockerty, Lovett & Watkinson, 2003).

In terms of future research requirements it is intended that we will focus on indicator species, defined as:

"Any biological entity whose presence defines the context of the environment it is in."

This definition was created to encompass the seven possible definitions as outlined by Lindenmayer, Botkin and Margules in 2000. The aim is to study indicator species at the extremities of their habitats using a climatic modeling technique to predict how the indicator species will move in response to the change in climatic variables resultant of climate change.

The HA has already commissioned a study from the UK MET Office to examine how climate will change over the next 80 years and large changes in temperature and precipitation are expected. Using a climatic modeling program to demonstrate these changes we intend to examine the shift in indicator species as a precursor to how habitat distribution will change.

The overall objective from this will be to predict how we can manage the soft estate for the future and maintain its viability in terms of an ecological resource and network of biodiversity corridors. Habitat take time to create as all habitats need a certain length of time to 'bed in' and become a stable enough environment to receive species. This research could be essential in the long term in ensuring the survival of the UK's rarer, more sensitive and less mobile species, allowing us to proactively manage environmental areas and create suitable habitats for when they will be needed in the future.

Conclusions

Overall the study has demonstrated that the HA soft estate reacts in a similar way to many other larger and non linear habitats, increasing in species richness until a saturation point appears to be reached. It has also highlighted the importance of the soft estate in terms of an ecological habitat and dispersal corridor.

One of the main findings is that management of the soft estate is a key issue to maintaining its viability as an ecological resource, particularly in the face of a changing climate, but this investigation does not offer any recommendations into which types of management practices should be adopted. Unfortunately the majority of road improvements planned for the next few years involve rapid widening, a process which allows for no further land take and therefore construction occurs within the soft estate. This in itself could be a greater threat to the UK meeting its biodiversity targets than lack of effective management or the impacts of climate change.

The next stages of study into this area of investigation should focus on how the soft estate will change in response to climate change and which management techniques will help maintain soft estate viability for the future.

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Biographical Sketches

Lucia Collinwood works full time for Parsons Brinckerhoff, an International Civil Engineering Consultancy, as the Environmental Assessment and Management (EAM) team leader for their Cardiff office. She has over 10 years experience of environmental assessment and management of the HA SRN project managing road Environmental Impact Assessments (EIA) and acting as an expert advisor to the HA on matters relating to environmental management of the SRN. Part time she undertakes a Ph.D. at Swansea University to examine the effects of climate change on management of the HA soft estate; Dr Sietse Los is her primary supervisor.

Sietse Los is a Reader in the Department of Geography at Swansea University. He obtained a PhD with the "Vrije Universiteit Amsterdam" in 1998 examining the linkages between vegetation and climate. He worked previously with the Global Inventory Modeling and Monitoring Studies (GIMMS) group at NASA Goddard Space Flight Center and was program manager and acting director of the NERC Climate and Land Surface Systems Interaction Centre (CLASSIC) He is/was/has been investigator on research funded by NASA, ESA and NERC. His research interests are in satellite based vegetation monitoring, land-cover change detection and understanding interactions between the biosphere and atmosphere.

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THE FHWA CARBON SEQUESTRATION PILOT PROGRAM: ECONOMICS, ENVIRONMENT, AND POLICY

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Abstract

Climate change legislation has mainly focused on a policy tool known as cap-and-trade. In this approach a cap is set on emissions and entities covered by the cap must hold enough allowances to cover their emissions for the specified time period – usually a year. Many proposals allow for the use of credits if the entity goes above its allotted cap. In such a case, the entity would purchase these credits in a market to achieve compliance with the cap. Biological carbon sequestration, the process that plants use to take up carbon dioxide from the air and turn it into biomass, has been proposed as one type of carbon credit. Thus, vegetation growing along highway rights-of-way, under certain circumstances, may be a marketable commodity. In late 2007, FHWA launched a pilot program to (1) develop estimates of the amount of revenue that could be earned by state DOTs if they undertook such a program; (2) determine the cost-effectiveness of such a program on a national scale; and (3) create decision support tools that DOTs could use to determine the efficacy of a program in their state. The tentative results, current status, and future direction of the program will be discussed.

Introduction

Climate Change

The potential effects of climate change appear to be one of the greatest environmental challenges humans have faced. The fourth assessment of the Intergovernmental Panel on Climate Change concluded, with very little doubt, that climate change is occurring and that human activities have played some role in it (IPCC 2007). In part because of the increasing scientific certainty expressed between the first and fourth assessments, US political leadership has placed more and more emphasis on the topic, resulting in a spate of bills since 2005 that would regulate carbon emissions, the major component of human greenhouse gases or GHGs (IPCC 2007).

Cap-and-Trade Versus Taxes

Two general policy tools have been proposed to control and eventually greatly reduce GHGs; a tax levied on each ton of carbon emitted, and a market-based cap-and-trade system. The single most important difference between the two is the variable controlled: a tax fixes the price of carbon while leaving uncertain the actual amount of carbon that will be emitted into the atmosphere, while cap-and-trade sets the amount of carbon that can be emitted, and allows the price of that carbon to vary.

Taxes have an advantage in that they are familiar to lawmakers and the general public and are relatively easy to administer. Also, many economists argue that the overall cost to the economy of a tax is less than cap-and-trade (Ramseur and Parker 2009). However, the lack of palatability of taxes to the American public means that nearly all climate change bills have focused on the alternative.

Cap-and-trade originated in the US as a means to progressively reduce sulfur dioxide emissions (Vig and Kraft 2006). To implement such a system for GHGs, a first step is to estimate the total amount of GHGs entering the atmosphere and determine the sources. Next, a decision is made on which components of the economy to regulate, and whether to place controls “upstream” or “downstream.” Most cap-and-trade bills are economy-wide, and focus on regulating the production end (e.g. electric plants and refineries) rather than the consumption end (e.g. individual homes and cars) due to the much smaller number of entities that would require regulation.

With total emissions and regulated entities determined, an end goal and timeline are set for reduction of GHGs. Most bills considered by Congress plan for a 65-80% reduction in emissions by the year 2050, based on straight-line reduction from a 1990 baseline. Emissions permits are then issued or auctioned each year in a number corresponding to that year’s total allotment. If an individual company emitted 1 million tons of carbon in the baseline year, and had to reduce that 1% each year, it would purchase or be allotted 990,000 permits in year one, 980,000 in year two, and so on. If the company were able to reduce its emissions to 960,000 in year two, it would have an excess of 20,000 permits it could sell to one or more companies that exceeded their cap. Thus, the market sectors most able to make emissions reductions cheaply have an opportunity to reduce or eliminate the cost of compliance by selling their excess permits. This works because the total number of permits is fixed and decreasing over time. However, this rigidity has the potential to result in highly variable cost of permits, a cost that would be passed on to consumers in the form of higher prices for nearly every good and service.

Carbon Offsets

To mitigate compliance costs, some bills have included a provision for carbon offsets, defined as actions taken by entities not covered by the emissions cap that reduce emissions or sequester GHGs already in the atmosphere. Examples could include a homeowner that installs solar panels to reduce dependence on a coal-fired power plant, or a landowner that chooses to grow vegetation specifically to sequester atmospheric carbon. In practice, a company that exceeded its permit allowance for a given year could achieve compliance by purchasing excess permits, carbon offsets, or some combination of the two. Because carbon offsets do not necessarily represent a permanent reduction in emissions but instead offset growth of emissions elsewhere, their use is typically limited to 5-15% of a company's total compliance portfolio. However, the potential for land managers to generate revenue from biological carbon sequestration in the form of sustainable forestry, no-till agriculture, range management, and converting pastures to native grasses has generated a great deal of interest, and is the genesis of the Federal Highway Administration's (FHWA) carbon sequestration pilot program.

The Pilot Program

Federal statutes allow state Departments of Transportation (DOT) to generate revenue from their land holdings. Because DOTs must retain unused buffers in their right-of-way (ROW) for safety, operations and maintenance purposes, FHWA recognized that an opportunity may exist to shape the future of a burgeoning ecosystem service market (NRC 2005).

The goals of the FHWA pilot program are (1) to estimate the amount of carbon that may be sequestered (and revenue generated) along highway ROW in the National Highway System; (2) determine whether FHWA should pursue a national-level effort; and (3) develop relevant decision support tools for use by state DOTs. The remainder of this includes discussion of the methods used to generate national and state-specific sequestration estimates, the barriers identified to-date that DOTs must overcome to enter the carbon offset market, and tools that are in development.

Methods

Initial Estimates of National and State-Level Sequestration Potential

A course methodology was initially used to determine whether a pilot program would be viable. First, the literature was reviewed and experts polled to determine the total acreage of the National Highway System (NHS). When it became apparent that this information was not readily obtainable, expert elicitation (Meyer and Booker 2001) was used to generate a range of ROW widths including the likely minimum, average and maximum ROW widths, paved and unpaved widths, and remaining widths that would be available for carbon sequestration via vegetation management. These estimates were multiplied by the length of the NHS, which is known with a relatively high level of certainty, to obtain national areal estimates.

Next, the literature was gleaned for biological sequestration rates of native habitats occurring in the US. For simplicity, these were narrowed to grasslands and forests.

Finally, a range of carbon prices was compiled based on several literature sources (EPA 2005; USDA 2004) and historic prices occurring on the Chicago Climate Exchange (CCX), the European Union Emissions Trading Scheme, and through other "over the counter" carbon offset providers. These ranges of acreage, sequestration rates, and carbon prices were combined to generate national level estimates of carbon sequestration potential, and concomitant revenue generated. Expenses, such as those related to vegetation planting and management, carbon quantification and verification, data management and market trading were not addressed at this point. These results were presented to FHWA management, and the decision was made to select a state for more in-depth analysis.

Several criteria were used to select a state for the pilot program. An Excel spreadsheet was developed that included data for each state, and a multi-criteria decision analytic approach (Clemen and Reilly 2000) was used to score and rank states.

As there was no single source for NHS acreage at the state level, the assumption was made that highway miles was a reasonable surrogate for acreage. A second criterion included percentage of the state historically and presently forested. It was assumed that locations of highways would not differ greatly from locations of these habitats. That is, if a state has 40% of its original forest intact, 40% of the highway mileage would fall within this forested area. A second assumption was that states where more deforestation had occurred had greater potential for carbon sequestration on ROW. Qualitative criteria included (1) a determination of whether the state was already mandated to carry out carbon sequestration activities (thereby making it the status quo, and therefore ineligible under the rules of voluntary markets such as CCX); whether the state was already a member of a voluntary market; and whether there was documentable support for such activities by the political leadership of the state. Quantitative attributes were developed for each qualitative criterion, thereby allowing scores to be awarded to each state in an objective fashion. The scoring range for each criterion was normalized (e.g. 0 to 1.0), and each criteria was weighted based on its perceived importance in selecting a state.

Once states were scored, a short list was developed and these state DOTs were contacted. Those that expressed interest were interviewed by telephone using a standard set of questions. These data were used for a final ranking of nominee states, from which a selection was made.

State Estimates of Sequestration Potential

The two states selected for the program were asked to hand-pick likely sequestration sites based on their knowledge of the DOTs' land holdings, known or perceived constraints, and sequestration potential. In addition, one state was asked to develop a statewide estimate of acreage potential based on aerial photographs and/or GIS.

Preliminary Results

Given rough range approximations for several variables, including NHS mileage, the amount of unpaved ROW along those miles, carbon sequestration rates, and estimated future carbon prices, the total revenue generating potential for sequestration along highway ROW is expected to be between \$48 million and \$1.8 billion annually (Table 1). These figures are based on estimated total CO_2 uptake values ranging from 1.6—20 million tons of CO_2 per year and carbon prices of at least \$30 per ton of CO_2.

Variable	*Lower bound*	*Upper bound*
NHS mileage	163,000	164,000
Estimated width of unpaved ROW along NHS	100 ft	600 ft
Estimated percentage of unpaved ROW available for sequestration	80%	99%
Estimated unpaved ROW acreage *=(NHS length * unpaved ROW)/sq. ft per acre*	2 million	8 million
Sequestration rates (tons CO_2/ac/yr)	0.8	2.5
Total annual uptake (tons CO_2)=*Est. unpaved ROW acreage*seq. rates*	**1.6 million**	**20 million**
Carbon price (\$/ton CO_2)	\$30	\$90
Total annual revenue (\$) *=Total annual uptake*carbon price*	**\$48 million**	**\$1.8 billion**

Table 1. Initial Estimates of National Sequestration and Revenue Generation Potential

After demonstrating the nationwide potential of a carbon sequestration program, an analysis was completed for all 50 states, Washington D.C. and Puerto Rico. States were scored on a 0 to 1.0 scale. High-scoring states were spread across the country, as shown in Figure 1. Note that this figure is designed to separate states into five similar groups. Thus, the first significant break in scores appears somewhere above 0.47. This is shown quantitatively in Table 2.

Prior to the telephone interviews, the top 10 states were Texas, Illinois, Michigan, Pennsylvania, California, Oregon, New Mexico, Idaho, Washington, and Minnesota (Table 2). Though Texas scored low in categories including "forest factor," it dominated the category of rural highway miles, thereby pushing it higher in overall score. Conversely, New Mexico and Minnesota had many fewer miles of highway, but rose in the final scores due to the presence of forests and grasslands, as well as taking early action such as developing a state climate action plan.

		TX	IL	MI	PA	CA	OR	NM	ID	WA	MN
NHS Factor (Weight = 0.2)	Rural NHS Mileage	8750	3356	3059	3459	5041	3266	2644	2188	2612	3263
	Normalized Rural NHS Mileage	1	0.38	0.35	0.4	0.58	0.37	0.3	0.25	0.3	0.37
	Factor Score	*0.2*	*0.08*	*0.07*	*0.08*	*0.12*	*0.07*	*0.06*	*0.05*	*0.06*	*0.07*
Forest Factor (Weight = 0.2)	%age of State Potentially Forested*	0.25	0.39	0.91	0.95	0.52	0.5	0.2	0.46	0.6	0.62
	Factor Score	*0.05*	*0.08*	*0.18*	*0.19*	*0.1*	*0.1*	*0.04*	*0.09*	*0.12*	*0.12*
Grassland Factor (Weight = 0.2)	%age of State Potentially Grasslands**	0.541	0.110	0.063	0.092	0.226	0.410	0.649	0.442	0.213	0.075
	Factor Score	*0.11*	*0.02*	*0.01*	*0.02*	*0.05*	*0.08*	*0.13*	*0.09*	*0.04*	*0.02*
Indicators Factor (Weight = 0.1)	Points	2	4	4	4.75	3.75	3	5	5	4.5	4
	Normalized Points	0.4	0.95	0.6	0.8	1	0.8	1	0.9	0.8	0.75
	Factor Score	*0.04*	*0.1*	*0.06*	*0.08*	*0.1*	*0.08*	*1*	*0.09*	*0.08*	*0.08*
Emissions Trading Member Factor (Weight = 0.1)	Points	1	2	1	1	-	-	1	-	-	-
	Factor Score	*0.1*	*0.2*	*0.1*	*0.1*	*0*	*0*	*0.1*	*0*	*0*	*0*
Self-indicated Interest Factor (Weight = 0.1)	1 = DOT Interest	1	1	1	-	1	1	-	1	1	1
	Factor Score	*0.1*	*0.1*	*0.1*	*0*	*0.1*	*0.1*	*0*	*0.1*	*0.1*	*0.1*
	TOTAL SCORE	**0.6**	**0.57**	**0.52**	**0.47**	**0.46**	**0.44**	**0.43**	**0.42**	**0.4**	**0.39**

**Percentage of State Potentially Forest was calculated using data from the USDA's Forest Resources of the United States (2002). **Percentage of State Potentially Grasslands was calculated using data from the USDA's Economic Research Service. Points for the Indicators Factor were based on a count of states' activities that were indicative of potential interest in the pilot program, for example a completed climate action plan for the state. Note: Weights in the table do not sum to 1.0 because a seventh factor, "unused wetlands factor," which had a weight of 0.1 but is not reported here, was used in the selection scoring.*

Table 2. Selection Criteria and Ten Top-Ranking States after Initial Evaluation

	TX	ID	OR	MN	NM	WA	IL
Rural NHS Mileage	8750	2188	3266	3263	2644	2612	3356
Min. Unpaved ROW Width Range	45-75	30-75	15-75	66-125	70-125	15-75	20-50
Min. Unpaved ROW Width Ave	60	53	45	96	100	45	35
Median Unpaved ROW Width Range	75-125	75-125	75-125	125-175	125-175	75-125	50-90
Median Unpaved ROW Width Ave	100	100	100	150	150	100	70
Max. Unpaved ROW Width Range	125-900	125-225	125-400	175-1000	175-400	125-500	90-500
Max. Unpaved ROW Width Ave	512	275	262	588	285	312	295
Weighted Ave Unpaved ROW Width	170.4	201	115.9	221.4	162.0	125.9	104.5
Weight Ave Acres	180727.3	26760	45882.4	87567.1	51918.5	39860.7	42509.3
Non-ROW	15000.0	45000	17500.0	14400.0	850.0	3000.0	5000.0
Normalized NHS Factor Points	1.00	0.37	0.32	0.52	0.27	0.22	0.24
NHS Factor Score (Weight 0.2)	0.20	0.07	0.06	0.10	0.05	0.04	0.05
Forest Factor Score	0.05	0.09	0.10	0.12	0.04	0.12	0.08
Grassland Factor Score	0.11	0.09	0.08	0.02	0.13	0.04	0.02
TOTAL SCORE	**0.36**	**0.25**	**0.25**	**0.25**	**0.22**	**0.21**	**0.15**

Table 3. Final Scores after Expert Estimation of ROW Widths

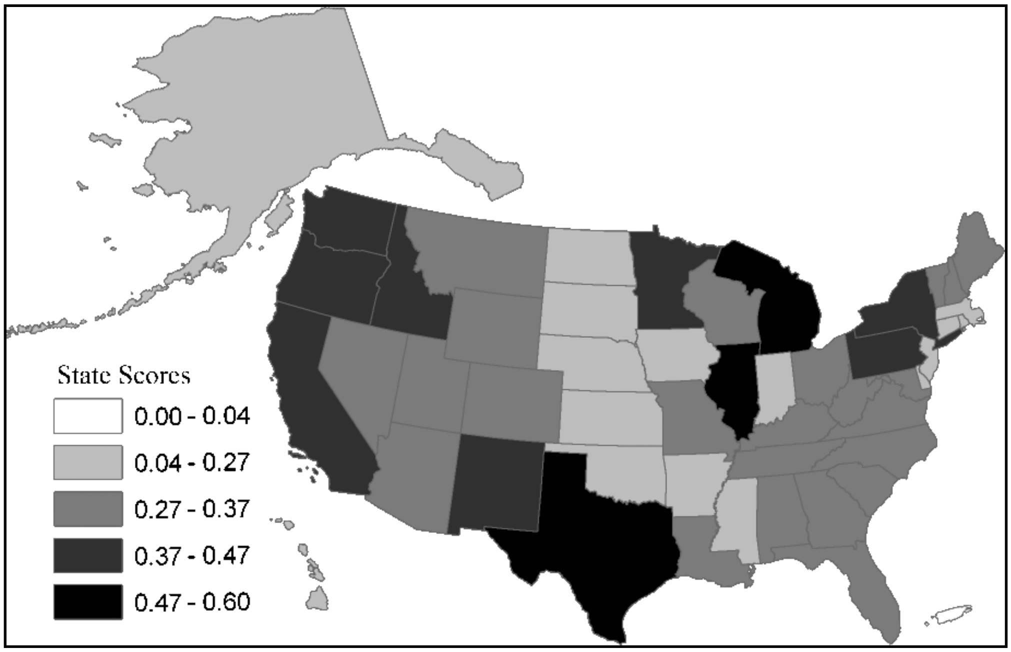

Figure 1. State Scores Based on Initial Selection Criteria

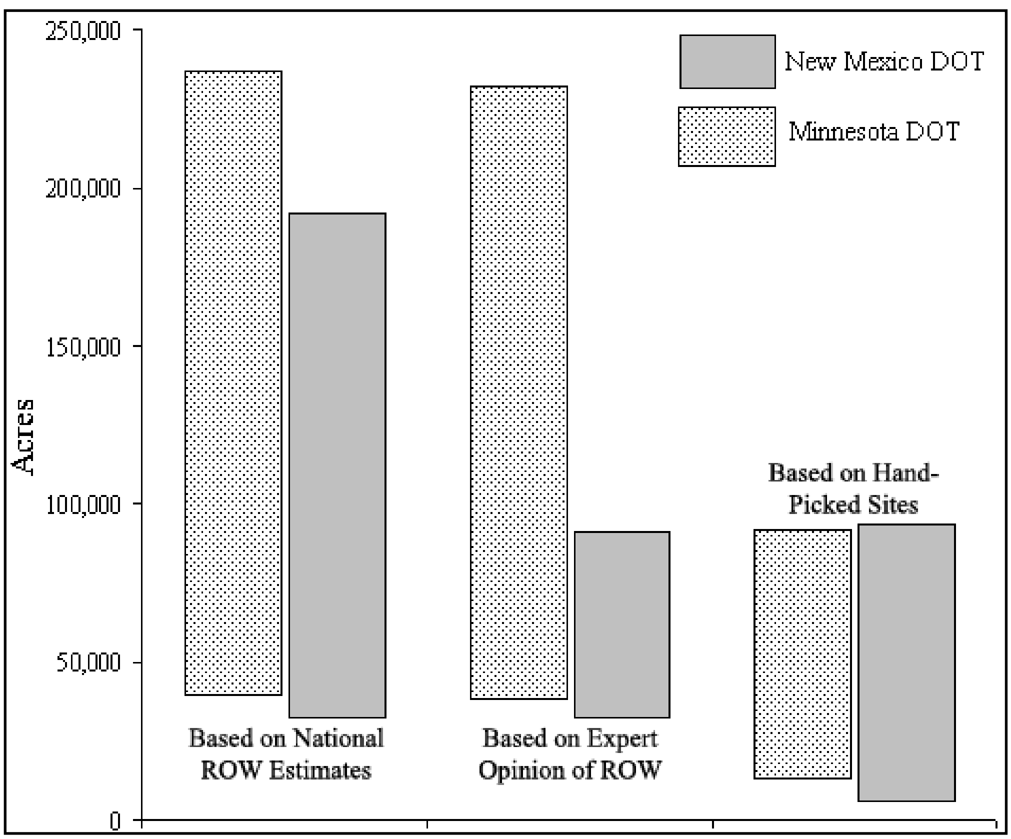

Figure 2. Estimated Ranges of Unpaved Row Acreage in Minnesota and New Mexico Available for Carbon Sequestration

Several states declined further participation in advance of the telephone interviews, citing existing workloads, lack of support from leadership, and in some cases, the desire to advance the concept without FHWA involvement. Candidates that continued in the selection process were asked to provide best guess estimates on the narrowest, most common, and widest widths of unpaved ROW in their respective states. These expert opinions were used to estimate potential ranges into which most unpaved ROW widths would fall. The midpoint of each range was multiplied by weighting factors and then summed together and with forest and grassland scores. The new scores (Table 3), which caused the overall state rankings to shift from the initial ordering, along with an expressed interest in carbon sequestration led FHWA to select New Mexico DOT (NMDOT) and Minnesota DOT (MN/DOT) to participate in the pilot program.

Using national estimates of ROW widths to approximate unpaved ROW acreage indicates between 39,000—237,000 acres could be available in Minnesota, and 32,000—192,000 acres in New Mexico. Both expert opinion from MN/DOT and NMDOT staff as well as data from their respective hand-picked sites suggest the available acreage amounts may be smaller (Figure 2).

Discussion

There was a large difference between the initial estimates of available acreage in New Mexico and Minnesota, and sites these states hand-picked for placement in the pilot program. This disparity hints at the number of challenges and limitations that were identified during the study. The following sections are therefore provided to help lay the groundwork for other DOTs that choose to undertake vegetation management for carbon sequestration.

DOT Options for Carbon Management

A number of options are available to state DOTs that wish to actively manage their carbon. Each comes with its own set of challenges and rewards.

Voluntary Markets

One option is for a state government to join a voluntary, legally binding entity such as CCX. New Mexico was chosen for the pilot program in part because it is a CCX member, and therefore can sell offsets on the trading platform. In most cases however, CCX membership requires that an entity track all its emissions as well as its offsets, and comply with the legally binding requirement to reduce emissions 6% by 2010, based on a 1990 baseline. If the state achieves its annual reduction goals, any offsets conforming to CCX protocols could be sold. On the other hand, if the state does not reach its goals, any offsets produced will likely be used as low-cost credit so that the state can minimize its outside purchases. Also, it is unclear what role CCX would play if federal cap-and-trade legislation is passed, though most bills give credit for early actions taken to reduce emissions and sequester carbon.

Compliance Markets

The US does not currently have a national compliance market for greenhouse gases. The European Union Emissions Trading Scheme is the largest volume compliance market, but its allowance for offsets does not extend to developed nations like the US. If and when Congress passes cap-and-trade legislation, the vast majority of US-based carbon sequestration projects will likely be sold into the domestic market. It should be noted that even if legislation passes during the current Congress, the complexity of the policy suggests that promulgation of regulations will take several years. Given this, the Minnesota DOT is currently planning to track its carbon sequestration activities with hopes of “banking” them for use in a future compliance market.

The only known regional compliance market in the US is the Regional Greenhouse Gas Initiative (RGGI). This consortium of 10 northeastern states has placed a cap on GHGs from electric utilities, and also allows offsets for reforestation. These offsets can come from outside the RGGI signatory states, but the process has not yet been clarified, and a potential over-allocation of permits may obviate any demand for offsets (Burgert 2008).

Over-the-Counter Carbon Credits

Entities such as Terrapass, Carbon Fund and growing number of others serve as carbon offset retailers, buying their offsets in bulk from a few sources, then selling them to individuals, businesses, organizations and events that wish to offset their carbon “footprint.” While neither New Mexico nor Minnesota DOTs have expressed interest in pursuing this option, Terrapass has developed several carbon offset projects working with municipal or county authorities, thereby suggesting that work with a state DOT might also be feasible. In this system, the retailer typically purchases credits that have been entered into a recognized carbon registry, or maintains a registry of its own. Prices vary greatly, and are a function of the cost of producing the offset, and passing it successfully through a quantification, verification, and registration process, of which there are several with varying levels of rigor.

Private Management

The time and expertise required to develop and manage carbon offset projects may lead some DOTs to opt for an administrative approach. For example, a state may choose to lease its ROW to private entities for the express purpose of carbon sequestration. This should reduce staff time commitment and may limit liability, and will also result in a smaller, but potentially more predictable revenue stream. State DOTs that consider this option should be aware of the issues discussed in the next section, and structure any legal agreements accordingly.

Limiting Factors and Barriers to Entry

As alluded to throughout this report, today's carbon market is challenging due to its nascent status. There is a lack of an overarching set of rules, complicated by the fact that regional initiatives are in various stages of development: the Regional Greenhouse Gas Initiative is in operation in the northeastern US with rules and protocols, while the Western Climate Initiative is much earlier in the process. During this pilot, several issues have been identified that state DOTs must resolve. Other state-specific concerns will invariably arise as well.

Safety, Operations, Maintenance, and Liability

State DOTs are uniform in the goal of providing a safe transportation system to their users. It should be noted that the pilot program has not, and never will, propose to grow and manage vegetation in areas where it would create a safety hazard. In nearly all highway ROW, native grasses are compatible with safety goals. In other areas, shrubs and/or trees may also be acceptable. However, due to liability concerns, the New Mexico DOT chose not to plant or actively manage any woody vegetation for carbon sequestration. Instead, it is focusing on grassland sequestration. In northern latitudes, trees set back sufficient to minimize vehicle-tree collisions may still shade the road in the winter, setting up black ice conditions. On the other hand, in these same climes, appropriately placed trees and/or shrubs may create "living snow fences," which are thought to improve safety by reducing the amount of snow blowing across, or accumulating on, roadways.

Land Ownership and Period of Commitment

State DOTs manage lands for highway-related purposes, but in many cases may be operating with a lease agreement rather than holding the land under fee title. In such cases, the DOTs may need to revise lease agreements or develop memoranda of understanding with the underlying landowner in order to clarify ownership of any carbon credits generated. This is due to the fact that selling a carbon credit essentially transfers the legal ownership to the buyer. The costs involved in resolving such a problem after the fact could quickly outstrip the value of the carbon traded. This is of particular concern in western states, where underlying land owner is often the Bureau of Land Management or the USDA Forest Service. The FHWA is currently working with these agencies to develop agreements that would be consistent with the land management agencies' goals, while allowing state DOTs to retain ownership of any carbon credits produced.

Existing rules are highly variable regarding the commitment made when registering and selling a carbon credit. The CCX requires a 15-year management commitment on the part of the landowner for forestry projects. Other entities require permanent easements, which results in higher prices charged for the offset. These long-term commitments can be cumbersome and essentially unworkable for state DOTs, since they must retain the ability to expand or reconfigure roads within existing ROW. This alone does not preclude a DOT from managing for carbon sequestration, but it does point to the need for appropriate and flexible protocols.

Lack of Appropriate Protocols

In order for biological carbon sequestration to be cost-effective, the expenses involved in measuring and verifying the amount of carbon sequestered must be significantly less than the price of carbon on the open market. Thus, a balance must be found between scientific rigor and associated costs. One challenge for state DOTs is that their land holdings are dispersed across the landscape rather than concentrated in a block. Depending on the protocol used, this can result in higher cost to measure the carbon baseline and measure subsequent sequestration. Aerial photography and GIS-based protocols that require little or no on-the-ground measurement could help drive down these costs.

It was also discovered that CCX has protocols for managing grasslands, but these only apply in instances where farmland is converted to pasture, or when managing livestock. Neither protocol applies to situations where low-diversity, non-native grasses are replanted to native species, which would be a common ROW activity. To address this gap, the New Mexico DOT has undertaken a research program to establish baselines of carbon sequestered along highways, with the intent of reseeding some of these locations to native grasses and measuring subsequent sequestration gains. The results of this research are intended to provide the basis for a general protocol that can be modified for use by state DOTs across the country.

Finally, most carbon sequestration protocols are developed around actions taken on a specified plot of land. As alluded to in the previous section, this is problematic for state DOTs. As part of this pilot, FHWA hopes to resolve this problem by developing a protocol that allows state DOTs to manage carbon in pools, rather than parcel-by-parcel. This approach is already accepted by CCX, whereby "aggregators" work with numerous landowners to pool many small projects, thereby reducing overall risk and administrative costs.

Ecosystem Services Markets

This article would not be complete without a brief discussion of environmental co-benefits. The FHWA strongly supports state DOT efforts to be good land stewards. Managing ROW for a full suite of ecosystem services, including carbon sequestration, can help to reduce stormwater runoff and related soil erosion, improve water quality, and provide wildlife habitat. To be clear, FHWA does not advocate managing ROW solely for carbon sequestration, any more so than it does for any other single environmental benefit. These ecosystem services, defined as services that ecosystems provide at no cost, but which humans have to pay to replace otherwise, are only beginning to be incorporated into markets. Crude markets have existed for more than a decade in the form of wetland mitigation banks, but these still lack fungibility and entail relatively large transaction costs.

While many ecosystem services have been recognized for decades, they have remained undervalued for just as long. That is beginning to change. Costanza *et al.* (2008) recently demonstrated the value of coastal wetlands for protection of human infrastructure against hurricane damage. We might assume part of the infrastructure protected was roadways, though this has yet to be studied. In another context, could planting and managing vegetation on highly erodible banks adjacent to highways reduce emergency maintenance costs associated with clearing roads after landslides? In fact, rains in Scotland in 2004 caused landslides that blocked several highways for one or more days, and required that 57 persons be airlifted to safety when their vehicles became trapped between two slides (Winters *et al.* 2008). According to the lead author of this study, the slide areas were likely forested historically, but were converted to grazing pastures many years ago.

Congress is placing great emphasis on minimizing the cost of any cap-and-trade legislation on the economy and consumers. Allowing carbon offsets opens up a potential revenue stream for those who wish to adopt carbon sequestration as a land management strategy, but it also effectively increases the supply of permits, thereby placing downward pressure on the price of carbon. Even under the best of scenarios, state DOTs will never replace their gas tax-based federal aid funds by growing vegetation on highway ROW. However, development of a carbon market is one step toward a more complete valuation of ecosystem services. Furthermore, considering the use of vegetation as living snowfences, landslide eliminators and other such protectors of human infrastructure may, in many cases, eventually be found to be more cost-effective than traditional engineering solutions, especially when all costs are included.

Concluding the Pilot Program

The FHWA carbon sequestration pilot program is expected to be concluded with a final report by the end of 2009. One task that remains to be completed is to develop an aerial photograph or GIS-based estimate of available ROW in Minnesota. This proof-of-concept will hopefully provide a model that other states can use to estimate their total available acreage for vegetation management. Related to this, a carbon function tool will be developed that will allow a DOT to generate estimated revenue and expenses associated with a carbon sequestration program. The tool will include input options such as capital costs of planting tree or grass seed, planting seedlings, or allowing vegetation to encroach naturally, and will provide estimates for revenue based on user-defined carbon market prices. Finally, the report will contain recommendations regarding whether and how FHWA should engage further in the carbon market. These recommendations will cover both policy and technical considerations.

Biographical Sketches

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Carson Poe is a Transportation Industry Analyst with the U.S. Department of Transportation Volpe National Transportation Systems Center. He has worked in the transportation field for six years, focusing on environmental streamlining, regulatory support for the Federal Highway Administration and the Pipeline and Hazardous Materials Safety Administration, strategic outreach, and operations analysis for the National Park Service. Mr. Poe has worked on projects involving: data collection/surveying, analysis, and forecasting; development and delivery of guidance and tools for transportation and energy industry professionals; design of outreach materials and initiatives; planning and implementation of websites and software tools; drafting of Reports to Congress; and, providing assistance with various aspects of the National Environmental Policy Act process. He holds a Masters Degree in Energy and Environmental Analysis from Boston University and a Bachelor of Arts in Interdisciplinary Studies; Concentration in Environmental Policy and Planning from Appalachian State University. Other certificate studies were completed with the University of Amsterdam (Amsterdam, the Netherlands) and The Mountain Institute (Kathmandu, Nepal).

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POTENTIAL IMPACTS OF CLIMATE CHANGE ON URBAN FLOODING: IMPLICATIONS FOR TRANSPORTATION INFRASTRUCTURE AND TRAVEL DISRUPTION

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Abstract

Climate change in the Pacific Northwest of America is likely to bring more frequent, heavier winter precipitation as temperature rises. These changes in precipitation patterns have significant implications in hydrology and socioeconomic sectors that could be affected by changes in hydrology. Transportation infrastructure and travel patterns are also vulnerable to potential changes in runoff regimes and stream geomorphology. The 2006 and 2007 winter storms resulted in massive flooding, causing several major road failures in Oregon. While the probability of these extreme events is projected to rise under the global warming scenarios, there is no study investigating this issue in Oregon.

The objectives of the project are threefold. First, we investigate the changes in the frequency and magnitude of winter runoff under climate change scenarios. Second, we determine the probability of road closure for representative road bridges under climate change scenarios. Third, we quantify these changes on transportation chokepoints related to flooding.

We examined two representative urban streams in the Portland Metro area. Johnson Creek and Fanno Creek were chosen because both creeks have historical flow data and exhibit high flooding potential; each also has high road density with high traffic volume. The hydrological processes of the two watersheds, however, are different (Fanno – highly urbanized and steep slope; Johnson Creek – mixed land use with gentle slope); thus, each serves as a good model for other urban watersheds in Oregon.

We used the following methodology to conduct our analysis.

1) *Hydro-climate modeling*: We applied statistically downscaled climate change scenarios for our study sites to predict the anticipated changes in winter precipitation amount and intensity. The US Geological Survey PRMS hydrologic model, together with a statistical model, were used to estimate runoff changes and resultant changes in flood frequency.
2) *Stream geomorphology survey and hydraulic analysis*: We surveyed channel profiles, patterns, and dimensions at the multiple cross sections of our study sites. The surveyed data were used to calibrate US Army Corp of Engineers' HAC-RAS for hydraulic analysis to project future water levels and identify vulnerable bridges and roads under different discharge scenarios.
3) *Traffic analysis*: We used Metro's travel forecast model to determine the potential impacts of road failure and congestion resulting from flooding. The model served as a reasonable and accurate assessment of the outcomes due to traffic disruption.

Our results show that there is a nonlinear relation between precipitation change and urban flooding and that impacts on travel disruption are subject to local hydroclimate and watershed land use conditions. This study is one of few interdisciplinary attempts to assess potential impacts of climate change on the transportation sector. Such integrated knowledge and spatially-explicit modeling is essential for establishing proactive flood and transportation management planning and policies under increasing climate uncertainty.

Introduction

The December 2007 storms amplified the ongoing flood risk in the Pacific Northwest (PNW). The problem has been cited as one of the worst cases of floods in the region. Many buildings and roads were closed as a result of prolonged and intense precipitation that brought severe floods. Flooding not only damaged various infrastructures but also disrupted freight and personal travel in the region. Flooding has become a persistent problem in recent years as more extreme weather events occur and development along the floodplain intensified. For example, in the city of Vernonia, the US Geological Survey recently revised a floodplain map, showing expanded floodplains into higher elevations. Flooding risk could increase in the future as a result of potential changing climate worldwide (Huntington 2006; Chang and Franczyk 2008). The stationarity assumption may not hold true in new infrastructure design and management (Milly et al. 2008). However, there is no quantitative study that investigates how future climate changes will affect flood frequency and its impacts on transportation infrastructure in the PNW.

While there is a growing body of literature on simulating future floods under climate change scenarios around the world (Ashley et al. 2005; Cameron 2004; Leander and Buishand 2007; Mazzarella and Rapetti 2004), there are only a few studies assessing potential consequences of climate change on the transportation sector in North America (NRC 2008). These studies include regional economic impacts as a result of changing transportation modes in Northern Canada (Lonergan et al. 1993) and flood risk mapping for vulnerable roads and the cost of travel disruption in the Boston Metropolitan area (Suarez et al. 2005). A unique feature of this study is to consider projected changes in land use and transportation demand as well as climatic conditions into the urban transportation modeling system. By incorporating broad environmental and socioeconomic scenarios, we will be able to discern the relative impacts of global warming on the transportation system as a result of additional riverine flooding.

Studies on natural hazard impacts from future climate change have struggled to adequately assess impacts (Soleckie and Rosenzweig 2001). This is largely due to a lack of adequate data, difficulty in interpreting the existing multi-disciplinary data, the complexity of cascading effects resulting from flooding on the regional transportation systems (NRC 1999), and the focus on attempting to model only extreme events, which are inherently more difficult to predict and model (Pielke and Downton 2000; Changon 2003). With this study, we are focusing on the cumulative effects of a range of flood events, which are to likely increase in frequency as a result of climate. In addition, we modeled the short-term transportation impact from temporary flooding in a few local roadways.

Study Area

The Portland metropolitan area serves our study site (Figure 1). Johnson Creek and Fanno Creek were chosen because both creeks have historical flow data and exhibit high flooding potential; each also has high road density with high traffic volume. The hydrological processes of the two watersheds, however, are different (Fanno – highly urbanized and steep slope; Johnson Creek – mixed land use with gentle slope); thus, each serves as representative for other urban watersheds in Oregon. While the urban areas of Upper Fanno and Lower Fanno Creeks, and Lower Johnson Creek are 83%, 87%, 89% of respective watersheds, the urban areas of the Upper Johnson Creek watershed are only 40% of the watershed. A portion of Upper Johnson Creek has been incorporated into urban growth boundaries in 2002.

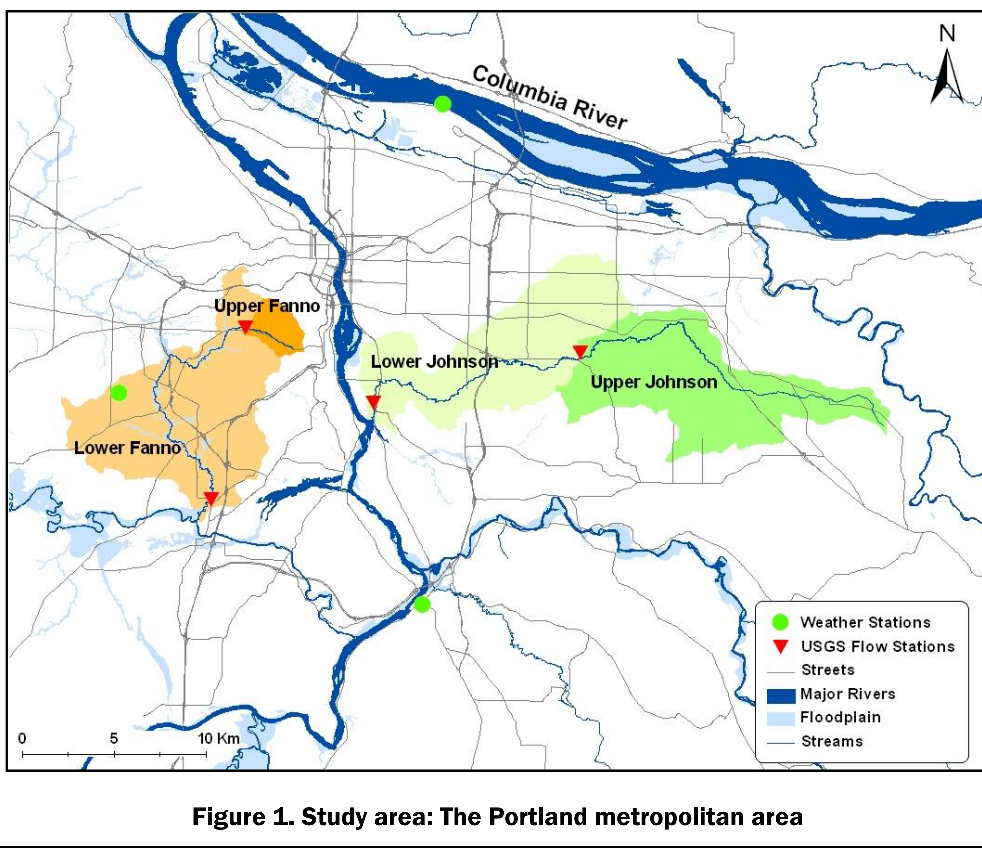

Figure 1. Study area: The Portland metropolitan area

Data and Methods

Hydroclimate modeling

We applied downscaled climate change scenarios for our study sites to predict the anticipated changes in winter precipitation amount and intensity. We used four representative climate change scenarios (CCSM-A1B, CCSM-B1, ECHAM5-B1, IPSL-B1) statistically downscaled at a spatial resolution of 1/16 degree for a period between 1960 and 2059. The years between 1960 and 1989 serve as reference period, while the years between 2030 and 2059 serve as future period representing the years around 2040s. These scenarios were obtained from the Climate Impact Group at the University of Washington (Salathe and Mote 2007). The precipitation and temperature data from the downscaled scenarios were compared with weather station data from PDX airport and Beaverton. When there are substantial biases in the downscaled data, we corrected the bias using quantile mapping. The bias-corrected data are then used as input to the hydrologic simulation model. Figure 2 shows changes in winter precipitation and temperature for the study area under the IPSL-B1 climate change scenarios.

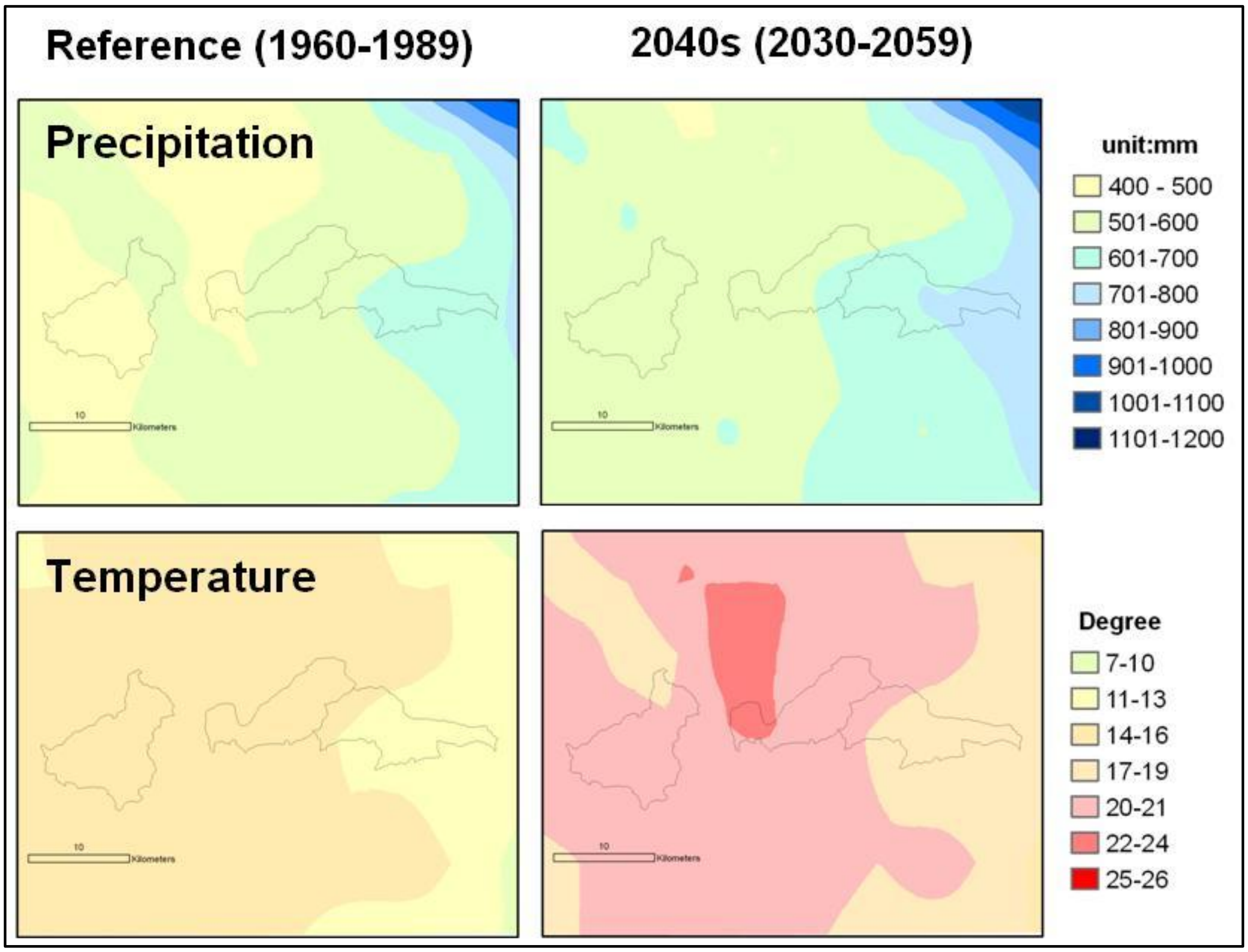

Figure 2. Changes in winter (December to February) precipitation and temperature under the IPSL-B1 climate change scenarios for the Portland metropolitan areas

The US Geological Survey PRMS watershed hydrologic model was used to simulate runoff changes and resultant changes in flood frequency. PRMS uses daily mean precipitation, temperature and streamflow to simulate daily streamflow conditions. PRMS is a physically-based watershed model that is ideal for simulating changes in flow under different environmental scenarios, including climate change.

The PRMS model parameters are derived from the literature (Laenen and Risley 1997), relevant GIS layers (e.g., geology, land cover, and soils), and the channel survey data.

Stream geomorphology survey and hydraulic analysis

In order to evaluate future flooding impacts at actual road crossings, we surveyed several stream cross-sections, gathered discharge information, and conducted a hydraulic analysis using HEC-RAS. The output of this effort is a water surface elevation at each location for a given discharge; that is, we can determine the particular discharge that floods the road. We surveyed channel geometry at the five cross sections of our study sites and determine the discharge necessary to produce a flood at each cross-section using the U.S. Army Corps of Engineers HEC-RAS discharge model. Each road was rated as either an arterial or major arterial and also served as a bus line. Four of the five locations have a history of flooding the road during large storm events. The other bridge site is a rather large span with no history of flooding; this site was selected as a possible example of a correctly sized structure with respect to climate-change induced flooding. All sites are located between USGS gauging stations.

We measured a channel morphological feature of interest, including the top of the stream channel, bankfull positions, the water surface and the thalweg position. Along this reach we also determined channel slope and roughness, which is used for modeling stream discharge. In this manner, we were able to determine the discharge necessary to induce floods of varying magnitudes. Each surveyed reach were tied to a precisely surveyed elevation benchmark allowing us to construct a GIS model depicting the water flow from the stream channel to the roadways during flood events.

The stream channel data, both geometry and flow data, were analyzed in HEC-RAS to determine water surface elevations for a given discharge. HEC-RAS is a one-dimensional steady flow model that calculates water surface height as a function of discharge, channel geometry, and energy losses due to friction (Manning's equation) and the expansion/contraction of flow through between cross-sections. We conducted a combined steady flow analysis using the bridge routine. This routine allows us to enter the bridge geometry the location of any pillars s a barrier to flow and also to define areas of ineffective flow. We established values for Manning's N based on field observation for both in channel on over-bank flow.

Transportation Impacts Methodology

Metro's regional travel model is the analytical tool for the measuring the potential disruption and costs of flooding on the transportation system. The model produces current and forecasted travel volumes based on land use assumptions. The current model uses 2005 as the base year and 2035 as the forecasted year. For travel forecasting purposes, land use assumptions are divided into geographical areas called transportation analysis zones (TAZs). The TAZ is the "unit geography" for travel within the demand model. Households and employment estimates are assigned to each TAZ. All the trips generated by the land use elements are aggregated and analyzed at the TAZ level.

The travel model estimates the number of trips that will be made, the distribution patterns of the trips throughout the region, the likely mode used for the trip and the actual roadways and transit lines used for auto, truck and transit trips. Traffic volume projections from these simulations help assess transportation system performance and identify future road and transit needs. Due to the macroscopic nature of the regional model, the model does not effectively analyze walking, biking or local street traffic volumes at detailed analysis levels. Also, the model assumes perfect knowledge by the traveler and may underestimate the traffic impacts of a road closure.

The traffic analysis began with the identification of transportation network links that are expected to flood based on the findings from the climate and hydrological analysis. Initial one-hour mid-day and two-hour pm peak traffic assignments were run using EMME^3 software to establish baseline traffic volumes and link volume/capacity for 2005 and 2035. Traffic assignments were then rerun with the flooded network links removed for both the Fanno Creek and Johnson Creek study areas. Using this output, a flood area of influence, comprised of TAZ clusters, was identified for each study area. Transportation evaluation measures were produced for each flood area of influence area that included vehicle miles traveled, vehicle hours and vehicle hours of delay for the one-hour mid-day and two-hour pm peak travel periods.

Results And Discussion

Changes in runoff

We estimated the changes in flood frequency with different recurrence intervals by the peakFQ program developed by US Geological Survey (Flynn et al., 2006). The PeakFQ provides estimates of instantaneous annual-maximum peak flows having recurrence intervals of 2, 5, 10, 25, 50, and 100 years based on flood-frequency analyses recommended in Bulletin 17B (IACWD, 1982). With this method, we constructed annual peak flows using daily discharge simulated by the PRMS results for 1960-1989 and for 2030-2059 at the four study areas.

As shown in Table 1, there are different patterns in changes in flood frequency across the four sites. Flood frequency is projected to increase mostly in highly urbanized watersheds such as Upper Fanno, Lower Fanno, and Lower Johnson Creek under most climate change scenarios. In the Upper Johnson Creek, however, flood frequency is projected to decrease except under the IPSL-B1 climate change scenarios. This suggests that highly urbanized areas are likely to be more vulnerable to climate change than less urbanized areas. The results also suggest that 5 year or 10 year flood events are likely to occur more frequently in the future. However, uncertainty still exists in projecting flood frequency in the future as changes are dependent upon what greenhouse gas emission scenarios are used when developing climate change scenarios.

Watershed Name	GCM & Emission scenario	Changes in flood frequency (%)					
		2 year	5 year	10 year	25 year	50 year	100 year
Upper Fanno	CCSM-A1B	+2.1	+5.9	+7.8	+10.1	+11.3	+12.9
	CCSM-B1	-5.3	+0.4	+2.2	+4.1	+4.9	+5.6
	ECHAM5-B1	+4.9	+3.4	+2.1	-0.4	-2.3	-4.1
	IPSL-B1	+14.7	+12.3	+13.2	+15.2	+17.0	+20.0
Lower Fanno	CCSM-A1B	+4.1	+8.0	+10.1	+12.7	+14.4	+16.0
	CCSM-B1	-3.2	-0.9	+0.3	+0.9	+1.6	+1.6
	ECHAM5-B1	+0.5	-4.5	-5.9	-7.0	-7.2	-7.4
	IPSL-B1	+13.6	+14.3	+17.4	+23.9	+29.8	+36.1
Upper Johnson	CCSM-A1B	+1.1	-2.6	-3.5	-3.4	-2.8	-2.0
	CCSM-B1	-15.0	-10.8	-9.9	-9.2	-9.2	-9.7
	ECHAM5-B1	+4.7	-2.7	-6.0	-9.3	-11.2	-12.7
	IPSL-B1	+9.1	+9.3	+11.1	+14.1	+16.7	+19.3
Lower Johnson	CCSM-A1B	+0.3	+0.2	+1.8	+4.6	+7.2	+9.9
	CCSM-B1	-10.1	-9.4	-9.5	-10.2	-10.7	-11.4
	ECHAM5-B1	-3.5	-8.0	-9.2	-10.0	-10.2	-10.1
	IPSL-B1	+5.6	+7.1	+11.4	+18.8	+25.4	+32.7

Table 1. Changes in flood frequency (%) in the 2040s from the reference period

Changes in the probability of road flooding

The HAC-RAS model output shows that all cross-sections with the exception of Scholls crossing are inundated during a 100-year flood event. However, the basins diverge greatly for smaller events. With Fanno Creek, the Oleson crossing is flooded during a 10-year magnitude event, while the Hall crossing is first flooded during a 25-year flood event. The Schools crossing is never inundated. The Oleson crossing area has an active floodplain upstream of the bridge but is controlled downstream by a wooden wall and riprap; in addition, the top of the bridge is below the 100-year flood plain as mapped by FEMA. This crossing is well known as a problem flood area, and our modeling simply reinforces the frequency with which this bridge can become impassable due to flooding. The Hall crossing has a much more extensive floodplain than the Oleson crossing and the channel is not constricted other than when passing through the bridge. Yet, the bridge opening itself is not large; hence, this road is subject to fairly frequent flooding. This bridge is crowned, as is Schools, and the stream does not cover the bridge during any flood event; however, water does flow across the road in the floodplain during a 25-year event, which leads to closure of this crossing. With a large floodplain and a large bridge opening, the Schools crossing does not flood at any discharge; however, the bike path adjacent to the stream that goes under the bridge is often inundated.

The bridge openings in Johnson Creek are much larger than most bridge openings in Fanno Creek, a legacy of channelization in Johnson Creek. Hence, neither bridge is inundated until a 100 year-event occurs. However, the rock walls at each crossing location are up to two meters lower than the bottom of the bridge but are still slightly higher than the areas adjacent the walls. Hence, water spills over the walls beginning with a 25-year event and floods the adjacent areas. In the case with Bell crossing, water will actually flow north of the stream channel, through a parking lot, and across the road approximately 3 meters north of the bridge itself; hence, this road is closed more frequently than would be expected by our models. The road at Linwood is higher above the walls than at Bell and is only truly flooded during a 100-year flood event.

Impacts on Transportation Network

The Fanno Creek and Johnson Creek flood area of influence generate an estimated 973,000 and 541,000 vehicle miles traveled (VMT), respectively, in the two-hour pm peak travel period. Together, these areas account for 24% of the total VMT generate in the 4:00 – 6:00 p.m. travel period. Both study areas are located in suburban locations where the arterial street network is fairly complete but local street network is often discontinuous. By 2035, as shown in Figure 3, many street networks will have more traffic volumes in the future.

An evaluation of the travel model output for the Fanno Creek and Johnson Creek flooding area of influence forecasted negligible increases (less than 1%) in vehicle miles travel in both travel periods for 2005 and 2035 when flooded links were removed from the street network. The modeled network assumes good alternative arterial routes to the flooded links and that travelers would choose these routes. In reality, travelers may not have perfect knowledge of the road conditions or alternatives in time to make an informed decision about travel, and therefore the model may have underestimated the level of out of direction travel that would contribute to an increase in vehicle miles traveled.

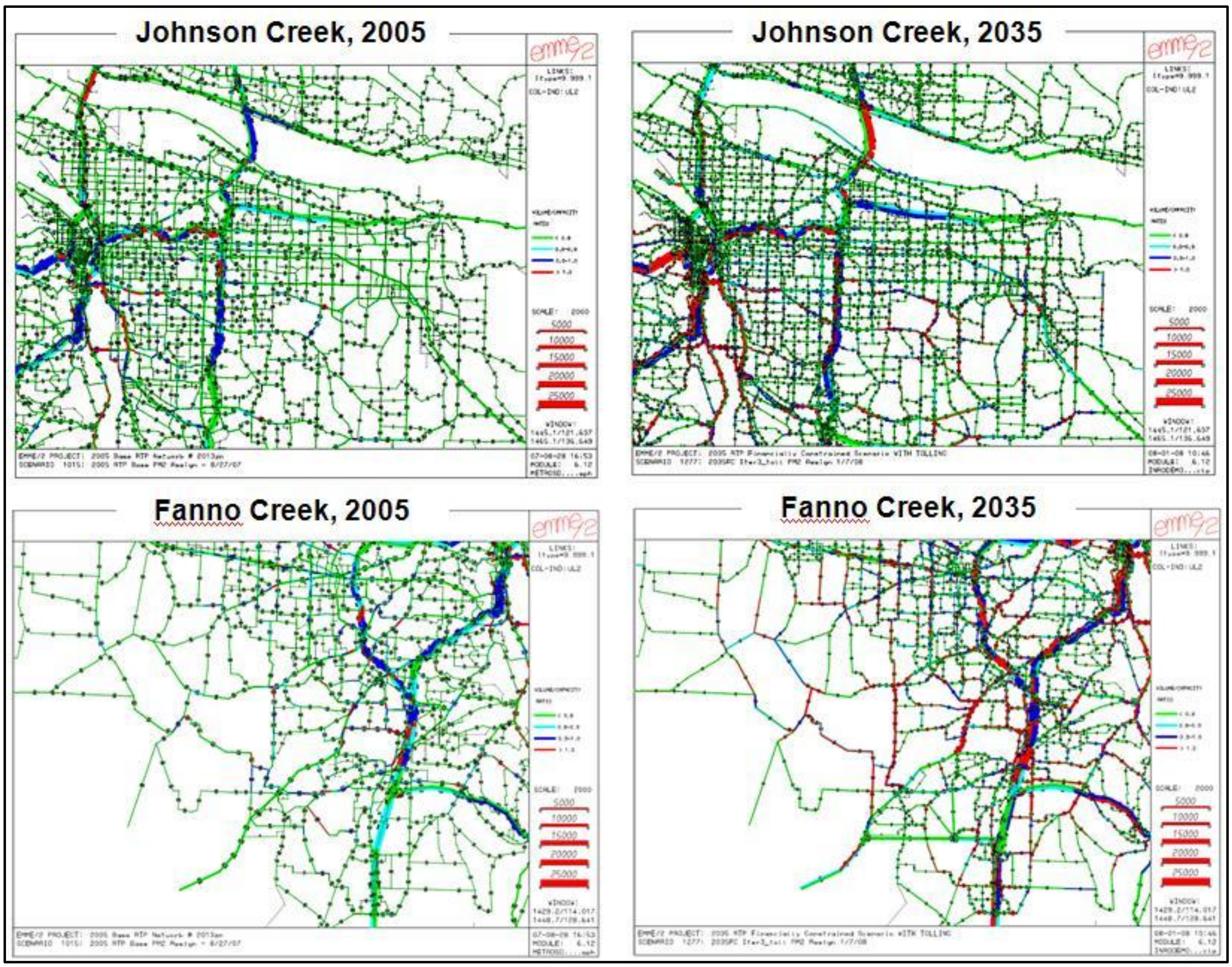

Figure 3. Changes in auto traffic volumes in the study area for 2005 and 2035.

An assessment of vehicle hours delay (VHD) demonstrated a greater impact from flooding. Regionwide delay in the 2005 two-hour pm peak is estimated at 8,900 hours. The base VHD for the Fanno Creek and Johnson Creek flood area of influence is 2000 hours and 800 hours respectively; and accounts for 32% of the region's total delay. In flooded conditions, VHD jumps by 10% in the Fanno Creek area and 4% in the Johnson Creek area. Not surprisingly, when capacity is removed from the network congestion grows as travelers are displaced to alternate routes.

Conclusions

Global climate change will have significant impacts particularly in urban areas where many socioeconomic activities are concentrated. Many growing urban areas such as the Pacific Northwest of America will experience higher amounts and intensity of winter precipitation. As projected in this simulation study, flood frequency is likely to increase in most study sites with more winter precipitation. Although there is uncertainty in projecting future flood frequency solely based on hydroclimate modeling, a 5-year, 10-year small events are generally likely to increase in one of the study site that has a history of chronic flooding. Stream channels will likely lag in adjusting to the new, slowly increasing discharge regimes, which is likely to act to exacerbate roadway flooding. While vehicle miles traveled in both periods show negligible increases, vehicle hours delay demonstrated a greater impact from flooding.

Our results show that there is a nonlinear relation between precipitation change and urban flooding and that impacts on travel disruption are subject to local hydroclimate and watershed land use conditions. This study is one of few interdisciplinary attempts to assess potential impacts of climate change on the transportation sector. Such integrated knowledge and spatially-explicit modeling is essential for establishing proactive flood and transportation management planning and policies under increasing climate uncertainty.

Acknowledgements

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Biographical Sketches

Heejun Chang is an associate professor of Geography at Portland State University, Portland, OR, USA, where he teaches courses in hydrology, climate and water resources, global water issues and sustainability, GIS for water resources, and spatial quantitative analysis. His research focuses on impacts of climate change and land cover change on runoff and water quality. He has published extensively on this topic in numerous scientific journals, including International Journal of Climatology, Climate Research, Hydrological Processes, Water Research, and Natural Hazards.

Martin Lafrenz is an assistant professor of geography at Portland State and a fluvial geomorphologist who focuses on the impacts of land use and land cover change on stream channel habitat. He has conducted and published several research projects using GIS and field data to classify watershed types as a function of the relationship between watershed attributes and stream channel function.

Il-Won Jung is a post-doctoral fellow at Center for Sustainable Processes and Practices and Department of Geography at Portland State University. His research interest intersects in the areas of hydrology and meteorology. He has been involved in climate change impact assessments for Korea and US river basins, conducting research on downscaling GCMs and hydrologic uncertainty assessment.

Miguel Figliozzi is a transportation engineering scientist and an Assistant Professor of Civil & Environmental Engineering at PSU with over 10 years of experience in the transportation and freight areas. He combines industry experience, consulting and a solid academic career. Figliozzi has published over 15 refereed research articles in transportation journals and has worked in research projects for NSF, FHWA, TxDOT, and the Port of Portland.

Deena Platman is a principal transportation planner at METRO, a regional government in the Portland metropolitan area. She has been instrumental in updating a regional travel model to measure the potential disruption and costs of flooding on the transportation system. She also serves as a board member of a regional transportation group in the Portland metro area.

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WASHINGTON STATE DEPARTMENT OF TRANSPORTATION INTERIM APPROACH TO PROJECT-LEVEL GREENHOUSE GAS AND CLIMATE CHANGE EVALUATIONS FOR TRANSPORTATION PROJECTS

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Abstract

The February 23, 2009, version of the Washington State Department of Transportation's *Interim Approach to Project-Level Greenhouse Gas and Climate Change Evaluations for Transportation Projects* is a recommended approach and is not required at this time. The approach is intended for projects where WSDOT is the lead/co-lead agency, but can be applied to all transportation projects, regardless of jurisdiction.

Within the approach, WSDOT recognizes the following:

- The need to better understand the relationship between GHG emissions and the transportation system,
- Transportation GHG emissions are best addressed at the planning level,
- Currently, there is no set "threshold" for project level GHG emissions to be considered significant,
- There is no federal guidance on how to address project level GHG emissions,
- The dynamic nature of climate change science and expects that any approach is likely to change.

WSDOT developed this interim approach in response to internal and public interest in information about GHG emissions on projects. The agency encourages consistency between projects by setting out a standard analytical process and including template language to maintain key messages. Technical support for application of the approach is provided by the WSDOT Air Quality, Noise, and Energy Program. In addition, by including the qualitative approach we are able to place our project actions in context with important regional and statewide efforts to reduce GHG.

WSDOT's approach explains how we recommend dealing with four types of emissions: operational ("tailpipe"), construction, embodied, and lifecycle ("cradle to grave").

The table below describes the level of analysis by the type of project-level environmental review (NEPA or SEPA classification). SEPA refers to Washington State's Environmental Policy Act.

Type of emission	CE	DCE/Checklist/EA	EIS
Operational	No	Qualitative*	Quantitative
Construction	No	Qualitative	Quantitative
Embodied/Lifecycle	No	No	Qualitative

** The Interim Approach also recommends that some highly visible and/or controversial projects consider a basic quantitative GHG analysis of operational GHG emissions for NEPA EA documents when VMT or energy use information is available and when a comparison with the No Action alternative is possible and useful.*

Introduction and Purpose

The Washington State Department of Transportation (WSDOT) has been working to better understand the relationship between our transportation system and climate change - especially with regard to our project-level environmental work. While WSDOT believes that the most informative GHG emissions information will be developed at the planning/regional level, we have a responsibility to our citizens to also discuss GHG emissions at the project level.

WSDOT is working to reduce greenhouse gas (GHG) emissions from transportation in our state. To do so we are looking for ways to better understand emissions from the transportation system. This document provides interim guidance and direction on how to consider the project-level effects on GHG emissions through the environmental documentation process where WSDOT is the lead agency. Planning-level GHG analysis will be addressed in future documentation.

WSDOT acknowledges the dynamic nature of climate change science, the understanding of implications from climate change on our transportation system, and GHG emissions calculation tools and will make its best efforts to keep this document updated with the most current recommendations. However, to ensure you are reading the most current version and/or to get copies of the most current standard language, please contact Karin Landsberg (206-440-4521) or Carol Lee Roalkvam (360-705-7126).

Why are we providing this guidance?

This interim approach is intended to clarify WSDOT's recommended process for addressing GHG emissions in environmental documentation and is responding to increased interest from the public and other agencies to determine and disclose information about GHG emission for transportation projects. This interim guidance is a proactive response to expected future GHG emissions reporting requirements ((RCW 70.94.151(5)) and an attempt at early action to help streamline future procedural changes.

Project-level GHG analysis is not explicitly required for transportation projects by the National Environmental Policy Act (NEPA) or Washington's State Environmental Policy Act (SEPA). Although the public has raised the issue during project-level environmental scoping, neither the Federal Highway Administration nor the Federal Transit Administration has issued formal direction on best practices for addressing project-level GHG emissions. In Washington State, the implementing regulation for SEPA lists "Climate" as a component of the environment under the "Air Element" (WAC197-11-444(1)(b)(iii)). However, no reference is made to climate or project-level GHG emissions in the disclosure section in the SEPA Environmental Checklist (see Appendix H). The Washington State Department of Ecology (Ecology) is expected to add a specific climate change section to the SEPA Environmental Checklist in the future.

Prior to the release of this interim approach document, WSDOT's Air Quality, Noise, and Energy (ANE) Program staff, policy staff, and executives have communicated the agency's internal and external efforts to address climate change through various forums. This interim guidance is the first time we have documented our approach in one place.

WSDOT's current project-level approach attempts to address two key emerging issues:

1) Disclosing greenhouse gas emissions related to a project, and
2) Assessing a project's adaptability to the effects of climate change.

WSDOT staff actively participated on the 2008 Climate Action Team's (CAT) SEPA Implementation Working Group (SEPA IWG). The SEPA IWG effort raised many questions about WSDOT's project-level approach and highlighted the need for WSDOT to clearly explain our underlying assumptions. The working group debated the assumptions and gaps in currently available GHG measurement tools. The final report of the SEPA IWG (www.ecy.wa.gov) is a valuable resource for project teams looking for more information on where the state is headed.

WSDOT acknowledges that effects of climate change may alter the function, sizing, and operations of our facilities. Therefore, in addition to mitigating GHG emissions, WSDOT must also ensure that its transportation facilities can adapt to the changing climate. To ensure that our facilities can function as intended for their planned 50, 70, or 100 year lifespan, they should be designed to perform under the variable conditions expected as a result of climate change. For example, drainage culverts may need to be resized to accommodate more intense rainfall events or increased flow due to more rapid glacial thawing. Additional guidance on adaptation is currently being developed.

Background and Lessons Learned

Since 2007, WSDOT has been an active participant in several climate change-related forums, including the Climate Action Team (CAT), several CAT subgroups, Puget Sound Regional Council's (PSRC) Climate change Technical Working Group, and a number of other interagency working groups. We have also worked closely with other lead agency partners and negotiated case-by-case on methods for conducting project-level GHG analysis. These lessons have formed our interim approach.

Our early approach for major projects

Prior to 2007, qualitative GHG emissions analysis lacked a consistent format, language, and/or methodology. In the fall of 2007, WSDOT 's Air Quality, Noise, and Energy Program (ANE), in consultation with the Environmental Policy Branch Manager, addressed the lack of consistency by developing standard language to discuss climate change qualitatively in the Cumulative Effects section in our Environmental Assessment (EA) and Environmental Impact Statement (EIS) documents. Project teams coordinated with the ANE staff to tailor the language specifically to their projects. Examples of this language can be found in a number of documents, including SR 522 Cathcart Rd EA, I-90 Snoqualmie Pass East Final EIS, and the Novelty Hill Road King County EA.

The standard cumulative effects language continues to be part of WSDOT's recommended approach and will be frequently updated and revised as new information becomes available. Project teams should contact Karin Landsberg (landsbk@wsdot.wa.gov) to tailor standard language to specific projects.

During this same time period (2007/8), two quantitative project-level greenhouse-gas analyses were prepared for major projects in Washington State: the Columbia River Crossing (CRC) Draft Environmental Impact Statement (DEIS) and the SR 520 Health Impact Assessment (HIA) (2008). Similar to the inconsistencies within the qualitative approaches to GHG analysis prior to fall 2007, the quantitative analyses for CRC and SR 520 used different language and methods for calculating project-level GHG emissions. The uncertainty surrounding quantification of project-level GHG emissions has not been unique to WSDOT. At WSDOT and among transportation agencies throughout the country, differences in methodology have been based on uncertainty surrounding the preferred best practices for project-level GHG analysis. These uncertainties have focused around the lack of a 'best' analytical tool; pressure from analysts using tools approved by the State of California under their California Environmental Quality Act (CEQA) law, a counterpart to SEPA; and a lack of consensus about the appropriate level of measurement.

WSDOT has learned from these environmental documents and our experience with cross-agency forums. We have evolved our understanding of quantitative project-level GHG analysis options and the essential "strengths and weaknesses" of the various approaches. These efforts highlight the critical areas where additional models, data, and policy development are needed to conduct more comprehensive and meaningful evaluations in the future. Examples of critical areas that future efforts will attempt to address include:

1. Models that can capture the effects of changes in speeds, congestion levels, and traffic flow are needed but are not yet available. Quantitative tools based solely on capturing the changes in vehicle miles traveled produce misleading results by not accurately capturing the effects of a project on fuel efficiency.

2. Limiting project-level GHG emissions analysis to a tight geographic area , similar to other environmental disciplines, may limit the understanding of project-level choices on GHG emissions for the larger transportation network. At the same time, most project-level choices, when modeled on the regional scale, do not produce discernibly different GHG emissions because of the relatively small impact most individual projects have on the regional transportation network.

How was this interim approach developed?

WSDOT's interim approach to project-level GHG analysis was developed through collaboration with internal and external stakeholders, evaluation of other agencies' approaches, and the assessment of a number of tools designed to calculate project-level GHG emissions. Tools were evaluated based on their ease of use, the complexity and availability of inputs, the effort needed to model, cost, and the usefulness of results.

WSDOT continues to recommend a qualitative approach for most projects because critical gaps in data and analytical tools remain. However, additional modeling tools are being developed that should improve the validity of quantitative analysis in 2009.

Other Agencies' Actions

What are other agencies doing to address climate change?

As of summer 2008, 35 states have climate or energy plans with 15 of these having a transportation analysis component. Within Washington State, as of the date of this guidance, only King County and the City of Seattle have a specific requirement to address GHG emissions in SEPA documents using a worksheet developed by King County to assist in estimating GHG emissions from development projects. However, they have acknowledged that this worksheet is not intended for transportation projects, which is why WSDOT recommends an alternate approach to project-level GHG analysis at this time.

PSRC's Climate Change Technical Working Group is also preparing guidance on conducting project-level greenhouse gas analyses. This guidance document is consistent with the WSDOT guidance, and is intended to provide technical assistance to local jurisdictions as they prepare greenhouse gas analyses on transportation projects and/or land use projects with impacts to the transportation system. The PSRC report is available online at http://www.psrc.org/projects/airqual/index.htm.

How do the actions of other agencies affect WSDOT?

Many WSDOT projects, especially highway improvement projects, share traits with other linear proposals (such as utility corridors, local roads, railroads, and ports). In addition, multi-agency oversight is standard for many larger-sized projects, often requiring approval from WSDOT, local jurisdictions, and the Federal Highway Administration or the Federal Transit Administration. Because of these common traits and joint-lead responsibilities, WSDOT will continue to compare processes across agencies and collaborate with other jurisdictions to develop and use the most effective and efficient tools available.

Project-level Analysis

Terminology

There are four types of GHG emissions that may be considered at the project-level: operational, construction, embodied, and lifecycle emissions. WSDOT's interim approach focuses on operational and construction emissions, while acknowledging embodied and lifecycle emissions.

Operational GHG emissions are released by vehicles using project roadways. The quantity of emissions released depends on the fuel type, vehicle fuel efficiency, speed of the vehicle, distance traveled, and the number of vehicles on a roadway. In general, operational emissions are the largest category of GHG emissions released by the transportation sector: Approximately 72 percent of the transportation sector's emissions are generated from on-road transport, including both passenger and freight travel (AASHTO, 2008).

Constructions emissions are released during project construction and primarily come from fuel burned in the equipment used to build a project, such as bulldozers, pavers, and rollers. Construction emissions can also result from increased traffic congestion caused by construction activities.

Embodied emissions are the emissions generated in producing the materials that are used in the construction process and include emissions from sourcing the raw materials from the earth and their conversion into a usable form, including the energy used in processing (Simons Group, 2009). Embodied emissions can be thought of as "cradle to site" emissions. For example, the emissions released while mining the coal used to manufacture the steel girders for a bridge would be considered embodied emissions.

Lifecycle emissions include emissions released during material production (embodied) and emissions released throughout a facility's lifetime, including demolition and disposal. Unlike embodied emissions, lifecycle emissions account for the durability of a product. Lifecycle emissions are often referred to as "cradle to grave" emissions.

Overview of Approach

Type of emission	CE	DCE/Checklist/EA	EIS
Operational	No	Qualitative	Quantitative
Construction	No	Qualitative	Quantitative
Embodied/Lifecycle	No	No	Qualitative

Figure 1: Overview of Analysis by Documentation Type

Environmental documentation level as a guide to type of GHG analysis

To focus our evaluations on the projects where we have the greatest GHG emissions, WSDOT has grouped transportation projects into three categories and recommends a different level of analysis for each category. Recommendations are based in part on the potential for substantial GHG emissions, the data typically available at different levels of documentation, and the likelihood of generating meaningful information that will be useful in decision making. Our approach is further guided by our position that project-level emissions should be treated as cumulative effects as an issue of global concern. Organizing our current approach according to the level of environmental documentation gives us a general idea of what level of analysis is needed.

Currently, no threshold determination of significance exists for GHG emissions at the project-level. Therefore, the amount of projected emissions from an individual project, even when combined with all other projects considered in the cumulative effects' section, cannot be considered a significant impact and cannot elevate the level of environmental documentation on a project. See WSDOT's cumulative effects guidance on-line at http://www.wsdot.wa.gov/Environment/Compliance/CumulativeEffects.htm

Highway Improvement Projects

1. **SEPA or NEPA Categorical Exemption (CE)**
   No Analysis Recommended
   - WSDOT believes evaluation of GHG is not warranted for minor transportation actions. WSDOT recommends no GHG emissions analysis for SEPA or NEPA CE projects for all type of GHG emissions.

   - A qualitative project-level GHG analysis is optional for projects that receive GHG questions/comments from public or agencies. Project teams can include the qualitative discussion in public materials. Discussion of embodied or lifecycle emissions is not recommended.

     Recommended standard language for ERS/ECS forms can be found in Appendix A.

   Rationale: Most SEPA or NEPA CE projects have little to no effect on GHG emissions. WSDOT actions that are categorically exempt from SEPA are mostly safety and maintenance operational activities. GHG emissions from WSDOT operations will be captured in the annual agency-wide GHG inventory that will be completed in accordance with recently passed reporting requirements.

2. **SEPA Checklist**
   NEPA: Documented Categorical Exclusion (DCE)
   Brief Qualitative Analysis of Operational and Construction Emissions
   - WSDOT recommends a qualitative analysis for operational and construction GHG emissions for SEPA Checklist and NEPA DCE projects because of the small potential for substantial GHG emissions. No discussion of embodied or lifecycle emissions is recommended.

     Suggested text to incorporate into most SEPA Checklists and NEPA DCE's is provided in Appendix A.

   Rationale: A qualitative project-level GHG analysis is currently recommended for SEPA DNS/MDNS and NEPA DCEs as these actions may have minor effects on greenhouse gas emissions.

3. **NEPA Environmental Assessments (EA)**
   Qualitative Analysis of Operational and Construction Emissions
   - WSDOT recommends a qualitative analysis for operational and construction GHG emissions on most NEPA EA projects because of the small potential for substantial GHG emissions. No discussion of embodied or lifecycle emissions is recommended.

     WSDOT Standard language is provided in Appendix B and should be included in the Cumulative Effects section of the EA document.

   - WSDOT recommends that some highly visible and/or controversial projects consider a basic quantitative GHG analysis of operational GHG emissions for NEPA EA documents. This basic quantitative approach is recommended when VMT or energy use information is available and when a comparison with the No Action alternative is possible and useful. WSDOT recommends construction emissions be addressed qualitatively and recommends no discussion of embodied or lifecycle emissions.

     The recommended standard "basic" quantitative approach for project-level GHG analysis for highly visible and/or controversial projects for EAs is outlined in Appendix C. This approach should also use the standard language in Appendix B. Within the EA, the discussion should be included in the Cumulative Effects section.

Rationale: A qualitative project-level GHG analysis is currently recommended for most EA's because of the following:

- These projects typically do not have alternatives
- An EA typically does not require an energy analysis, which provides the data required for the current "advanced" methodology to quantify project-level GHG emissions
- Most EAs do not have the traffic data needed to use EPA's Motor Vehicle Emissions Simulator (MOVES) model (expected in March 2009)

4. **SEPA or NEPA Environmental Impact Statements (EIS)**
Quantitative Analysis
    - WSDOT recommends a quantitative analysis of operational and construction GHG emissions for SEPA or NEPA environmental impact statements (EIS) because the intensity and magnitude of projects triggering this level of documentation have the potential for substantial GHG emissions. The analysis should use the EPA MOVES model for operational emissions and use the results of the Energy Discipline Report for construction emissions. Qualitative discussion of embodied and lifecycle emissions is recommended.

      The quantitative analysis should be included in the Energy Discipline Report. Within the EIS, discussion of the analysis should be included in the Cumulative Effects section.

      The recommended standard approach for SEPA and NEPA EIS documents is outlined in Appendix D and should include the standard language in Appendix B.

Rationale: A quantitative analysis for operational GHG emissions is recommended for EIS documents because these projects have the potential to affect regional traffic, typically have a high-level of public interest, and already have the extensive traffic data needed to conduct a detailed or "advanced" quantitative analysis.

Other Modes

Ferries
Recommended approaches for ferry projects will be developed.

Rail
Recommended approaches for rail projects will be developed.

Bicycle/Pedestrian
Recommended approaches for non-motorized projects will be developed.

Contacts and Coordination

To determine the appropriate level of analysis for SEPA DNS/MDNS, NEPA EA and SEPA or NEPA EIS documents and to ensure you are reading the most current version of the standard language, please contact Tim Sexton (206/440-4549) or Carol Lee Roalkvam (360/705-7126).

Biographical Sketches

Tim Sexton has an MS in Urban and Regional Planning and an MPH in Environmental Health from the University of Iowa and is a certified planner (AICP). He has worked in the US and internationally in the air quality and energy field since 2003 and joined the Washington State Department of Transportation (WSDOT) in 2006. Currently, he is the WSDOT Air Quality, Noise and Energy Policy Manager and acoustic lead for WSDOT's Quieter Pavement Research Program.

Carol Lee Roalkvam oversees Washington DOT's statewide effort to better communicate environmental effects of transportation projects and prepare "reader-friendly" environmental documents. Some of her other emphasis areas are: ensuring comprehensive tribal consultation during environmental review processes, right-sizing cumulative effects analysis, and assisting the department in meeting the Governor's goals for addressing climate change and implementing "plain talk". She works with environmental staff in seven regions, state ferries, transit/rail and aviation to address emerging issues and resolve project-specific environmental and compliance issues. She came to the DOT in 1999 after seven years at the Washington State Department of Natural Resources.

Karin Landsberg is the WSDOT Climate Change Technical Program Lead. She received a BS in General Science with an emphasis in Biochemistry from Oregon State University and earned her MA from Antioch University Seattle in Whole Systems Design with focus in Ecoimmunology and Sustainable Living. She also completed a certificate in Environmental Law and Regulation at the University of Washington. Prior to working for WSDOT, she worked in the non-profit world and did a brief stint in market research.

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Washington Administrative Code (WAC) 197-11-444(1)(b)(iii)

Appendix A – ERS/ECS Examples

ERS

- SEPA CE and NEPA CE – *"No GHG emissions analysis is recommended"*
- SEPA Checklist or NEPA DCE – *"A climate change discussion is needed in the 'Air' section of the SEPA Checklist. Please refer to Appendix B of WSDOT's Interim Approach to Project-Level Greenhouse Gas and Climate Change Evaluations. Contact Tim Sexton, Air, Noise, Energy Group, or Carol Lee Roalkvam, ESO Policy Branch Manager, if assistance is needed."*
- NEPA EA – *"The cumulative effects section will need to include a climate change discussion. Refer to the standard language provided in Appendix C of WSDOT's Interim Approach to Project-Level Greenhouse Gas and Climate Change Evaluations. Please work with Tim Sexton, Air, Noise, Energy Group, or Carol Lee Roalkvam, ESO Policy Branch Manager, if assistance is needed."*
- SEPA/ NEPA EIS – "*A quantitative GHG emissions analysis using the EPA MOVES model is recommended and should be included in the Energy Discipline Report. Contact Tim Sexton, Air, Noise, Energy Group or Carol Lee Roalkvam, ESO Policy Branch Manager, for more information*."

ECS/Checklist Language suggestions

- SEPA CE/NEPA CE – "*No GHG emissions analysis is recommended*."
- SEPA Checklist/NEPA DCE
    - <u>No change in traffic</u> – *"Because the project will not change traffic, operational greenhouse gas emissions are not expected to change. Construction greenhouse gas emissions will result primarily from fuel used in construction equipment."*
    - <u>Expected to improve traffic flow/reduce congestion</u> – *"The project is expected to improve traffic flow, which should reduce greenhouse gas emissions. Construction greenhouse gas emissions will result primarily from fuel used in construction equipment."*
    - <u>Expected to add traffic to roadway</u> – *"The project is expected increase traffic flow [Describe in one sentence how, for example, adding lane.]. This may increase operation greenhouse emissions. However, quantitative modeling tools to evaluate greenhouse gas emissions for linear transportation projects are limited at this time. Construction greenhouse gas emissions will result primarily from fuel used in construction equipment." Please consult with Karin Landsberg, Air, Noise, Energy Group, or Carol Lee Roalkvam, ESO Policy Branch Manager, for more information when a project is increasing traffic.*

Appendix B – Qualitative Approach for NEPA EA Documentation

Although emissions will not be quantified, a consistent approach should be followed to ensure that the relevant aspects of every project are adequately addressed. We recommend using the standard language developed for this purpose. Please contact Karin Landsberg, with the Air, Noise, Energy Group or Carol Lee Roalkvam, ESO Policy Branch Manager for the most recent version of the language.

If for some reason, this language is not used, we recommend the following elements be incorporated in the discussion of a project's effect on GHG emissions:

- Discussion of the GHG emitted by vehicles
- Relevance of transportation and vehicles to state's overall emissions
- Pie charts showing the percentage of GHG emissions in WA state that come from the transportation sector
- Discussion of agency efforts currently underway to reduce GHG emissions and transportation GHG emissions
- Description of agency's role in current activities
- Existing transportation programs and activities that reduce emissions
- Explanation of how projects currently in design and construction fit into efforts to reduce emissions
- Description of project-level actions that can reduce GHG emission
- Statement of the current status of availability of tools and data to conduct meaningful analysis at the project-level
- Statement of efforts underway to develop tools
- Specific information about how the project affects driving conditions that may improve GHG emissions
- Statement on how the project will minimize construction emissions
- Detail(s) on how the project is designed to adapt to a changing climate

WSDOT Recommended Standard Language for EA/EIS Discussion

The standard qualitative language template below is recommended for the Cumulative Effects section of environmental documentation. Please work with the Air, Noise, Energy Group to tailor language to a specific project.

Climate Change – Greenhouse Gas Emissions

Vehicles emit a variety of gases during their operation; some of these are greenhouse gases (GHGs). The GHGs associated with transportation are water vapor, carbon dioxide (CO_2), methane (also known as "marsh gas"), and nitrous oxide (used in dentists' offices as "laughing gas"). Any process that burns fossil fuel releases CO_2 into the air. Carbon dioxide makes up the bulk of the emissions from transportation.

Vehicles are a significant source of greenhouse gas emissions and contribute to global warming primarily through the burning of gasoline and diesel fuels. National estimates show that the transportation sector (including on-road vehicles, construction activities, airplanes, and boats) accounts for almost 30 percent of total domestic CO_2 emissions. However, in Washington State, transportation accounts for nearly half of GHG emissions because the state relies heavily on hydropower for electricity generation, unlike other states that rely on fossil fuels such as coal, petroleum, and natural gas to generate electricity. The next largest contributors to total GHG emissions in Washington are fossil fuel combustion in the residential, commercial, and industrial sectors at 20%; and in electricity consumption, also 20%. Figure 1 shows the gross GHG emissions by sector, nationally and Washington State.

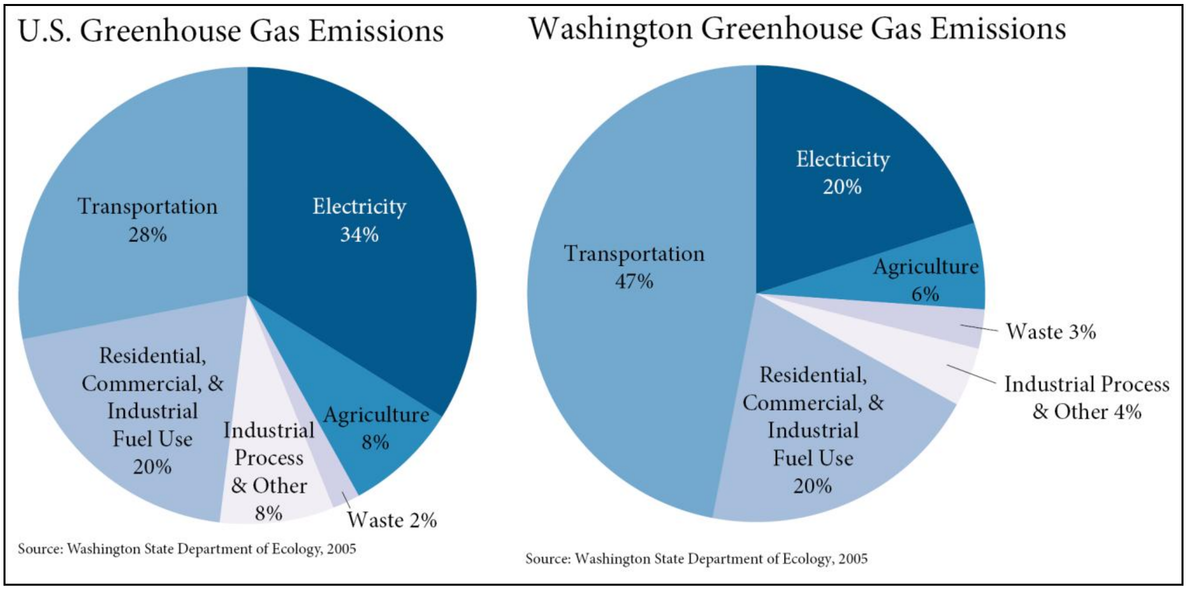

Figure 1: GHG Emissions by Sector, 2005, US and Washington State

What efforts are underway to reduce greenhouse gas emissions in Washington State?

In 2007, Governor Gregoire and the legislature set greenhouse gas reduction goals for Washington State:

- 1990 greenhouse gas levels by 2020
- 25% reduction below 1990 levels by 2035
- 50% by 2050.

Also in 2007 the Climate Advisory Team was formed by Governor's executive order 07-02 to find ways to reduce greenhouse gas emissions. The final report included 13 broad recommendations of actions.

The Washington legislature passed and the Governor signed HB 2815 in the spring of 2008. This bill includes, among other elements, statewide per capita VMT reduction goals as part of the state's GHG emission reduction strategy.

This bill also established the Climate Action Team, a group similar to 2007's Climate Advisory Team. This group refined 2007's broad recommendations into specific actions the state can take to reduce emissions. WSDOT worked as a member of this group on strategies to reduce vehicle miles traveled (VMT)[1] and on how to include climate change in SEPA evaluations. The final report and other information on the process are available at: http://www.ecy.wa.gov/climatechange/2008CAT_overview.htm.

In addition to work with others in our state, WSDOT is leading the development of effective, measurable, and balanced emission reduction strategies. Current WSDOT activities that reduce GHG emissions include:

Transportation Options – For 30 years, WSDOT has supported carpooling, vanpooling, and public transportation through the funding, building, and maintenance of the freeway HOV system, ferries, rail, and other programs. Our Commute Trip Reduction program has been partnering with employers to offer alternatives to drive alone commuting for 17 years and we have the nation's largest public vanpool program. These programs continue to expand and with recent high gas prices, demand for these programs has surged.
These investments help to reduce the number of vehicles on the roadway during peak congestion and help reduce total vehicle miles traveled

[1]VMT stands for vehicle miles traveled and is the number of miles vehicles travel each year. For transportation projects with set boundaries, VMT can refer to the aggregate number of miles that all the vehicles travel using the specified roadways. Per person (or per capita) VMT in Washington has been stable at 9,000 miles per person since the 1980s, meaning the statewide VMT has grown at roughly the same pace as population. Methods of reducing VMT typically target transferring trips from single occupant vehicles to multiple person vehicles like carpools, vanpools, and transit. VMT can also be lowered by reducing the distance of travel through changes in land use.

Incident Response Team (IRT) – WSDOT has 55 vehicles that patrol 500 miles of highway to clear blocking incidents quickly and safely. IRT clears 98.6 percent of all incidents in less than 90 minutes, reducing the amount of time motorists spend sitting and idling in traffic.

Using Biodiesel in Ferries – Each year, the state ferry system burns approximately 17 million gallons of diesel fuel in its ferries, making the agency a significant fuel consumer in Puget Sound. In March 2008, WSF began testing the use of biodiesel in the marine environment. Using biodiesel instead of traditional petroleum-based fuels reduces emissions of particulate matter and greenhouse gases, improving both local air quality and the Earth's climate.

In addition to working to reduce emissions on our transportation network, WSDOT is also taking action to reduce our agency's emissions. Steps include:

No Idle Policy – In 2006, WSDOT adopted a no-idle policy to reduce fuel use and vehicle emissions. We estimate by reducing vehicle idling by 50 percent, we can save as much as $500,000 annually in fuel costs.

Reducing diesel emissions – In 2005, WSDOT started using five percent biodiesel (B5) mixed with regular diesel in maintenance vehicles operating in the Central Puget Sound area. Currently, 25 WSDOT fueling stations have 10 percent biodiesel (B10) available and we are working towards using 20 percent biodiesel (B20), depending on availability.

WSDOT and our partners are also actively implementing the 2005 Transportation Partnership Act, a 16-year plan to meet Washington State's most critical transportation needs. Many of these local, regional, and statewide transportation system improvements in conjunction with ongoing programs help to reduce the number of miles that vehicles need to travel each year. Together these efforts combine to create more efficient driving conditions, offer mode choices, and help move us toward state GHG reduction goals.

What effect will the transportation improvements from this project have on greenhouse gas emissions?

In general, project-level actions that can help reduce greenhouse gas emissions include:
- Reducing stop and go conditions
- Improving roadway speeds to a moderate level
- Improving intersection traffic flow to reduce idling

Quantitative modeling tools to evaluate greenhouse gas emissions for linear transportation projects are limited at this time. At the project level, we are currently unable to show the effect of improved traffic flow on emissions.

WSDOT and regional transportation planning organizations are working on methods and models to improve the quality of information and guidance for evaluating GHG emissions from transportation. Tools under development will allow for GHG calculations that account for changes in VMT and other factors depending on project size and type in the future. Guidelines for applicable projects and how to discuss GHG emissions in a more meaningful way are also under development.

Example Project Description paragraph:
Traffic improvements proposed by this project will create smoother driving conditions. More specifically, widening and intersection improvements proposed on the project will minimize stop and go conditions thereby conserving fuel. It will also promote more efficient energy consumption by moderating speeds. This proposed project will enable better movement of vehicles in (insert air quality horizon year) for project area intersections and on the mainline, thereby reducing traffic congestion and collisions. Decreased vehicle delay at off and on ramps further reduces collisions and promotes more efficient driving.

Example How will this project minimize emissions while under construction?
Construction of the project is currently planned to last ___ years from 20__ to 20__. The project traffic plan includes detours and strategic construction timing (like night work) to continue moving traffic through the area and reduce backups to the traveling public to the extent possible. WSDOT will seek to set up active construction areas, staging areas, and material transfer sites in a way that reduces standing wait times for equipment. WSDOT will work with our partners to promote ridesharing and other commute trip reduction efforts for employees working on the project.

Did the project consider future conditions related to climate change?

Governor Gregoire committed the state to preparing for and adapting to the impacts of climate change as part of Executive Order 07-02. A new focus sheet entitled “Preparing for Impacts” is available on line at: http://www.ecy.wa.gov/pubs/0801003.pdf

The focus sheet provides a brief summary of the key climate changes that Washington State is likely to experience over the next 50 years:

- increased temperature (heat waves, poor air quality)
- changes in volume and timing of precipitation (reduced snow pack, increased erosion, flooding)
- ecological effects of a changing climate (spread of disease, altered plant and animal habitats, negative impacts on human health and well-being)
- sea-level rise, coastal erosion

The project is designed to last (30, 50, 70 Years). As part of its standard design, this project has incorporated features that will provide greater resilience and function with the potential effects brought on by climate change.

Example Design Efficiency paragraph:
WSDOT has designed the project using materials with the longest available life. This includes replacing the existing pavement with Portland cement pavement rather than asphalt, and using bridges rather than highway fill at the stream crossings. These choices mean that the new highway would have a longer life before needing to be replaced, which would reduce overall emissions for highway reconstruction and replacing materials.

Example Preserving Vegetation paragraph:
WSDOT and its partners have preserved land with vegetation from development, through purchases of private land for mitigation sites and to maintain wildlife corridors. Vegetation cover helps to reduce the effects of greenhouse gas emissions through absorption of CO_2.

Appendix C – Basic Quantitative Approach to SEPA DNS/MDNS and NEPA EA Documents

WSDOT recommends that highly visible and/or controversial projects use the following procedure to analyze GHG emissions when the need for a basic quantitative GHG analysis has been determined in coordination with the Air Quality, Acoustics, and Energy Group. WSDOT is currently describing the following as a “basic” quantitative GHG analysis:

1. Include the qualitative discussion outlined in Appendix B.

2. Compare vehicle miles traveled (VMT) values and discuss the changes.

Without detailed traffic data available, the only way to quantify GHG emissions is to apply an emissions factor based on average fuel economy to VMT.

Example: King County - Novelty Hill Road Project.

Methodology: For this project, the analyst multiplied VMT by an average fuel economy and an emissions factor. Percent changes in emissions/VMT between the alternatives were compared.

Appendix D – Approach for "Advanced" Quantitative Analysis

Operational GHG emissions from road projects depend on several factors – primarily distance traveled and fuel economy. Total VMT in a project area is determined by the project and the project's relationship to the surrounding transportation network. Fuel economy varies with speed and vehicle type. The traffic data required for a highly detailed analysis such as this is only prepared on the largest projects. WSDOT's recommended process is expected to change as new tools become available.

Recommended - Converting an energy analysis

Example: Columbia River Crossing DEIS

Methodology: Details to come.

Standard language on embodied/lifecycle emissions is under development.

Appendix E – Standard Language for Construction GHG Emissions in NEPA EA's

This language is under development.

Appendix F – Construction GHG Emissions in NEPA EIS's

This language is under development.

Appendix G – Standard Language for Embodied and Lifecycle GHG Emissions in NEPA EIS's

This language is under development.

Appendix H - What Does SEPA Say About "Climate Change"?

Currently, there is no direct reference to "climate" or "climate change" in the statute establishing SEPA and the SEPA checklist (RCW 43.21C). However, the implementing regulation (WAC 197-11-444) outlines the rules for SEPA compliance and does include "climate" as a component of the "Air" element of the environment that must be considered on projects.

Currently, there is also a statewide effort underway to ensure that the consideration of climate change is included in the State Environmental Policy Act (SEPA) process. This effort is expected to produce clear and straightforward guidance to minimize lawsuits and contribute to understanding and mitigating GHG emissions that result from activities covered under SEPA.

Air related items in the SEPA Checklist (WAC 197-11-960)

2. Air

- a. *What types of emissions to the air would result from the proposal (i.e., dust, automobile, odors, and industrial wood smoke) during construction and when the project is completed? If any, generally describe and give approximate quantities if known.*
- b. *Are there any off-site sources of emissions or odor that may affect your proposal? If so, generally describe.*
- c. *Proposed measures to reduce or control emissions or other impacts to air, if any.*

WAC 197-11-444 Elements of the environment

To be considered for SEPA compliance

(1) Natural environment

- *(a) Earth*
  - *(i) Geology*
  - *(ii) Soils*
  - *(iii) Topography*
  - *(iv) Unique physical features*
  - *(v) Erosion/enlargement of land area (accretion)*
- *(b) Air*
  - *(i) Air quality*
  - *(ii) Odor*
  - ***(iii) Climate***
- *(c) Water*
  - *(i) Surface water movement/quantity/quality*
  - *(ii) Runoff/absorption*
  - *(iii) Floods*

Appendix I - State Environmental Policy Act (SEPA) – Guidance for Incorporating Climate Change into Development Decision-making

The following is an excerpt from the 2008 Climate Action Team Report, November 2008.

The SEPA Implementation Working Group IWG developed products and recommendations to provide guidance for local and State agencies on how to incorporate climate change considerations into SEPA analyses. The IWG's work responded to the CAT Headline 3, to "analyze greenhouse gas emissions and mitigation options early in decision-making, planning processes, and development projects."

In other states and on a federal level, climate change policy under SEPA-like statutes has been made on an ad hoc basis through piecemeal litigation or through piecemeal precedent set by individual environmental reviews negotiated between individual applicants and individual lead agencies. In neither case has there been consistency or predictability.

The purpose of the SEPA IWG's work was to diminish the potential for litigation (and to provide consistency and predictability) by giving State and local agencies the tools and framework they need to fully incorporate climate change considerations into their decision-making. Through its recommendations, the IWG seeks to provide assurance to government decision-makers and project proponents that proposals will be assessed under a predictable climate change framework which will help Washington meet its GHG reduction requirements. Through these recommendations, the IWG also sought to present ways in which SEPA can be leveraged to provide incentives for "climate friendly" plans, policies, and projects.

The IWG notes three key shared principles:

- The SEPA IWG generally supports the concept of upfront nonproject SEPA review of climate change planning, based upon adequate standards, to reduce GHG emissions and to eliminate duplicative project-level SEPA review.
- The SEPA IWG does not intend for any of its recommendations or ideas to unintentionally impact existing categorical exemptions under SEPA. Any desired changes to categorical exemptions put forward by the group or any of its members will be made explicit in the text of its report. The IWG did not address categorical exemptions in depth or focus on whether they should be expanded, reduced, or remain the same.
- The SEPA IWG acknowledges that it is equally important to provide clarity and predictability for treatment of both project and non-project actions and proposals under SEPA.

The subjects addressed by the 11 SEPA IWG recommendations are.

1. Clear Guidance and Revised Checklist
2. Regularly Updated Materials and Coordination
3. Emissions Tool Development
4. Use of Qualitative Analysis
5. Guidance Regarding Mitigation
6. Develop Approach to Threshold Determination
7. Conceptual Ideas for Leveraging SEPA
8. Analysis of Future Vulnerabilities in Checklist
9. Taking into Account Lead Agency Resources, Capacity, and Constraints
10. Training
11. Advisory Committee

Please see the full report at http://www.ecy.wa.gov/climatechange/2008CAT_iwg_sepa.htm for additional detail on these recommendations and other ideas, as well as the resources developed by the SEPA IWG.

Citizen Science – Effective Strategies and Stakeholder Involvement

ROAD WATCH IN THE PASS: WEB-BASED CITIZEN INVOLVEMENT IN WILDLIFE DATA COLLECTION

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Abstract

The successful development of wildlife-transportation mitigation strategies requires access to timely and accurate information on the spatial and temporal movement patterns of wildlife. Unfortunately, conventional long term monitoring programs can be expensive and time consuming. In addition, expert-based approaches often marginalize local participation and knowledge. Alternative approaches to knowledge generation and information sharing, including mechanisms to collaboratively engage citizens, academics and decision makers offer innovative means to overcome the challenges associated with conventional data collection.

To address this challenge in relation to wildlife and transportation issues in the Canadian Rocky Mountains, the Miistakis Institute established a community-based monitoring (CBM) framework for wildlife and transportation issues in the Crowsnest Pass. The Crowsnest corridor consists of a two lane highway, a railway line and five principle settlements. There are plans to upgrade the highway to four lanes due to expected increases in traffic volume. Information on spatial and temporal movement patterns of wildlife through the region is essential for the development of effective mitigation strategies to facilitate movement and reduce collisions with vehicles. *Road Watch in the Pass* is an innovative framework for connecting researchers, citizen volunteers and decision makers through a CBM project to address wildlife transportation issues. It enables citizens to use an interactive Web-based mapping tool (please see www.rockies.ca/roadwatch) to enter wildlife observations along Highway 3.

Road Watch is an on-going project started in late 2004 and has proven to be a successful model for engaging volunteers (70 users) and for generating a large dataset of wildlife observations (currently over 4,000 observations). One of the best measures of success has been the use of Road Watch data in a number of land use planning processes and by local citizens to build support for protecting a wildlife movement corridor across Highway 3. In addition, the Road Watch mapping tool has been used as a model by other groups across North America.

Some of the challenges of the program are typical of CBM projects, such as engaging new volunteers, keeping existing volunteers motivated, reporting accuracy (location and species) and improving data collection methodology based on scientist and citizen feedback. Overall the Road Watch project demonstrates the value of integrating citizens in monitoring related to Road Ecology issues as well as highlighting the importance of collaboration and adaptive management to address the challenges of integrating volunteers into a research and monitoring program.

Introduction

Transportation networks present challenges for wildlife by interrupting movement patterns, alienating animals from critical habitat and causing genetic isolation as well as causing mortality from collisions with vehicles or trains (Forman and Alexander 1998; Trombulak and Frissell 2000). In Canada an average of 4-8 large-animal vehicle collisions occur every hour, and the rate of wildlife-vehicle collisions (WVCs) in North America continues to increase (Conover et al. 1995; L.P. Tardif and Associates Inc. 2003). The effects reach beyond individual wildlife populations and pose broader conservation, economic and social consequences, including a considerable human safety risk from vehicle-wildlife collisions (Husijer et al. 2007; L.P. Tardif and Associates Inc. 2003).

Wildlife and transportation issues are highly significant in the Crowsnest Pass, a east-west transportation corridor through the Canadian Rocky Mountains in southwestern Alberta, where WVC rates are high and the barrier effect may have significant negative consequences on movement opportunities, especially for wide-ranging carnivores such as grizzly bears (*Ursus arctos*), cougars (*Puma concolor*) and wolves (*Canis lupus*) (Apps et al. 2007; Proctor et al. 2005; Carroll et al. 2005).

Addressing wildlife transportation issues requires access to timely and accurate information on the spatial and temporal movement patterns of wildlife. The success of mitigation measures in ensuring movement and reducing collisions is highly dependent on appropriate placement and therefore on obtaining an accurate understanding of wildlife spatial movement patterns (Alexander et al. 2004; Clevenger and Waltho 2000; Farrell et al. 2002; Ng et al. 2004). However, long term monitoring information on wildlife movement and collision patterns for highways and railways is lacking in most jurisdictions. This is partly due to the cost and complexity of more conventional expert-based methodologies (Irwin 1995; Pollock et al. 2003).

To address this issue, the Miistakis Institute, a research institute at the University of Calgary, established Road Watch in the Pass, a CBM program to help address wildlife and transportation issues. Road Watch in the Pass (hereafter referred to as Road Watch) is an innovative means for connecting researchers, citizen volunteers and decision-makers through a citizen science project to address wildlife conservation issues. Road Watch enables citizens to collect information on wildlife observed along Highway 3 and share the data with other community members, municipal and provincial government and non-governmental organizations.

Methodology

There are currently three ways citizens can contribute to the Road Watch project: 1) submit observations through an interactive Web-based mapping tool, 2) report through a phone-in hotline; and 3) involvement in systematic wildlife surveys of Highway 3. This multi-pronged approach ensures that a diversity of users is reached as it addresses different commitment and computer literacy levels across the community. Recruitment of participants occurs through posters displayed throughout the community, local media announcements, demonstrations of the tool, attendance at local conservation workshops, and through personal communication. A local project coordinator promotes Road Watch and is responsible for engaging, motivating and addressing participants concerns. The project Web site acts as an effective mechanism for soliciting citizen participation and posting results.

Mapping tool

The Road Watch mapping tool runs on an Internet Information Server (IIS) using two open source products, *Map Server* and *Chameleon*. Open source software is freely distributed and accessible thus allowing programmers to access and modify the code to meet their specific needs (Hall and Leahy 2006). The mapping imagery is of 1m resolution allowing participants to locate and recognize local landmarks, thereby increasing the mapping precision. The mapping tool consists of basic GIS functionality to assist participants in adding their observation accurately to the map. A customized "add observation" button enables participants to add their observation directly onto the map. Once a participant enters their wildlife observation they are prompted to provide information through a pop-up form. Raw data are instantly converted into a spatial layer and are displayed back to participants through the mapping tool. The on-line mapping tool facilitates the collection of local observations into a useable format. Once observations are entered on the Web site, the information is readily available to be displayed in maps or converted to tabular data for analysis. This allows easy access for researchers and timely feedback to participants and the community.

Systematic survey

The systematic wildlife driving survey was designed based on requests from dedicated users for a more efficient data entry method as well as recommendations from a graduate project to improve current data collection methodology (i.e., based on opportunist rather than systematic sampling) (Paul 2007). Collecting information systematically enables Road Watch to calculate the rate of movement and collisions across the transportation corridor as data represents both species presence and absence. Participants of the systematic survey are assigned a defined transect (a section of highway they regularly drive). Each user commits to driving a transect twice a week and records start and end times as well as wildlife observations that occur along their designated route. To increase the efficiency and precision of this approach, a new device, called the *Otto Wildlife Companion* (http://www.myottomate.com) is used which combines a GPS unit and species keypad to mark observations.

Results

Road Watch dataset

The Road Watch model has successfully engaged a local community in data collection. Over 4,044 wildlife observations have been entered into Road Watch by citizens through the on-line mapping tool (95%) and phone in hotline (5%). Of the 4,044 records, 2, 246 observations (56%) of the observations are within 100 m of the highway and 500 (12% of total observations) represent highway crossing observations. The data predominately consists of ungulate observations (70% deer, 13% bighorn sheep (*Ovis Canadensis*), 7% elk (*Cervus elaphus*), 3% moose (*Alces alces*)) but also includes 1% rare carnivore sightings (including 3 grizzly bear crossing observations). The remaining records are comprised of coyotes (*Canus latrans*) and other smaller mammals including birds. Since project inception in 2004, over 70 individuals from the region have added Road Watch observations to the project.

Road Watch observational data can be analyzed to inform wildlife conservation issues and human safety concerns in the region. For example, Figure 1 is a display of high WVC zones, along Highway 3 for ungulate species commonly involved in collisions with vehicles. In this display the data have been aggregated in 250 m segments along the highway, and higher bars represent more mortality observations within the 250 m segment.

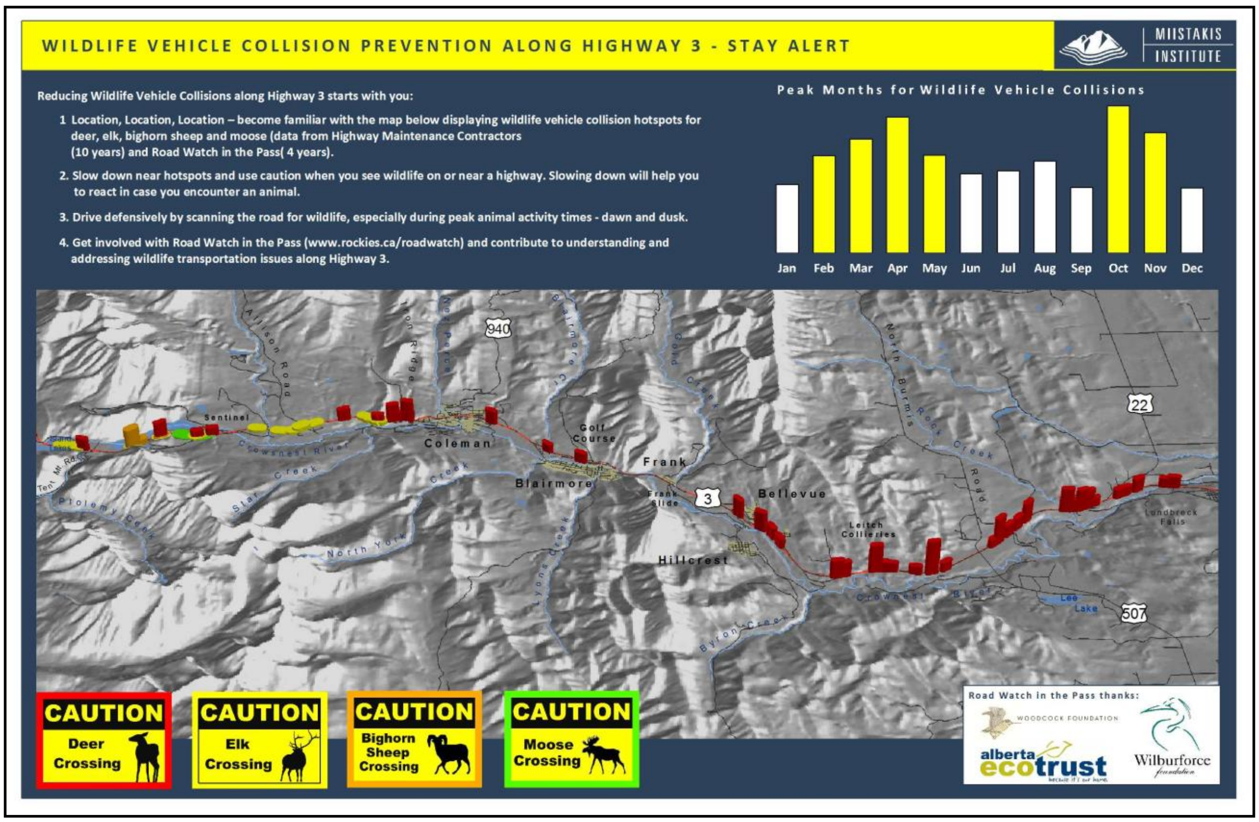

Figure 1: Community map displaying high collision zones using mortality data from Road Watch and highway maintenance crews.

In addition Road Watch data have been used: 1) in combination with other datasets or models to inform conservation planning processes in the region (including provincial and municipal government agencies and land trust organizations), 2) to document the presence and absence of species, 3) to identify conservation significance of blocks of land by private land owners and 4) as one of the datasets referred to in a regional science synthesis and mitigation report being developed by a partnership of research institutes, scientists and conservation groups aimed at informing transportation agencies responsible for the Highway 3 transportation corridor in Alberta and British Columbia. In all occasions the Road Watch dataset was used in conjunction with other observational data or habitat/movement models for the area. These examples highlight the important role of Road Watch for informing land use and conservation initiatives within the region.

The systematic driving survey

The systematic driving survey was developed in conjunction with Road Watch personnel; data collection methodology was designed and documented by participants. Initially six individuals were assigned segments of Highway 3 and were provided with Otto Driving Companions. Although training sessions were carried out, the following complications arouse:

- The cables between the GPS unit and keypad were too short, making set up difficult,
- Units regularly lost satellite connections, especially when in narrow valley between mountain ranges, which represented a large portion of the highway, and
- Individual drivers found data entry difficult and expressed concern about safety.

To address these issues, the developer of the software visited the site to test the units and recommended relaxing the Doppler Effect on the GPS unit. Testing of new units showed improvements and the systematic driving program is now being re-launched. However a number of participants returned to using the mapping tool as their choice of data entry due to frustration with the units and the concern for safety while on the highway.

Lessons learned in regard to the systematic survey include the importance of testing developed methodology and hardware prior to release, regular meetings hosted after implementation to address concerns in a timely manner and marketing the program to individuals whom regularly drive Highway 3 (especially individuals that carpool). This is an important component of the Road Watch program as it enables us to understand the rate of wildlife movement and collisions along Highway 3.

Educational experience

One of the objectives of a community based monitoring approach is to increase individual's knowledge on wildlife movement as well as enhancing the community's ability to address wildlife conservation and management issues in the region. In late 2007, Road Watch posted an on-line survey and interviewed a selection of participants to evaluate the following: individual learning experiences; their descriptions of the value of Road Watch; the projects ability to create a learning environment, and tangible actions as a result of project participation.

Of the 43 responses to the on-line survey, 85% felt their knowledge of WVC and movement zones had increased as a result of participating in the project. The other 15% indicated their knowledge did not increase. Results from interviews suggested these individuals felt they were already knowledgeable on wildlife movement prior to project inception.

Participants were asked to describe the value of the Road Watch project in an open ended question. Results were evaluated using qualitative software. Figure 2 highlights the different responses and their frequency.

The responses move beyond the direct benefits of increasing the knowledge base on wildlife in the region. Participants understand the potential of the data to inform the community, decision makers, highway mitigation and future land-use decisions to improve conditions for wildlife and human safety. Two individuals also suggested the project could foster a stronger sense of place and a conservation ethic in the region.

The projects' ability to create a learning environment is difficult to measure. One indicator considered through the Road Watch program was the number of individuals that had shared the program with other people in the community. The survey found that 88% of respondents had discussed aspects of the Road Watch project with other community members, including the project objectives, data collection methods and results. This indicates participants are spreading information through word of mouth within the community, demonstrating one-way knowledge exchange. Additional indicators are needed to strengthen our understanding of this component of the program.

The interview process indicates an increase in knowledge about wildlife may result in individual behavioral changes, such as changes in driving behavior including slowing down in areas of WVC hotspots. In addition, participants are likely to pass this knowledge onto family members and friends. To effectively evaluate our ability to foster a learning environment that leads to positive action, Road Watch needs to better define success. While Road Watch indicates some level of success in many areas it is only one tool on the ground for building community conservation capacity. Therefore understanding the place of Road Watch in relation to a community vision and other conservation initiatives will provide the context for evaluating success.

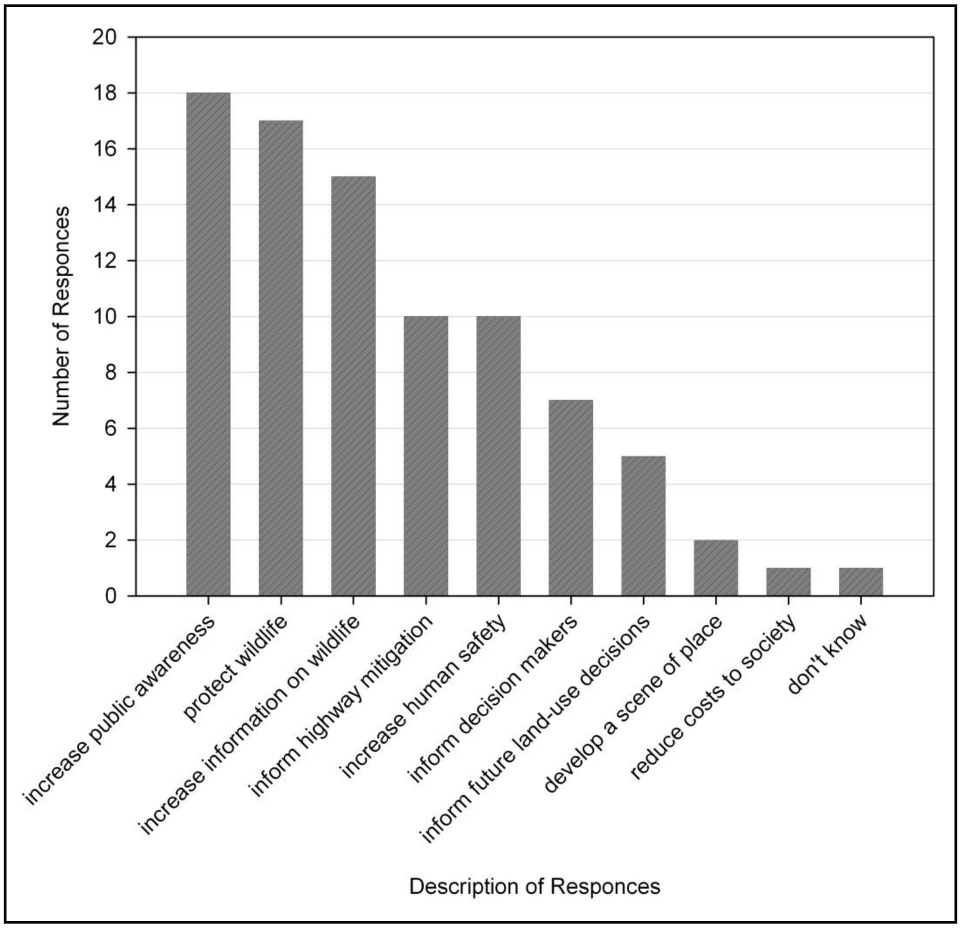

Figure 2: Participants perception of the value of the Road Watch program

Discussion

Road Watch in the Pass is an innovative framework for engaging citizen volunteers, researchers and decision makers in addressing wildlife and transportation related issues along Highway 3, a major transportation corridor through the Canadian Rocky Mountains. Road Watch has successfully generated a large dataset of wildlife observations along Highway 3. The dataset and results have been used to inform numerous conservation planning processes, including municipal and provincial government agencies, local citizens and non-governmental organizations. In all occasions the Road Watch dataset was used in conjunction with other observational data or habitat/movement models for the area.

The systematic driving survey was developed in response to participant's desires for a simplified data collection method and recommendations from a graduate project that compared Road Watch data to a one-year systematically collected dataset. The survey was designed with participants but not tested prior to deployment. Although the systematic driving survey had a rough start, changes to the design and hardware suggest potential for this component of Road Watch.

Road Watch is a successful model for increasing individual knowledge on wildlife movement and collision zones in the region. A qualitative study suggests participation has resulted in some behavioral change (such as self described changes in driving behavior). Participants are also sharing information about Road Watch with the community including project. Results indicated a high level of understanding in regard to the value of the Road Watch project. Values were expressed beyond simply generating a large dataset such as informing decision makers, community and the development of mitigation strategies to protect wildlife and increase human safety. Results indicate Road Watch success in achieving the educational goal to a certain point, certainly from the perspective of implementing community based monitoring project as a framework for engaging citizens into local sustainability issues.

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WILDLIFE TUNNELS UNDER A BUSY, SUBURBAN BOSTON ROADWAY

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Abstract

Wildlife use of passage structures has been documented in rural locations but infrequently in suburban settings. State Route 2 in Concord, MA is 20 miles west of Boston and has an average daily volume of about 50,000 vehicles. The roadway bisects some of the few remaining areas of open space, presenting a major potential barrier to wildlife movement. In 2005 MassHighway completed the installation of four wildlife crossing structures along a 2.5-mile segment of Route 2. The underpasses were constructed to mitigate wildlife habitat fragmentation exacerbated by the road safety improvement project that further divided the highway. The Town of Concord Division of Natural Resources formed the volunteer Wildlife Passages Task Force (WPTF) to study how wildlife responded to the underpasses. The four pre-cast concrete box culverts measure either 82.5' or 96' long and contain a 2-inch layer of dirt substrate. The internal dimensions are 6' high by 9' wide (two tunnels), 5' by 8', and 3' by 5'. Wildlife activity was determined by two complementary methods: a tracking bed made from sifted substrate in the one tunnel that was sufficiently dry, and passive infrared-triggered digital photography in all underpasses. We recorded 32 species that used the tunnels, some frequently. The mean annual rate of passage detected by the tracking bed and cameras was calculated for each species recorded. The tracking bed documented species missed by cameras, primarily most small animals such as mice, voles, frogs, salamanders and snakes. Rate of passage varied widely by species and also by location and method of capture. Most species common to the area were recorded using the underpasses; however, the rate of use for some species was inconsistent with our expectations based on their relative abundance in the area. Road kill and snow tracking studies demonstrated that wildlife continue to cross Route 2 outside the underpasses. Remote photography recorded behaviors (e.g., carrying prey, scent marking, travel with young) that indicate the crossing structures provided linkage within species' home ranges. We conclude that the Route 2 underpasses can facilitate wildlife movement even in areas severely impacted by human activity. Future studies will continue to monitor trends in species use over time, and possibly to evaluate wildlife responses to varied conditions within the tunnels.

Project History

Route 2 runs east-west along the north part of Massachusetts from Boston to the NY state border. When it goes through Concord, MA, it has four lanes, two in each direction, and a daily traffic volume of about 50,000 (see Figure 1). It is commuter roadway and has major rush hour traffic. At the same time, despite the traffic and suburban location, there is a variety of wildlife that frequent the roadside, as shown by a tracking study (L. Rogers, unpubl. data) and other reports (Forman and Deblinger 1998; Open Space Task Force 2004). To increase driver safety and avert head-on collisions, MassHighway planned to upgrade the roadway and further divide the highway with additional median barriers. To help mitigate the increased obstruction to wildlife movement that this would likely entail, MassHighway and the Town of Concord decided to install wildlife crossing structures while the road was under construction. (In this report, "tunnel" and "underpass" are used interchangeably to mean a box culvert installed under the roadway that functions as a wildlife crossing structure.) MassHighway worked with the town, Massachusetts Fish and Wildlife, and consultants at the University of Massachusetts to determine tunnel size and locations.

The construction project included no provisions to monitor the tunnels for animal crossings. For that purpose, the Town of Concord Division of Natural Resources created an eight-member volunteer group, the Wildlife Passages Task Force, to investigate wildlife use of the underpasses. Currently, there are twenty-four sites with wildlife crossing structures in MA, eleven of which are for general wildlife, of which the Route 2 underpasses are the only ones being monitored (D. Paulson, pers. comm.).

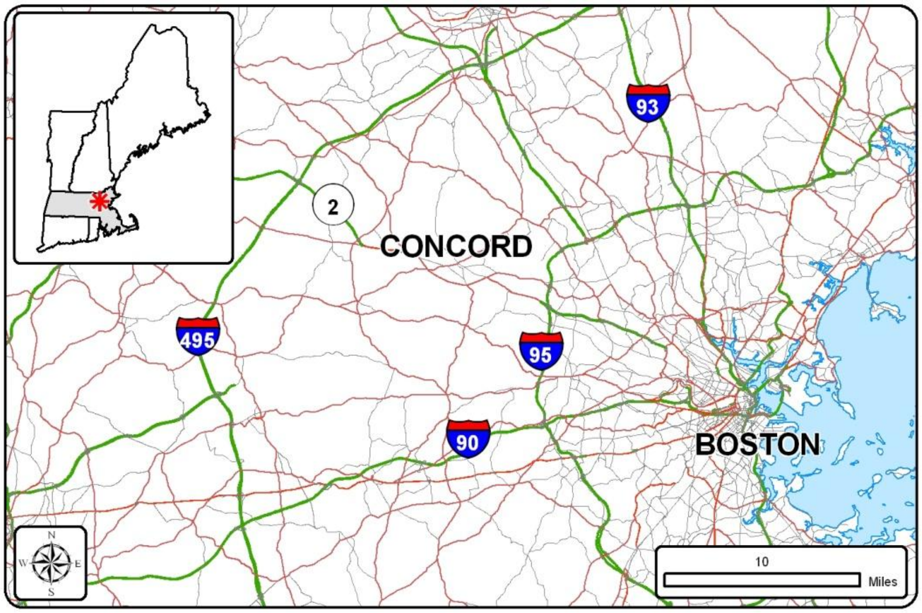

Figure 1. Location of study area. Map created by Sudbury Valley Trustees (SVT). GIS data provided by Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Energy and Environmental Affairs.

Study Area

The study area is a 2.5 mile portion of Route 2 in Concord that runs east-west, from Crosby's Corner to the Sudbury River. The segment includes three intersections with traffic lights and turning lanes, smaller feeder roads (two eastbound and three westbound), and one active railroad line passing under Route 2. After construction, Jersey barriers (both 42" and 32" high) and median guardrails at intersections divide most of Route 2 in Concord. There are guardrails along the side of the road over most of this section. The medians are unvegetated. About a third of the roadway is somewhat elevated above the adjacent land, especially in wetlands where fill was added during earlier construction.

The surroundings land is a patchwork of different uses: residential, open space (town, state and private land trust), wetlands, agricultural and playing fields, and commercial property. Development in Concord is mostly residential. Concord is about 25 square miles and has a population of 15,397 (Concord Town Clerk's Office 2009). Route 2 forms part of the border with the Town of Lincoln, which is 14.6 square miles and has 5990 residents (Town of Lincoln 2008). The highway largely appears tree-lined; a band of deciduous and mixed coniferous-deciduous forests and forested wetlands line both sides within 10 to 30 feet of the road. Route 2 bisects the Sudbury River and its floodplain. At the landscape scale, the road separates larger patches of open space to its north and south, including Walden Woods and the Great Meadows National Wildlife Refuge (see Figure 2). Local accounts show Concord has a diversity and abundance of wildlife, likely an outcome of the town's diverse wetland resources (Open Space Task Force 2004).

Wildlife Crossing Structures

Together MassHighway, the town staff and consultants considered different locations for the multi-species wildlife underpasses. A good site was easily located for one underpass (#1) by previous snow tracking. The locations of the other three underpasses were chosen based on a combination of construction and habitat issues: Given the topography, where would the largest structures fit and be reasonably expected to facilitate movement? Four pre-cast concrete box culverts (in 10' sections) were installed under the four-lane highway (see Figure 3). See Table 1 for tunnel dimensions and "openness" (Reed et al 1975, Jackson 1999, Clevenger and Waltho 1999).

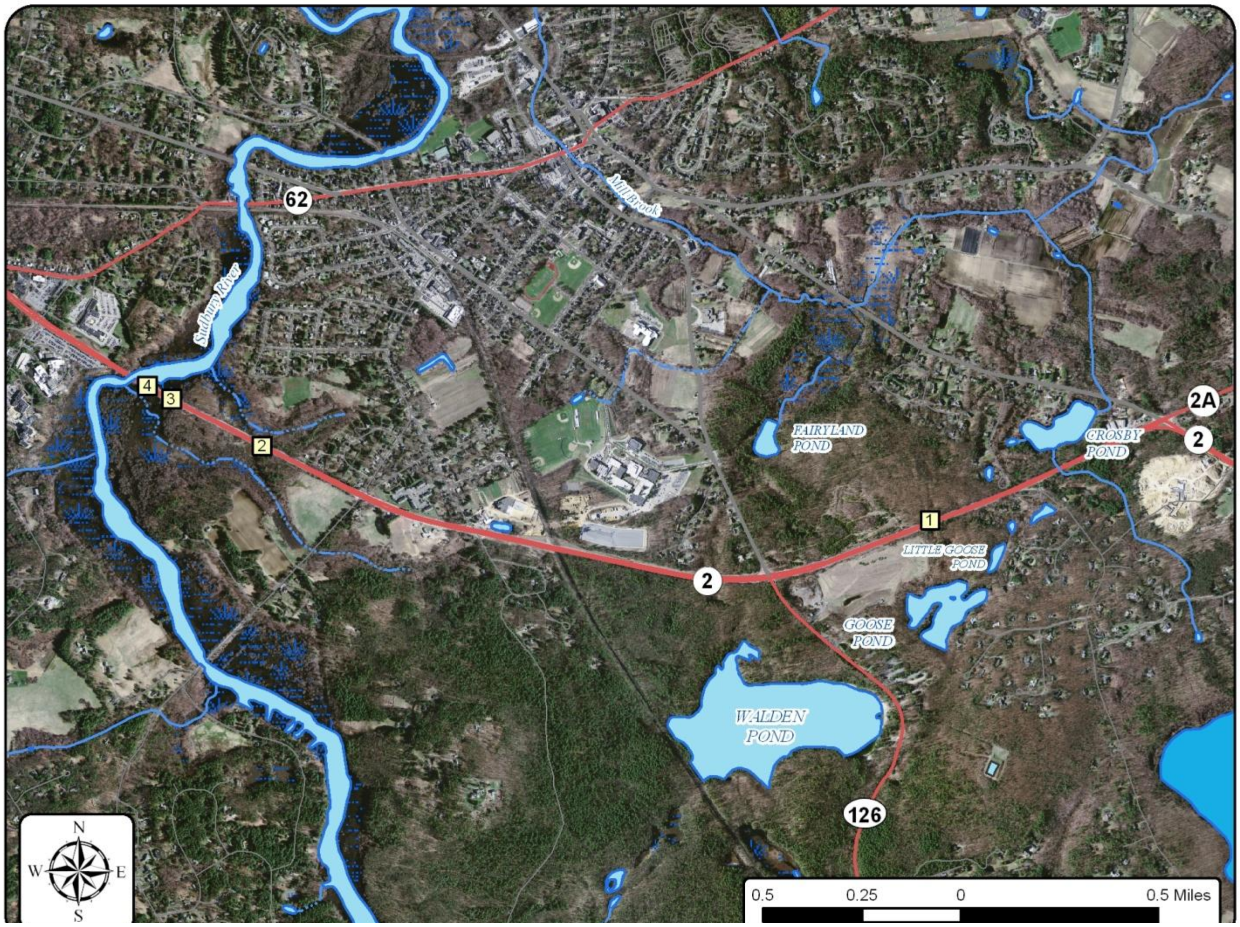

Figure 2. Aerial photograph of Route 2, Concord, MA with underpass locations. Map created by SVT. GIS data provided by Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs.

Figure 3. Photograph of underpass # 1

No.	Length (meters)	Height (meters)	Width (meters)	Openness (meters)	Length (feet)	Height (feet)	Width (feet)	Openness (feet)
1	30.5	1.83	2.74	0.164	96	6	9	0.562
2	25.2	0.91	1.52	0.055	82.5	3	5	0.182
3	25.2	1.83	2.74	0.197	82.5	6	9	0.654
4	25.2	1.52	2.44	0.147	82.5	5	8	0.485

Table 1. Dimensions of four wildlife underpasses in meters and feet, Concord, MA. Height times width divided by length was used to calculate "openness".

Underpass entrances were graded with dirt-covered riprap aprons. Stock-piled material that had been excavated from the site during construction was spread in the structures as substrate to a depth of about 2". To make underpasses less conspicuous and disturbing to wildlife, the retaining wall surface (in the raised sections of highway) had a simulated quarried rock appearance, and native plantings were added at entrances and along the adjacent retaining walls. There was no added fencing for funneling animals into the underpasses or keeping them off the highway. However, there are different types of fencing (including cyclone, wood, barbed wire) of varying heights near residences, playing fields, state highway property, the railroad tracks, and other sections. In places where the roadway is higher than the surrounding land, the retaining walls partly block wildlife movement onto the roadway. The underpasses and other road construction were completed in the fall of 2005, after which we began evaluating monitoring techniques.

Project Goals

The goal of the study was to determine whether wildlife would use the crossing structures; if so, which species and how frequently? Also, how would a group of volunteers accurately monitor animal crossings?

<u>Methods</u>

Track Bed Study

A tracking bed was made in one underpass by sifting the dirt substrate through wire screening onto black plastic between two 2" by 4" boards to a depth of about ½". When dry, this fine, sandy dirt proved to be very good for registering tracks. The bed was in the center of the underpass, the width of the tunnel floor and about 10' long. See Figure 4. Usually two experienced trackers read the track bed twice weekly. The bed was visited 158 times between January 2006 and June 2008. We recorded species, direction of travel, location within the track bed, and degree of certainty. When necessary, tracks were identified to a group of species, e.g., "small mammal" for mice and vole, or "weasel" for both long- and short-tailed weasel. Unidentifiable tracks were noted. We "erased" the track bed after each reading with a synthetic duster. The track bed and tracks of interest were photographed for future reference. There was a track bed in only one underpass (#1).

Camera Monitoring Study

We tested several camera models and configurations to find the most reliable way to record photographic images of the animals while they registered tracks in the bed at the same time.

The first model was a homemade unit using a Sony P41 camera and Pixcontroller (www.pixcontroller.com) pyroelectric infrared sensor, or "PIR" sensor. The camera was modified with an infrared filter to eliminate the white flash. The unit captured very high quality images, but the relatively slow triggering time caused many misses. See Figure 5. Modification with an external power source (6V battery) improved trigger speed by enabling the camera to run in an "always on" mode. However, replacing and charging the battery weekly was labor intensive, and the camera still missed many animal crossings. The Leaf River Model iR-3BU Infrared Digital Game Camera as tested in the underpass lacked sufficient illumination and also missed most passages.

Figure 4. Track bed with Reconyx camera in underpass # 1.

Figure 5. Images from Sony P41.
Clockwise from top left: two raccoons, cottontail rabbit, woodchuck, and long-tail weasel.

We found the Reconyx Silent Image Recreational Model RM30 (www.reconyx.com) cameras to be more successful at recording most animal crossings. The Reconyx models were also triggered by a PIR sensor but were substantially faster in recording the first image, resulting in a many fewer misses. The RM30 contained infrared LEDs to illuminate the images, though a very visible red glow was noticeable when operating under the low-light conditions within the tunnels. Through trial and error, we found that instead of aiming cameras perpendicular to the animals' line of travel, angling the camera down the underpass captured more passages because it allowed enough time after triggering to photograph the animal with sufficient illumination.

We then installed cameras on the walls of the other underpasses. Wooden camera mounts were affixed to the concrete walls using heavy-duty construction adhesive. The camera and motion-detector unit was mounted on a tripod head (VersaMount™) and secured with a cable and padlock. In two underpasses (# 3 and # 4) cameras were mounted in the center of the underpass 58" or 44", above the ground, respectively. The camera in the smallest underpass (# 2) was mounted 19" above the ground in the north entrance, rather than in the center of the underpass so it could be easily accessed. The cameras installed in the underpass with the track bed (# 1) were mounted 14" and 53" from the floor. The lower location more successfully photographed the small mammal crossings. From 2006 to 2008 in tunnels one, two, three, and four, cameras were active for 404, 275, 457, and 466 nights, respectively.

The Reconyx cameras were powered by rechargeable AA nickel-metal hydride batteries. Compact flash media cards stored 1/2 megapixel images. The cameras were set to record three images per triggered event with one second between each photo. Subsequent triggers were possible without lapsed time. The cameras were in place for weeks at a time. We visited cameras every three or four weeks to swap batteries and the flash card and change desiccant pack as needed. We rotated the three cameras in the four tunnels.

Data Analysis

For the camera analysis, we calculated crossing rates for each species by counting the number of individuals recorded crossing through the tunnels and dividing by the number of days the cameras were active. We only included individuals that appeared to cross all the way through the tunnels. If it looked as though the animal turned back to exit from the side it entered from, we did not count this as a passage. Motion-sensor cameras will take multiple images of the same animal if it stays in front of the camera. To avoid repeatedly counting a single tunnel visit, we counted as one crossing event any series of images of the same species in which there is not a ten-minute gap (recorded in time-stamps on the photographs) between any two successive frames. When multiple individuals of the same species could be distinguished in the photographs, we counted each individual as a separate crossing event.

For the track bed data, we counted each of the 158 visits by the trackers to the tunnel as a separate observation window. During each observation, trackers recorded the number of trails of each species that had been created since they last erased the track bed on their previous visit. The number of nights that elapsed between visits varied. To obtain crossing rates, we divided the number of trails observed for each species during a given observation window by the number of nights that had elapsed since the previous visit. This methodology gave us 158 crossing rates for each species, from which we calculated mean and standard errors of estimated crossing rates. We did not include tracks in this analysis for which the identity could not be determined with high confidence.

Results

At least 32 different animal species were documented using the wildlife culverts by either the track bed or the remote cameras. There were no Massachusetts listed endangered, threatened or species of special concern. See Table 2.

Figure 6 shows the passage frequency by species detected by the tracking bed in underpass # 1.

For the camera data, we calculated the mean crossing rates for each species based on the combined results from cameras in the four underpasses during 2007 and 2008. See Figure 7.

Discussion

Comparison of Remote Photography and Tracking Bed Methods

We mounted a camera over the track bed in tunnel # 1 so that we could compare passages detected by the camera with those recorded in the same time period within the track bed. Figure 8 compares mean crossing rates for each species that used the underpass obtained by the two methods over this interval. For some species (e.g., raccoon) the passage rates whether by camera or track bed were similar. For other species (e.g., chipmunk), the camera detected fewer passages than the track bed. For an additional group of species, (e.g., salamander), the camera missed passages altogether.

We found some drawbacks to using tracking beds to document species movement through the underpasses. The tracking bed was only useful under dry conditions. When the substrate was water saturated, it was too compacted to be cleared of tracks or to reliably register tracks of animals except for deer, which was the case in three of the underpasses. The track bed method required twice weekly visits and occasional added maintenance, such as removal of blown leaves and debris. A sign posted at the underpass entrances explained the purpose of the crossing structures and requested that the public refrain from entering. However, people did walk through and their prints (as well as overlapping animal trails, such as woodchuck) could confound track identification. Species identification from tracks was not necessarily self-evident (Rezendes 1999); it required experience and training, and more than one observer when possible.

The Reconyx cameras had the advantage that they could be left for weeks at a time, even in the winter. However, when we compared passages recorded in the track bed with photographs taken by a camera mounted over the track bed for the same time interval (Figure 8), we found the cameras missed many animal crossings. The Reconyx cameras are triggered by a moving object with a substantially different temperature than the background environment. Almost all snakes, and all frogs and salamanders did not trigger the cameras. The cameras also missed most small mammals, though success was improved by lowering the height of the camera. Precise aim of the camera affected image capture and was hard to consistently replicate. The camera also sometimes missed even fisher and other medium-sized mammals going through the underpass. Occasionally, blurry photographs of rapidly moving animals were difficult to interpret.

Species	By Tracks	By Camera
Humans (*Homo sapiens*)	+	+
Domestic cat (*Felis catus*)	+	+
White-tailed deer (*Odocoileus virginianus*)		+
Domestic dog (*Canis familiaris*)	+	+
Eastern coyote (*Canis latrans*)	+	+
Red fox (*Vulpes vulpes*)	+	+
Gray fox (*Urocyon cinereoargenteus*)	+	+
Northern raccoon (*Procyon lotor*)	+	+
Virginia opossum (*Didelphis virginiana*)	+	+
Striped skunk (*Mephitis mephitis*)	+	+
Northern river otter (*Lutra canadensis*)		+
Fisher (*Martes pennanti*)	+	+
American mink (*Mustela vison*)	+	+
Weasel (*Musela frenata* or *M. erminea*)	+	+
Eastern cottontail rabbit (*Sylvilagus floridanus*)	+	+
American beaver (*Castor canadensis*)		+
Woodchuck (*Marmota monax*)	+	+
Muskrat (*Ondatra zibethicus*)		+
Eastern gray squirrel (*Sciurus carolinensis*)	+	+
Eastern chipmunk (*Tamias striatus*)	+	+
Mice spp.(recorded as "small mammal")	+	+
Vole spp. (recorded as "small mammal")	+	+
Mole (species not determined)	+	
Common snapping turtle (*Chelydra serpentina*)		+
Snake sp. (one garter snake, *Thamnophis sirtalis sirtalis* observed)	+	
Frogs (species not determined)	+	
Salamander sp. (dead northern redback salamander, *Plethodon cinereus*, observed	+	
Mallard (*Anas platyrhynchos*)		+
American robin (*Turdus migratorius*)		+
Mourning dove (*Zenaida macroura*)	+	
Bird spp.	+	
Bat sp.		+

Table 2. Animal passages through wildlife underpasses in Concord, MA detected by tracking bed and remote photography 2006 to 2008. Plus (+) denotes presence recorded.

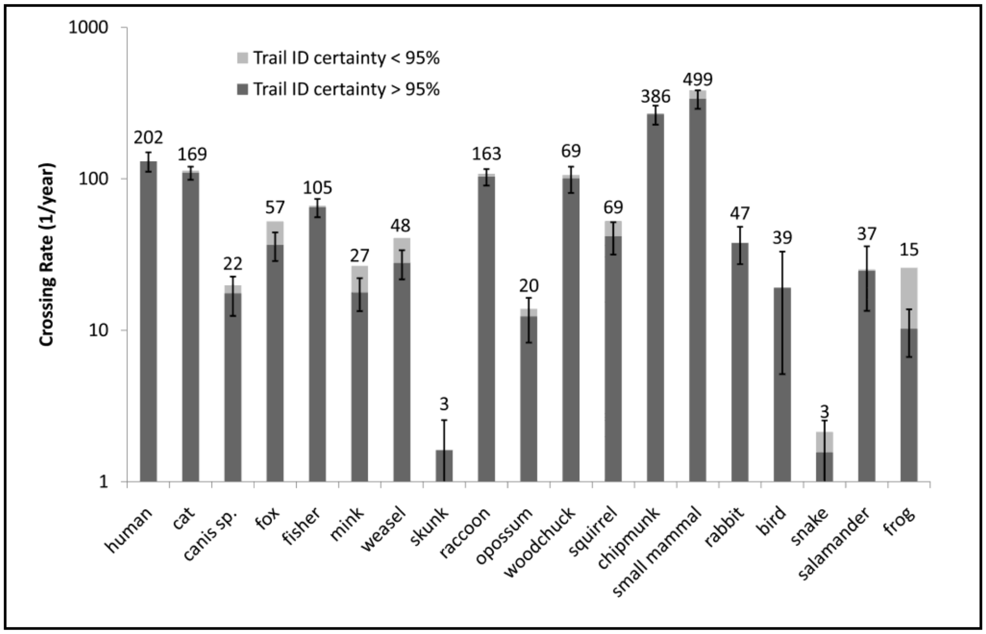

Figure 6. Mean crossing rates through one wildlife underpass based on track bed data monitored along Route 2 in Concord, Massachusetts from 2006 to 2008. For each visit to the track bed, crossing rate is calculated as the number of trails observed divided by the number of track-nights since the last visit to the track bed. Track beds were visited on 158 occasions. Light gray bars represent tracks that observers were not highly confident the species identity. Error bars represent standard error of rate estimate based on high-ID-certainty trails. The numbers above the bars represent the number of high-ID-certainty trails observed.

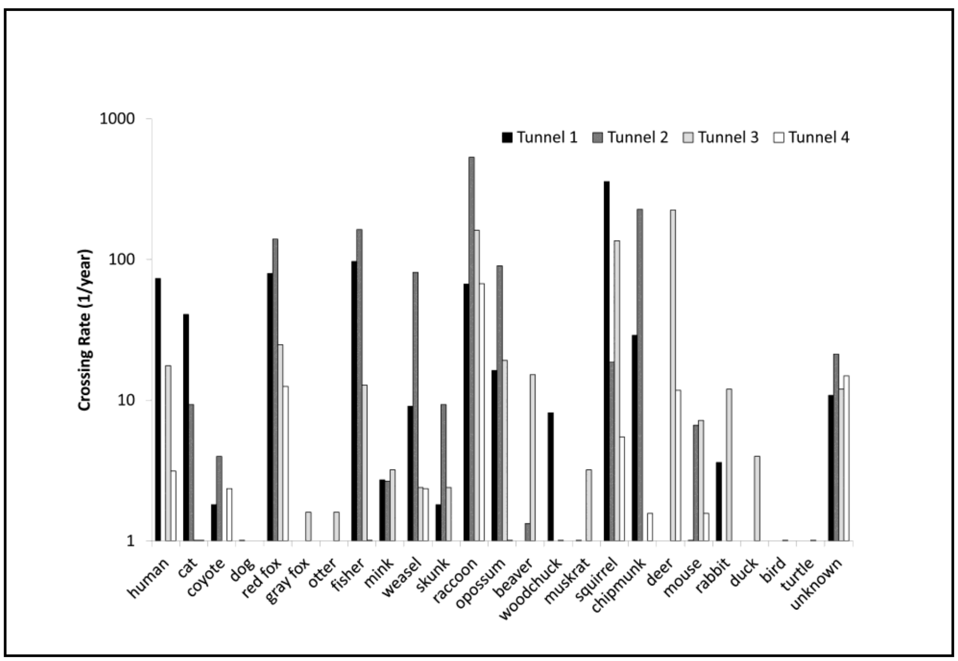

Figure 7. Estimated crossing rate for species based on camera data from four wildlife underpasses monitored along Route 2 in Concord, Massachusetts during 2006, 2007, and 2008. The number of camera monitoring days for tunnels one, two, three, and four are 404, 275, 457, and 466, respectively. The unknown category represents animals for which positive species identification was not possible. Animals that did not appear to cross through the tunnels are not included.

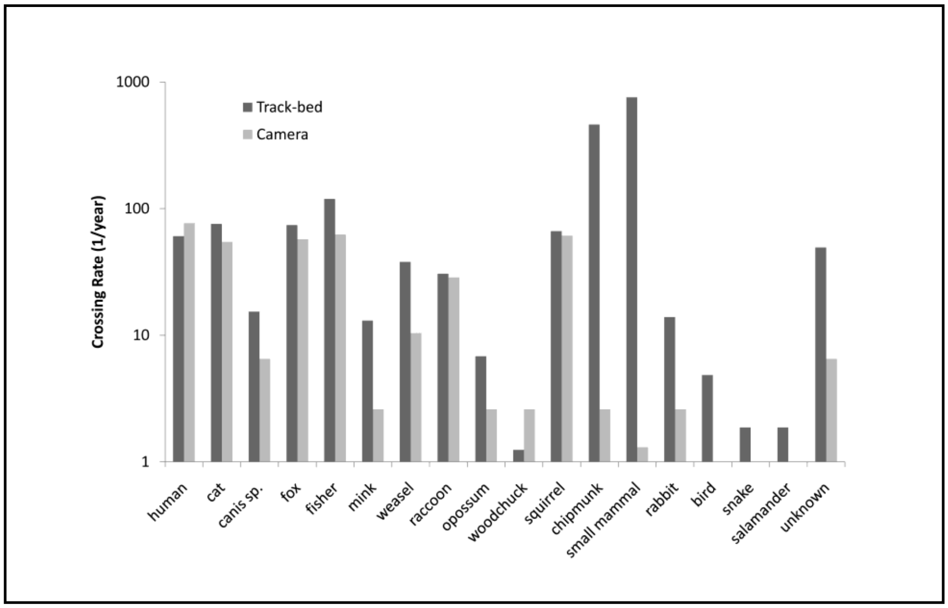

Figure 8. Mean crossing rates for species estimated using track-beds and cameras to monitor one wildlife underpass under Route 2 in Concord, Massachusetts during 2007 and 2008.

There was considerable difference in cost and maintenance of the two methods. The Reconyx cameras cost about $900 each. It took less than half an hour per person per week to maintain operation and another person-hour to enter the data. The track bed cost less than $20 in materials but took about five person-hours to initially install it. The track bed required about four to six person-hours per week to read and maintain it and only a few minutes to enter the data.

Since we were concerned that the camera monitoring would deter wildlife from using the crossing structures, we used only cameras without white flash. It was clear from the photographs that wildlife were quite wary of the Reconyx RM30 cameras; they were silent but had a visible red glow. (According to the Reconyx website, newer models have NoGlow™ illumination.) Some animals balked and attempted passage repeatedly, eventually either leaving the tunnel or going through. Photographs taken at the tracking bed indicated the bed was much less disturbing than the camera, though not completely.

Remote photography, despite its drawbacks, provided information that could not be garnered from tracking alone. Cameras documented exactly when animals crossed, whereas the passages in the track bed occurred within a three- to five-day window. Also, the photographs recorded interesting behaviors that showed how animals were interacting with the underpasses.

Passage Frequency

The crossing structures are relatively small and long (see Table 1), there is no fencing to direct wildlife, and locations are somewhat arbitrary. Nonetheless, most wildlife species documented within the surrounding areas were also recorded using the underpasses, some frequently. The exceptions to this were red squirrel (*Tamiasciurus hudsonicus*), southern flying squirrel (*Glaucomys volans*), and wild turkey (*Meleagris gallopavo*). Frequency of passage rates for gray fox and eastern cottontail rabbit was lower than anticipated from snow tracking along the roadside. In one tunnel (# 1), although snow tracking recorded extensive deer trails in the immediate area before and after construction, and deer tracks were often found in the south entrance of the underpass, there were no recorded deer passages.

The detection of a given species within the underpass could be quite variable over time. It took months before some species (e.g., cottontail rabbit, coyote, gray fox) were recorded using the underpasses. For some species, there were very high passage rates. Since in most instances we were not able to distinguish individual animals by photographs, the many crossings recorded of fisher, red fox, and raccoon may represent a few busy individuals. Also, mice photographed using the small weep holes inside the tunnel (which were, in turn, visited by predators) were more likely residents than animals crossing through. Woodchuck, chipmunk and gray squirrel crossing frequencies were high in the fall.

Since rivers can serve as natural movement corridors, we had anticipated that the underpass closest to the Sudbury

River (# 4) would show high crossing rates. However, comparison of passage rates in the tunnels did not show this (Figure 5). One reason may be that during flood conditions, the tunnel becomes isolated by high water. Adding space for crossing under the bridge, especially on the other (west) side of the river, when the bridge span is updated may provide more opportunities for animal crossings (Mullin et al 2007).

We also monitored road kill in the study area. Road kill with odometer location was recorded while driving the speed limit (45 mph) along the study area in both east- and westbound directions. (Lower speeds or walking were unsafe due to traffic and little to no roadside space.) Species were identified if possible or recorded as "small" (e.g., squirrel), "medium" (e.g., raccoon), or "large" (e.g., coyote). There were 159 road kills from 194 days of observation over 35 months. At 45 mph these data have limited validity but do demonstrate that a variety of wildlife still attempt crossing over the roadway. Preliminary road kill data for white-tailed deer as reported to the Concord Police suggest that there may be a slight reduction in deer-vehicle collisions since completion of the underpasses (Detective Forten, pers. com).

During the winter of 2007, a snow-tracking study was done 24-48 hours after snowfall on six occasions. Positively identified tracks within 25 yards of the roadway and GPS coordinates were recorded using CyberTracker software on a Palm Pilot. We recorded and mapped the following seven movement patterns: movement alongside the road, movement onto the road, movement off of the road, approach and retreat from the road, entering crossing structure, exiting crossing structure, and approach and then retreat from a crossing structure. Snow tracking data indicates that wildlife continue to cross over Route 2 as well as going through passage structures and that animals often parallel the roadway and may make repeated crossing attempts. Tracking in the study area was constrained by the fact that there is a lot of wildlife activity in a small space with many intersecting trails. Following a trail soon led the observer to an impassable wetland or someone's backyard. Snow tracking gave an interesting snapshot of how animals interacted with the roadway and underpasses, and presented more questions for future study. Over time, would there be relatively more passages through the underpasses than over the roadway? Would the animals that approached and retreated from the underpass, eventually go through?

Conclusions and Recommendations

Crossing Structure Design

There may be ways to even further enhance the design of the underpasses. Water from leakage between concrete sections, road runoff released at tunnel entrances, and river flooding curtailed monitoring at times and most likely influenced animal usage (deer, raccoon, weasel, and kayakers were often undaunted). It would have been interesting to see if shelves retrofitted into the underpasses in the floodplain would have facilitated more passages, especially for small mammals (K. Foresman, 2003). Snow plowed and pushed over the roadway accumulated and partly blocked underpass entrances and once may have compelled a red fox to go over the roadway with fatal results.

The dry underpass (# 1) enabled us to set up the track bed and record salamander, frog and snake passages that cameras missed. However, dryness had its downside as well; the underpass may have been a conduit for some salamander crossings, but several salamanders were found dead in the substrate, apparently victims of desiccation. It would be desirable to add a moisture source in this underpass that does not interfere with the track bed but helps the salamanders survive. We were unable to record salamander use of the three other underpasses.

The crossing structures will require maintenance. Underpass substrate and dirt that covered riprap at entrances was partly washed out by flooding will need replacement. Trash rapidly accumulates along the study section. The Department of Corrections road crew removed a tremendous amount of trash in several sections. Many of the added plantings did not survive, and some original (and invasive) plants overgrew them. Both planted and preexisting roadside vegetation will need management so that it does not obstruct wildlife movement.

Human Usage

We assumed that human activity could deter at least some wildlife use, even if the animals were already habituated (Clevenger and Waltho 2003). Signs posted at underpass entrances informed the public about the project and requested their cooperation in staying out. When talking about the structures to the public, we avoided describing exact underpass locations. Nonetheless, photographs show approximately 100 human crossings per year. People were photographed on foot, in boats, with dogs, on cross country skis, snowshoes, and bikes.

Not surprisingly in a residential area cut by a busy highway, there was considerable interest in connecting access to open space on either side of Route 2. The *Walden Passage Feasibility Study December 2007* (Mullin 2007) evaluated the plan to build an additional crossing structure within this same study area that would provide recreational and "cultural connectivity", while further facilitating wildlife passage. Although they concluded that "the existing wildlife crossing culverts under Route 2 are already being used successfully by a majority of species", pressure to provide pedestrian crossing continues. Our data were insufficient to document how human presence affects wildlife use of the underpasses.

Volunteer Monitoring

Citizen groups have contributed important data for a number of projects, such as the Christmas Bird Count and local chapters of Keeping Track®. In this study, all observations about wildlife use of these underpasses were the result of volunteer efforts. We had intended to include more volunteer trackers; however, having a small, core group minimized observer-related variability in track interpretations (Hardy 2003). Also, we felt the need to balance the value of sharing the project with the public with the need to limit human visitations to the structures.

Effectiveness of crossing structures

The tracking bed and remote photography results estimated wildlife use of four crossings structures by measuring the rate of detections for each species (van der Ree et al 2007). The results clearly show that a wide variety of animal species use the underpasses, some frequently, despite somewhat arbitrary locations, relatively small size of the structures, and a highly fragmented suburban setting. This study was not able to determine if the crossing structures were used in preference to crossing over the road surface or if road mortality declined compared to levels before the underpasses were installed. However, if the desired "effect" of the underpasses is to allow individual animals to cross the road, the Route 2 underpasses are a success.

It is not clear how effective the tunnels will be in the long term at mitigating the negative impacts of habitat fragmentation (Hardy et al 2003). The most desirable mitigation goal would most likely be preventing a reduction in the viability of local populations over the long-term (van der Ree et al 2007). Even if, as our results would suggest, the underpasses enabled wildlife to access resources and move without hindrance between both sides of the roadway, it is unknown whether this permeability is sufficient to counter the other negative impacts of the roadway on the long-term health of wildlife populations (Roedenbeck et al 2007).

On the other hand, the monitoring results indicate that wildlife species present in the remnant patches of land close to Route 2 are surprisingly adept at dealing with the highway and human-impacted landscape. Photographic images suggest that wildlife are successfully incorporating the underpasses in their activities and linking parts of their home range. Raccoon were usually photographed in pairs and larger family groups. Photographs record unexpected crossings, such as coyote using even the smallest, 3' by 5' (# 2), underpass. Deer often moved in small groups. Two different bucks were photographed using the same underpass in one season. A doe and her fawn were repeatedly photographed together in one underpass. In an amazing display of fidelity to a flooded underpass, a deer swam through, upstream. A fisher was photographed carrying prey to one side of the road June to September, presumably to a den. Fisher, red fox and raccoon marked with scent inside the underpass and at the entrances. One industrious gray squirrel traveled back and forth, leaf by leaf, to build a nest on the other side of the road. See Figure 9.

Irrespective of the biological value of the crossing structures, the Route 2 underpasses have proven successful in terms of social and political factors (Servheen et al 2007). Publicity about the underpasses in local and regional media helped educate the public about the presence of wildlife near roadways in their communities, the impacts roads have on wildlife, and measures taken to mitigate the negative effects. The photographs gathered by this study proved to be a valuable public relations and educational tool. Citizen involvement has been part of the project from the beginning. The underpasses were planned and installed in part because of local interest; they were monitored by a volunteer group who were curious and committed to finding out if they "worked". Ultimately it will be the public that decides whether the crossings structures are "worth" the expenditure.

We conclude that the underpasses facilitate wildlife movement under Route 2 in Concord, MA. The two methods we developed to monitor usage did record usage but had different advantages and disadvantages. Future study will focus on trends in wildlife populations over the long-term and perhaps how wildlife crossings are affected by different conditions. In particular, we would like to design a controlled study to determine whether human presence in the crossing structures affects wildlife use.

Figure 9. Reconyx photos from within four underpasses, Concord, MA. By row, left to right: kayaker, fisher, doe and fawn; gray squirrel with leaf, fisher with skunk, raccoon family; swimming deer, coyote, and buck.

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Delia R.J. Kaye received a B.S. degree in wildlife biology from the University of Vermont. She is currently the Natural Resources Director for the Concord Division of Natural Resources.

Ron McAdow is author of a guide to the nature and history of the Concord, Sudbury, and Assabet Rivers, and a similar work about the Charles River. Ron has worked as a volunteer and staff member of a regional land trust called Sudbury Valley Trustees for the past two decades, and has served as Executive Director since 2002. He co-chairs the Wildlife Passages Task Force.

Bob Metcalfe is founder of New England Discovery. He has taught tracking to children and adults for twelve years. Bob is a registered Maine Guide.

Bryan Windmiller holds a PhD in biology and a Master's degree in Environmental Policy from Tufts University and has consulted in wildlife ecology since 1987. His interests include the impacts of residential construction on vernal pool amphibian populations, conservation of Blanding's turtles, and vernal pool aquatic insects. He studied chytridiomycosis in Australian frog populations and continues to work on local amphibian and reptile conservation efforts in New England and Honduras.

Noah Charney has conducted research on amphibians, mammals, birds, a variety of conservation issues and experimental physics. He is currently pursuing a PhD in salamander terrestrial ecology at the University of Massachusetts, Amherst as a National Science Foundation Graduate Research Fellow. He has studied and taught about animal tracking for over a decade and is co-author of an upcoming field guide to invertebrate tracks and sign.

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MOTORISTS AS CITIZEN SCIENTISTS: THE BENEFITS OF A WILDLIFE REPORTING WEBSITE

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Abstract

In a growing number of states, wildlife-vehicle collisions are a top safety issue that generates interest with the public and the media. State Highway 75 near Ketchum, Idaho (SH-75), Interstate 90 near Bozeman, Montana (I-90), and Interstate 70 near Vail, Colorado (I-70) are examples of roads that concern the public and officials about collisions with large mammals. Inspired by the Canadian "Road Watch in the Pass" project, the Western Transportation Institute (WTI) designed a wildlife reporting website so the public may enter their wildlife sightings (dead or alive). Live animal observations are important in order to get a clearer picture of wildlife use in the roadway corridor. Live animal observations are also more difficult to obtain. Therefore, a network of motorists/citizen scientists can supplement traditional data sources; however, there are potential biases and limitations of citizen science. The website also provides information about the road mortality problem and potential mitigation measures.

During a deer/elk-vehicle collision (DEVC) study on SH-75, 312 public reports were logged on the "Ketchum on the Road" website between March 28, 2007 and March 24, 2008. Two hundred fifty six of the reports were considered to be related to separate events (i.e. they were "unique") and within the scope of the study. Live reports were of black bear, (escaped) bison, coyote, mule deer, white-tailed deer, elk, moose, red fox, and wolf. Road mortality reports were of deer, elk, red fox, raccoon, skunk, domestic dog, bird, and unknown animals. In addition to using the public's reports, the study also relied on crash data (Idaho Highway Patrol), carcass data (Idaho Transportation Department), and road mortality data from four ten-day surveys (once per season) conducted during the study period (WTI). A minimum of 134 deer and elk were estimated to have been killed by traffic in the 26-mile section (an average of 5 carcasses per mile/year) after analyzing all data sources for 2007 only and accounting for replicate reports between sources. This minimum estimate of 134 DEVCs is considerably higher than previous annual estimates of 30-50. The website and systematic surveys likely account for the dramatic increase in the number of carcasses detected. Only 51% of the DEVCs were reported in agency databases. The public reported 38 unique deer and elk carcasses (28% of total) not accounted for by any other method. The findings show that the public's wildlife reports from SH-75 in Idaho 1.) reduced underestimation of DEVCs, 2.) suggest that the need for mitigation is greater than previously thought, 3.) bring attention to species smaller than deer that are also killed by traffic, and 4.) help identify locations of live animals on or near the road and locations with potential successful crossings.

In October 2008, WTI's wildlife reporting website was modified for American Wildlands' "I-Spy on the Pass" project along I-90 in Montana. The website template will also be adapted for the "I-70 Wildlife Watch" project in Colorado by fall 2009. For both of these projects, the website, and the citizen science data it generates, aims to 1.) supplement existing agency road mortality databases with information on live animals on or alongside the road, 2.) provide a venue for engaging local communities, and 3.) aid in the development of mitigation recommendations for wildlife. Based on the past and ongoing data collection efforts we conclude that using motorists' observations via a wildlife reporting website is an effective way to boost data collection and increase support for mitigation measures.

Background

Wildlife-vehicle collisions (WVCs) constitute a top safety issue which requires consistent monitoring and spatially specific data in order to mitigate. Relying on highway patrol crash data, department of transportation carcass data, and even systematic roadkill monitoring can underestimate or incompletely describe the road mortality situation. Utilizing the motoring public as citizen scientists can supplement traditional data sources while increasing support for mitigation measures to reduce WVCs and allow for safe passage. A wildlife reporting website can provide a convenient venue for engaging a local community in this effort but such data does not replace the need for formal data collection.

Inspired by the Canadian "Road Watch in the Pass" project, the Western Transportation Institute (WTI) designed a wildlife reporting website template so the public may enter data on the location, date and time they see animals, dead or alive, on or alongside the road. The website also provides information about the road mortality problem and potential mitigation measures. Following are three examples where the WTI wildlife reporting website has or will be used in conjunction with wildlife-transportation projects.

"KETCHUM ON THE ROAD," STATE HIGHWAY 75, BLAINE COUNTY, IDAHO

Site and Project Description

A 26 mile section of State Highway 75 (SH 75) near Ketchum, Idaho no longer meets safety and transportation capacity needs and may require reconstruction (Blaine County 2006) (Fig. 1). In 2007, average annual daily traffic (AADT) was approximately 13,000 vehicles and the volume is expected to increase (ITD 2008). In addition, there are concerns about the number of WVCs on this section (Blaine County 2006). It was estimated that 30-50 mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) succumbed to vehicle collisions occurred every year [(Parrish 2002) cited in Shapiro & Associates 2003]. WTI researchers conducted a road mortality study during March 2007 to March 2008.

Road Mortality Study

The road mortality study was based on historic and recent data from different organizations [i.e., Idaho Transportation Department (ITD), Idaho Department of Fish and Game (IDFG) and Idaho Highway Patrol (IHP)] as well as data collected by WTI researchers and the general public during the study period from March 12, 2007 to March 30, 2008. In addition to data collection and analysis of road mortality data and wildlife crossing data, this study also investigated the feasibility of installing an animal detection system in sections with the highest concentration of deer/elk-vehicle collisions (DEVCs).

Wildlife Reporting Website

In order to increase our understanding of wildlife-vehicle collisions and wildlife movements across the road in the study area, the public was asked to submit their wildlife sightings into an online database called "Ketchum on the Road." A link from the Blaine County website led users to the wildlife report submission site located on the WTI server (Appendix). A variety of methods were used to inform the public about the website (Table 1).

Variable Message Signs Mile post 117.2 McKercher north of Hailey April 12-19, 2007 Mile post 107 near Walker Road south of Bellevue June 7-14, 2007 Mile post 120.3 between Hailey and Ketchum November 2 - December 2, 2007
Promotions Fliers in Ketchum, Hailey and Bellevue (e.g., in businesses, libraries, County and Federal offices, etc.) The Environmental Resource Center published an announcement in their newsletter
Web and print media coverage Press release by Blaine County and Western Transportation Institute on March 12, 2007 Blog announcement by Tom Bowman on April 17, 2007 "A steady diet of road kill", Wood River Journal, May 1, 2007; http://www.woodriverjournal.com/articles/2007/05/02/news/local_news/astory.txt "Information on wildlife road kill still sought", Idaho Mountain Express, November 2, 2007; http://www.mtexpress.com/vu_breaking_story.php?bid=4523 "Study aims to solve road kill dilemma", Idaho Mountain Express, November 7, 2007; http://www.mtexpress.com/index2.php?ID=2005117865&var_Year=2007&var_Month=11&var_Day=07 "Motorists contribute to road kill survey", Idaho Mountain Express, March 12, 2008; http://www.mtexpress.com/index2.php?ID=2005119766
Public Service Announcement Played multiple times during the course of the study at the discretion of KECH 95 radio personnel
Public Presentation "Ketchum on the Road – Wildlife Reporting Website" at The Community Library in Ketchum on November 1, 2007

Table 1. Media and outreach activities to encourage the public to report wildlife sightings

A total of 312 wildlife reports were made by the public during the approximately one year study period (Table 2). After accounting for replicates and those reports which did not fit our study criteria, there were a total of 256 unique and usable reports.

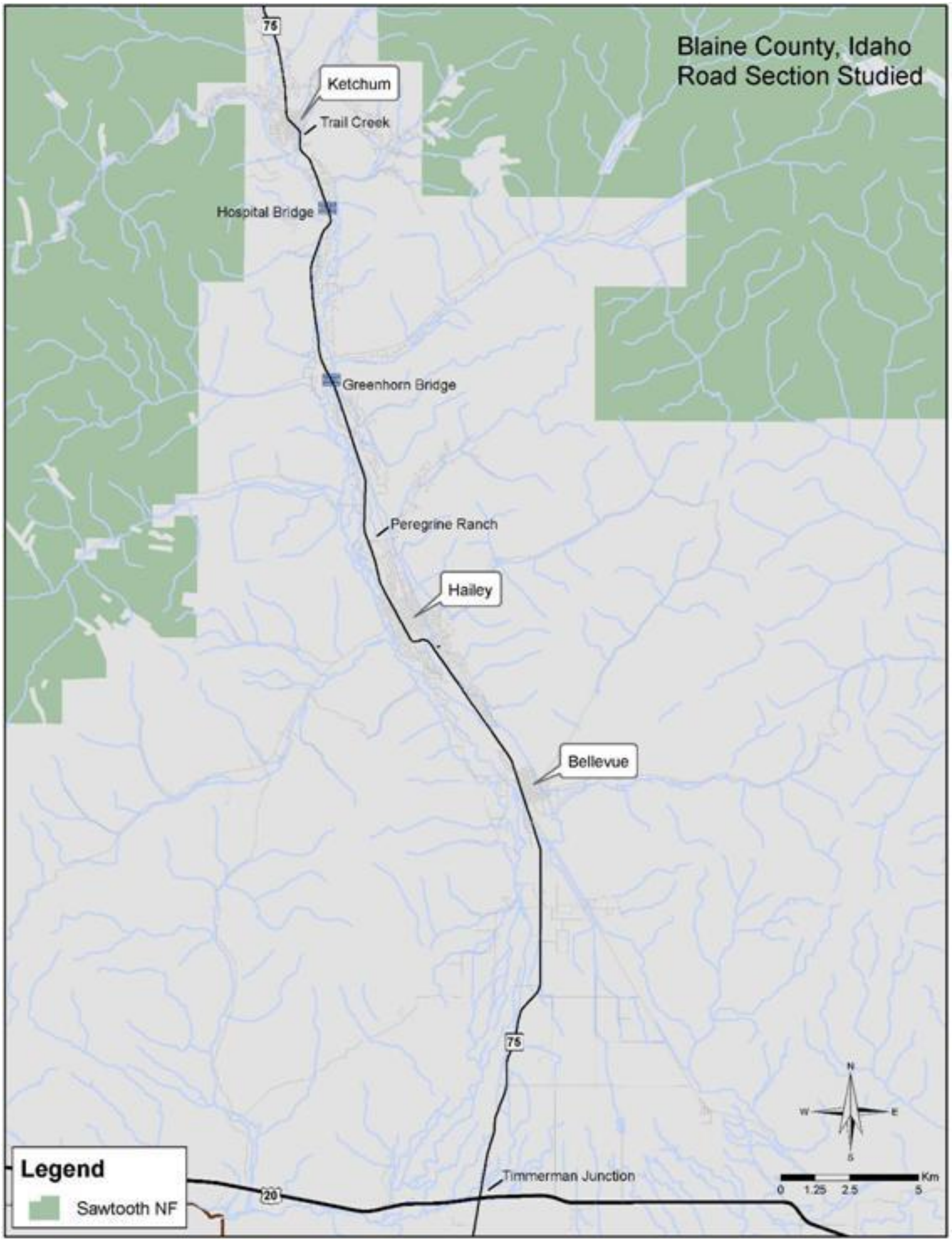

Figure 1: The 26 mile long road section of SH 75 under study. The road section starts at Timmerman Junction (junction with Highway 20) at the south end, and ends at the Trail Creek Bridge in Ketchum. In addition, the map shows the location of two bridges across the Big Wood River that may be used by large mammals as a wildlife underpass.

Total public reports on website	312
Comments with no wildlife data	- 3
Reports from outside of study area	- 4
Reports of observations prior to the study period	-10
Total live (n=200) and dead (n=95) observation reports	295
Replicate reports of a single wildlife or carcass observation	- 39
Total unique live (n=184) and dead (n=72) reports	256

Table 2. Break down of wildlife reports received from the public via website

There were 184 reports of live animals including black bear, buffalo (escaped), coyote, mule deer, white-tailed deer, mule or white-tailed deer, elk, moose, red fox, and wolf. Due to the possibility of multiple reports from different people for the same wildlife sighting, the following rule was applied: Live observations of the same species that were reported to occur within one hour of each other and that were within .2 miles of each other were treated as replicates. In those cases where replicates had differing animal counts, the largest number was chosen. Based on this rule, sixteen reports related to replications of a single wildlife sighting, therefore, there were 184 unique live wildlife reports.

There were 95 reports of dead animals, including mule deer, white-tailed deer, elk, red fox, raccoon, skunk, domestic dog, bird, and unknown species. Due to the possibility of multiple reports from different people for the same carcass sighting, the following rule was applied: Dead observations of the same species that were reported to occur within 2 days of each other and that were within .2 miles of each other were treated as replicates. Based on this rule, 23 reports related to replicate reports of a single carcass, therefore, there were 72 unique reports of carcasses. Some collisions resulted in more than one carcass; therefore, the total unique carcass count for all species was greater than the number of reports (Fig. 2).

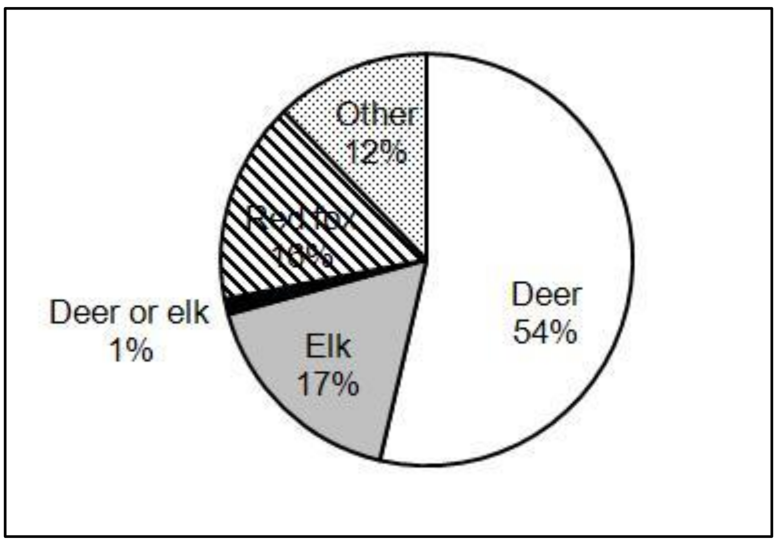

Figure 2: Public reports of unique carcasses by species (Total n =82). "Other" category includes bird, raccoon, skunk, domestic dog and "unknown species."

This study was most concerned with vehicle collisions with large bodied mammals (i.e., deer and larger) that pose a safety concern to humans. There were 50 unique dead deer and elk reports for a total of 59 carcasses. There were 158 unique live reports of deer, elk or moose, some of which reported more than one individual animal per sighting. Unique live and dead reports for all ungulate species (deer, elk and moose) were categorized by location (Fig. 3). Most of the ungulate reports (live or dead) focused between mile post (MP) 117 and 127 (Figs. 3 and 4).

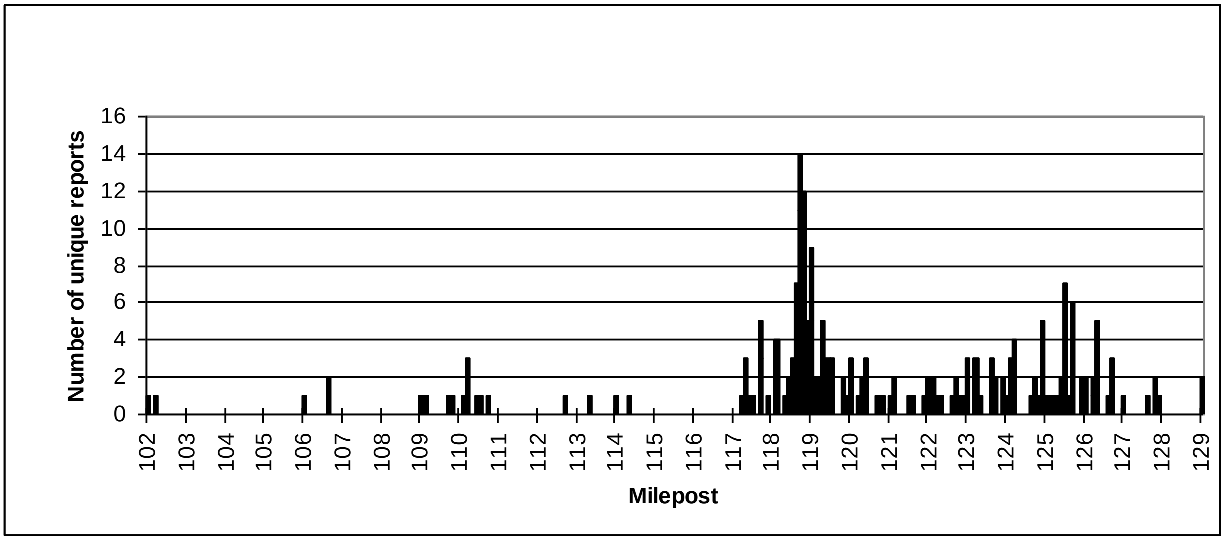

Figure 3: Public reports of unique ungulate reports (alive and dead combined) by milepost for the entire study area (Total n = 208). Note that this figure illustrates the number of unique reports only (i.e. one report may relate to multiple animals).

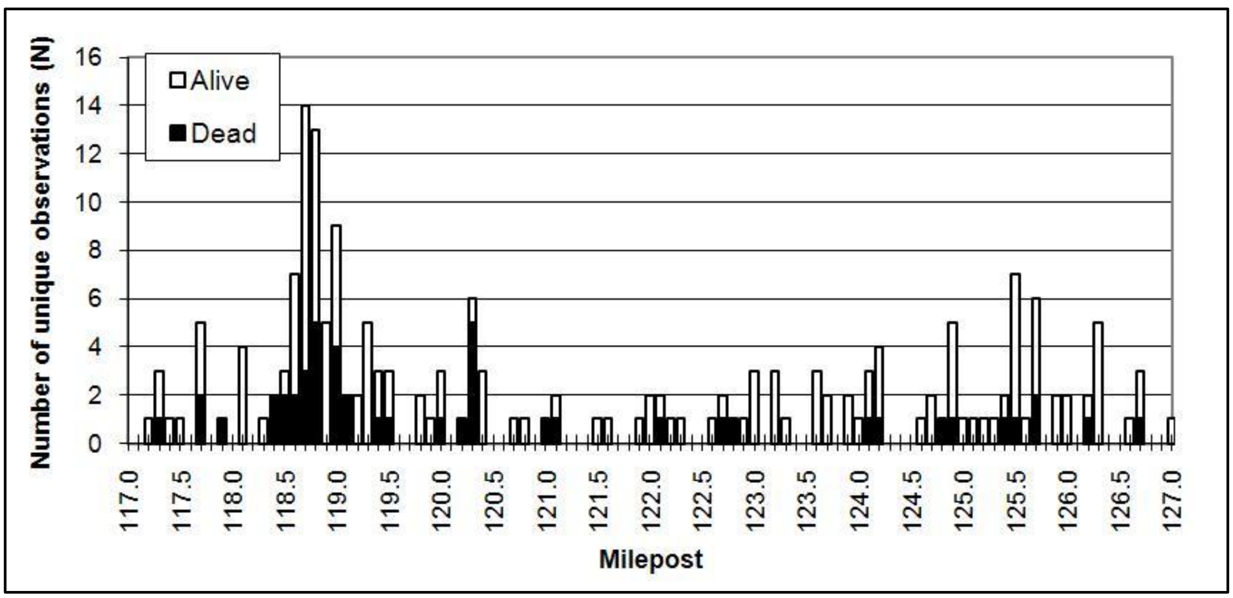

Figure 4: Public reports of unique ungulate (deer, elk and moose) carcasses (each carcass is counted in the graph) and unique alive reports (the number of reports of live animals is counted, but not the number of animals seen alive) by mile post for MP 117-127 (Total n = 187).

The highest concentration of deer and elk carcasses was observed between MP 118.4 and 119.1 (Fig. 5).

Road mortality data from all sources (ITD, IHP, WTI and the public) were compared to estimate the number of road killed mule deer and elk (carcass count) in the study area on an annual basis (Table 3). Replicate reports between different data sources were defined as carcasses found within .2 mile of each other and/or within 2 days of each other.

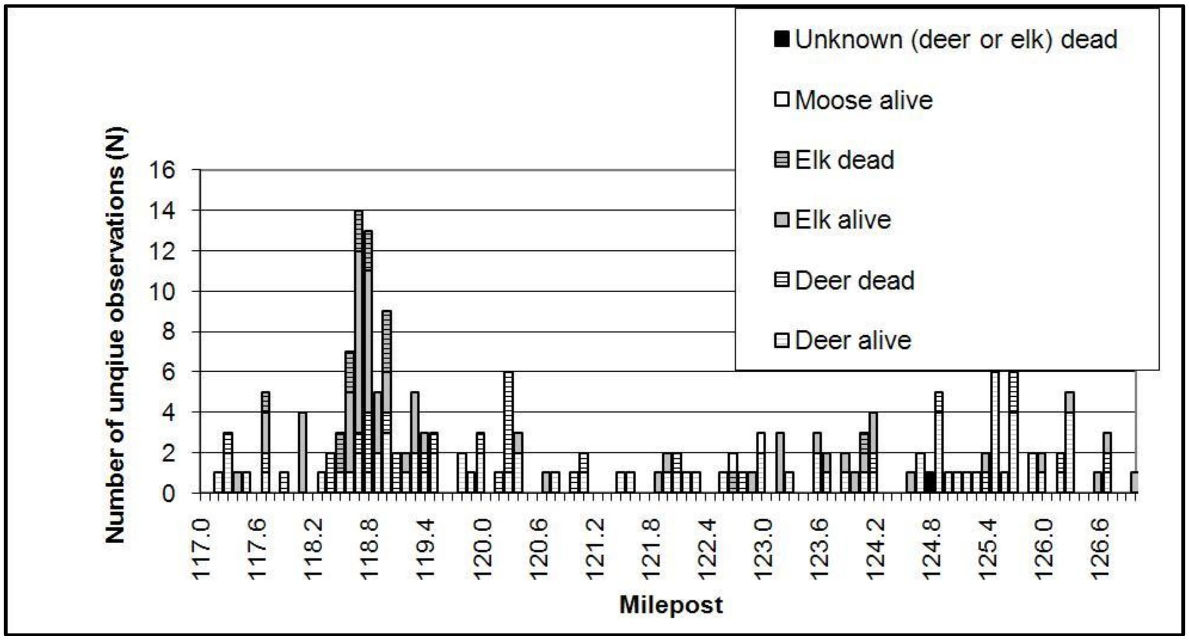

Figure 5: Public reports of unique deer, elk and moose carcasses (each carcass is counted in the graph) and unique alive reports (the number of reports of live animals is counted, but not the number of animals seen alive) by mile post for MP 117-127 (Total n = 187).

Calendar year	Data source				
	ITD	IHP	WTI	Public	Reported Total/Estimate
2004	16*	11	n/a	n/a	(27 minus two possible replicate reports) 25
2005	24	8	n/a	n/a	(32 minus one possible replicate report) 31
2006	31	10	n/a	n/a	(41 minus one possible replicate report) 40
2007	53	17	26**	54	(150 minus 16 replicate reports) 134
* Data appeared to include reports from June to December only. ** 2007 figure derived by subtracting carcasses found in 2008 (n=3) and carcasses found in April 2007 survey period which were categorized as “old” or “age unknown” (n= 17) from WTI carcass total of 46; 46-20 = 26 carcasses.					

Table 3. Reported carcass counts for deer and elk from different sources and combined minimum estimates per year.

The total number of reported mule deer and elk carcasses was dramatically higher in 2007 compared to three previous years. This may be due to one or more of the following factors:

1. Engaging the motoring public to report road mortality.
2. Conducting systematic road mortality surveys that included walking sections of the study area.
3. A possible increase in deer and elk populations.
4. A possible change in ITD carcass removal search and reporting effort.

Dividing the 2007 estimated minimum number of mule deer and elk carcasses (n=134) by the number of miles in the study area (n = 26), results in an estimated 5 carcasses per mile/year.

The data collected by the public has had the following benefits:

1. Carcass removal and accident data collected by ITD and IHP was supplemented by the public and helped reduce the underestimation of deer- and elk-vehicle collisions. It is estimated that 54 unique carcasses were reported by the public in 2007.

2. The public reported other species, smaller than deer, which were killed on SH 75. This increased the understanding of what species are killed by cars on the road section concerned.
3. The data showed where deer and elk are observed on or close to the road. This type of information is best obtained by multiple observers that travel the route at different times of the day. Therefore this type of data is best collected by the public rather than an agency that may be able to "monitor" the entire route with more consistent search and reporting effort. However, with only one observation session a day, perhaps at certain fixed times, agency efforts are likely to be substantially less effective than efforts of the public.
4. Public awareness was raised through the media, especially in combination with periodic press releases that provided feedback to the public with regard to the data entered. Increased awareness and participation in the data collection may help increase support for potential future mitigation measures.

"I-Spy on the Pass," Interstate 90, Gallatin And Park Counties, Montana

Site and Project Description

Bozeman Pass, which is approximately 40 miles north of Yellowstone National Park, was identified as an important linkage for wildlife movement in the Northern Rockies (Ruediger et al. 1999). This mountain pass is crossed by Interstate 90 (I-90), which runs east/west between the towns of Livingston and Bozeman. More than 13,000 vehicles cross Bozeman Pass each day and more than 1,300 wild animals of 37 different species were killed on the Bozeman Pass section of I-90 between 2001 and 2005 (Hardy et al. 2006). This heavy vehicle use and the resulting impacts on wildlife will likely only continue to increase.

The "I-Spy" project was launched in the fall of 2008 with technical support from the Western Transportation Institute. This citizen science data collection effort was modeled after the "Road Watch in the Pass" project in Canada (Lee et al 2006). There are three primary project goals: 1) gather data about where and when animals attempt to cross or utilize habitat near the roadway; 2) supplement other sources of road kill data; and 3) increase community involvement and support for wildlife mitigations. The information collected through this project can be helpful in addressing the impact I-90 has on habitat connectivity and wildlife movements on Bozeman Pass and guide wildlife/vehicle mitigation measures.

Wildlife Reporting Website

"I-Spy on the Pass" uses an interactive website to compile driver's observations of wildlife on the I-90 corridor on Bozeman Pass. Citizen scientist volunteers note their wildlife observations then log onto the I-Spy website to enter when and where the animal was spotted, the species observed and whether the animal was dead or alive. To encourage broad participation, the program is designed to be as inclusive as possible; anyone who drives Bozeman Pass can contribute data. I-Spy involvement requires no special training and the easy to use web-based interface facilitates accurate observation reporting. The resulting data, especially the live animal sightings, will supplement other available data sources to provide a more thorough understanding of wildlife movement patterns on the pass.

As of the end of June 2009, there were 161 distinct entries into the database, with a total of 868 individual animals belonging to 13 different species reported. Of these 868 animals, 806 were reported to be alive and 62 were reported to be dead. Table 4 summarizes the data collected during the first eight months of the project. A subset of this data is graphically displayed on a map (Fig. 6).

A large and active volunteer group is necessary for maximum data collection. Because the ideal volunteers are those who drive Bozeman Pass often, initial recruitment efforts focused on daily commuters over the pass. Future efforts to engage new volunteers will focus on the broader communities on both sides of the pass. Volunteers are recruited through the local media, presentations, events, newsletters, brochures and by word of mouth.

Continual volunteer engagement is vital for project success, and feedback is essential in maintaining relationships with volunteers. To that end, the reported data is regularly summarized and provided to the volunteers and others through email updates that include a map and highlights of unique or interesting sightings. Volunteers are encouraged to make suggestions for program improvement. To date there are 15 active I-Spy volunteers. I-Spy program staff are actively working to increase the volunteer base to get a more comprehensive special and temporal understanding of how wildlife are using habitat near the roadway.

Species	Alive	Dead
Black Bear	0	2
Bobcat	0	1
Coyote	4	0
Deer: Mule and White-tail	382	45
Elk	32	3
Moose	3	0
Porcupine	0	1
Pronghorn	1	1
Rabbit	0	1
Skunk	0	1
Wolf	1	0

Table 4. "I-Spy on the Pass" wildlife observations: November 2008 through June 2009

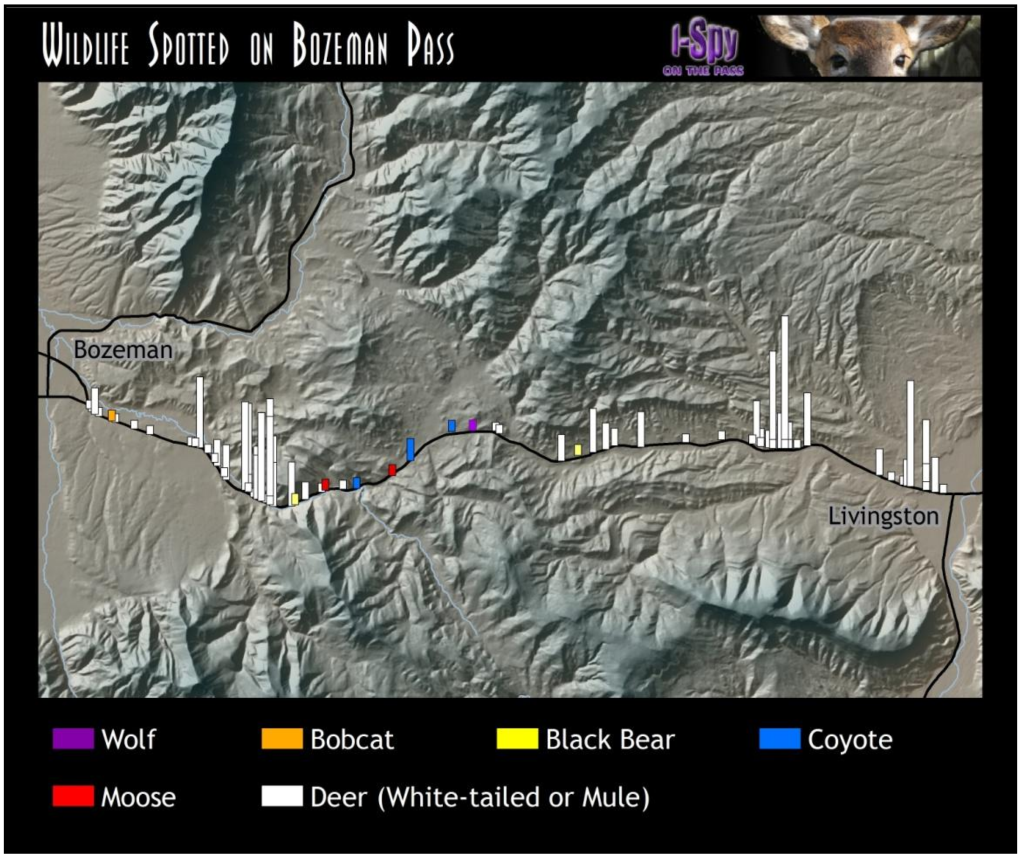

Figure 6. All recorded wildlife observations, live and dead combined. Displaying the data on a map is an effective way to quickly identify spatial clustering of reported wildlife locations.* Some reported species were not included in the above map.

While "I-Spy" indicates that engaging citizens in data collection efforts is a cost effective way to gather a broad range of information and educate communities about the effects of roads on wildlife, this data does have limitations. There are no strict protocols or controls on data collection or reporting, other than the fields available on the website, and there are many factors that may influence the quality and accuracy of the data being reported. While complementary and valuable in its own right, citizen science data must be used differently than that gathered by more rigorous research efforts. Overall this project is proving to be a valuable tool for American Wildlands' efforts to increase public involvement in wildlife and transportation issues and to promote the economic, ecological, and human safety benefits transportation mitigations for wildlife

"Mountain Corridor Reconstruction Project," Interstate 70, Eagle, Summit, Clear Creek and Jefferson Counties, Colorado

Site and Project Description

The heavily traveled Interstate 70 (I-70) Mountain Corridor from Evergreen to Glenwood Canyon, Colorado is slated for reconstruction to ease congestion and is recognized as a major barrier to wildlife through the Southern Rocky Mountains (USFS 2002). Center for Native Ecosystems and ECO-resolutions, LLC are collaborating with Colorado Department of Transportation (CDOT) to conduct an assessment of the wildlife habitat-roadway interface using the Federal Highway Administration's Eco-Logical framework (Brown 2006). The project is identifying connectivity zones for aquatic and terrestrial wildlife and the barriers to movement in these zones, ultimately resulting in a suite of recommended mitigation measures to provide safe passages for wildlife.

Wildlife Reporting Website

The "I-70 Wildlife Watch" project, which will launch in the fall of 2009, will provide an observational database of wildlife activity on and adjacent to the roadway, thereby augmenting conventional data collection efforts (including comprehensive field inventories, animal-vehicle collision data analysis and camera monitoring). Motorist observations will supply additional information on wildlife activity, including both live and dead observations, and, in some cases, information on behavioral responses to the roadway. While limited in its analytic potential, such opportunistic data is highly complementary to the standard animal-vehicle collision database, as live animal observations can help to flag areas where wildlife are successfully crossing the roadway or where they approach, but do not attempt to cross at all – this information cannot be captured by roadkill surveys, camera monitoring or track and scat surveys alone.

As such, the data collected through the "I-70 Wildlife Watch" website will help highlight patterns in wildlife activity along the roadway. An understanding of where wildlife are crossing the interstate, attempting to cross, or barred from crossing is essential in the effective placement of mitigation measures (Clevenger and Waltho 2000). These citizen-reported data, combined with conventional data collection efforts and compiled information from other studies throughout the project area, help paint a more complete picture of wildlife use of roadside habitat and crossing activity. All of this information will assist in the development of mitigation measures for the safe passage of wildlife along this stretch of I-70.

Based on previous versions of WTI's wildlife reporting websites, the "I-70 Wildlife Watch" website has been adapted to the specific needs and species of the I-70 Mountain Corridor to create a user-friendly web-based tool. Participants in the "I-70 Wildlife Watch" will be recruited through messages on CDOT's variable message signs along the interstate, local media, targeted community forums, and posters and flyers distributed throughout the community and at recreation hotspots (e.g., ski area parking lots, major trailheads). As motorists along I-70 include residents of mountain communities as well as a number of Front-Range recreationists and tourists, and interstate truckers, we are also developing outreach tools for these types of travelers, including outreach to Front Range residents and a special effort targeting drivers of the Colorado Mountain Express, a shuttle service between Denver International Airport and the resort communities whose drivers are on this stretch of road several times a day. These outreach efforts are designed to reach a wide audience of potential website users with the goal of maximizing participation among various types of motorists to capture a broad array of observations, both spatially and temporally.

The capacity of interactive websites for public engagement is also a primary motivating factor in adapting the wildlife reporting website to the I-70 Mountain Corridor. Local communities and economies value the natural environment in which people live, work and recreate, yet a lack of public awareness and political support for wildlife mitigation continues to be a major obstacle to the implementation of highway safe passage measures for wildlife (Paul, 2007). The "I-70 Wildlife Watch" website will act as a forum, both for collecting information from motorists, and educating users on the importance of habitat connectivity for wildlife and the techniques that can be used to preserve and restore connectivity at the roadway interface.

Successful participation also requires feedback and encouragement. As opposed to creating one-time users, the "I-70 Wildlife Watch" project seeks to maximize on-going participation. Immediate feedback on the website itself is an important tool for these purposes. Upon entering their observations, users can access the database to see how their observation fits in with others – for example, where hot spots are located, which species have been observed – all in a visually-compelling Google Earth framework. Users can also choose to opt in to receive e-newsletters with periodic updates on the project to stay informed and involved.

Conclusions

In addition to the potential for obtaining better estimates of roadkills, engaging motorists also aids in collecting live animal observations. Observations from live animals are important because they help determine placement of mitigation measures. For example, if wildlife fencing (i.e. a barrier) is erected along road sections where no or low mortality occurs, it may be because there are 1.) no animals crossing, or 2.) animals do cross but they are not or rarely hit by vehicles. If the placement of safe crossing opportunities would be solely based on road mortality hot spots, and if a wildlife fence or another type of barrier is erected between such safe crossing opportunities, important wildlife movement areas where animals cross the road successfully may be blocked. Observations of live animals on or near the road reduce such unintended consequences of mitigation measures. Live observations are also harder to obtain than observations of road killed animals. While many (but not all) dead animals are recorded by agency personnel, routines (certain days, certain times of days) would heavily influence agency observations of animals seen alive. Having multiple observers that travel a road on different days and times help reduce the bias associated with such routines (though there are other biases involved with citizen data).

For these types of projects with limited capacity and funding, engaging local citizens in the research effort is highly advantageous. A wildlife reporting website has the potential to enhance traditional data collection efforts and aid in determining the placement and design of mitigation measures for wildlife. In addition, wildlife reporting websites provide a venue for engaging the motoring public, increasing awareness, and building support to ensure the future implementation of mitigation measures for safe passages.

Acknowledgements

The authors thank the Miistakis Institute for their inspiration, the Systems Engineering Development and Integration Group at the Western Transportation Institute for their technical assistance in creating the web based data collection tool, and the motoring public for sharing their wildlife observations. This work could not have been possible without the support of our respective sponsors including Blaine County in support of "Ketchum on the Road," The Bullitt Foundation, The Bosak-Kruger Foundation, and the Winslow Foundation in support of "I-Spy", and the Federal Highway Administration, TransWild Alliance, and Animal Assistance Foundation in support of "Wildlife Watch."

Biographical Sketches

Angela V. Kociolek received her M.S. in Biological Sciences (1997) at Montana State University-Bozeman. She served as an environmental educator with the Peace Corps in Northeast Thailand (1998-2000). Currently Angela is part of the Road Ecology team at the Western Transportation Institute. Her background in community outreach was well-suited for this project which required public involvement. She believes an informed public is a resource worth tapping into to forward the goal of reducing transportation impacts to wildlife and the environment. Angela continues to work on a variety of projects related to wildlife-highway interactions.

Marcel J. Huijser received his M.S. in population ecology (1992) and his Ph.D. in road ecology (2000) at Wageningen University in Wageningen, The Netherlands. He studied plant-herbivore interactions in wetlands for the Dutch Ministry of Transport, Public Works and Water Management (1992-1995), hedgehog traffic victims and mitigation strategies in an anthropogenic landscape for the Dutch Society for the Study and Conservation of Mammals (1995-1999), and multifunctional land use issues on agricultural lands for the Research Institute for Animal Husbandry at Wageningen University and Research Centre (1999-2002). Currently Marcel works on wildlife-transportation issues for the Western Transportation Institute (2002-present). He is a member of the Transportation Research Board (TRB) Committee on Ecology and Transportation and co-chairs the TRB Subcommittee on Animal-Vehicle Collisions.

Doug Galarus has nearly 20 years experience in information technology development, testing, implementation and management. He has extensive experience as the project lead for mobile data communications systems, database-driven web sites, web site design, desktop applications, kiosk development, PDA and Tablet PC –based development, and interactive CD-ROMs. At the Western Transportation Institute, he has applied his technical expertise to the development of specific applications for transportation safety, including improved tools for road weather management and road ecology. Doug holds Master's degrees in Computer Science and Mathematics Education, and is Program Manager for the Systems Engineering, Development and Integration Program at Western Transportation Institute.

Dylan W. Taylor works on wildlife habitat connectivity and transportation issues at American Wildlands. He has 10 years experience in conservation policy and wildlife biology in the Rocky Mountains. In addition to his current efforts in Montana, he has worked on transportation and wildlife movement research and advocacy in Banff National Park in Canada, on the Bridger-Teton National Forest in Wyoming, the in the Vail Pass section of Interstate 70 in Colorado.

Dylan earned a B.A. in Environmental Studies at the University of North Carolina, Wilmington (1994), and a Masters of Forestry at the Yale School of Forestry and Environmental Studies (2002).

Julia Kintsch is a conservation ecologist with over 10 years of experience in applied ecology and conservation planning. Her work focuses on the development of practical and effective science-based solutions to mitigate humanity's impacts on natural systems. Prior to founding ECO-resolutions, LLC, Julia was the program director for the Southern Rockies Ecosystem Project from 2003-2008. Her experiences include working as an environmental educator in Senegal, West Africa as a Peace Corps Volunteer, and developing conservation plans for the Michigan Chapter of The Nature Conservancy. Her work has involved extensive collaboration with federal and state agencies, local municipalities, and non-profit organizations, and she brings a creative and resourceful approach to natural resource decision-making.

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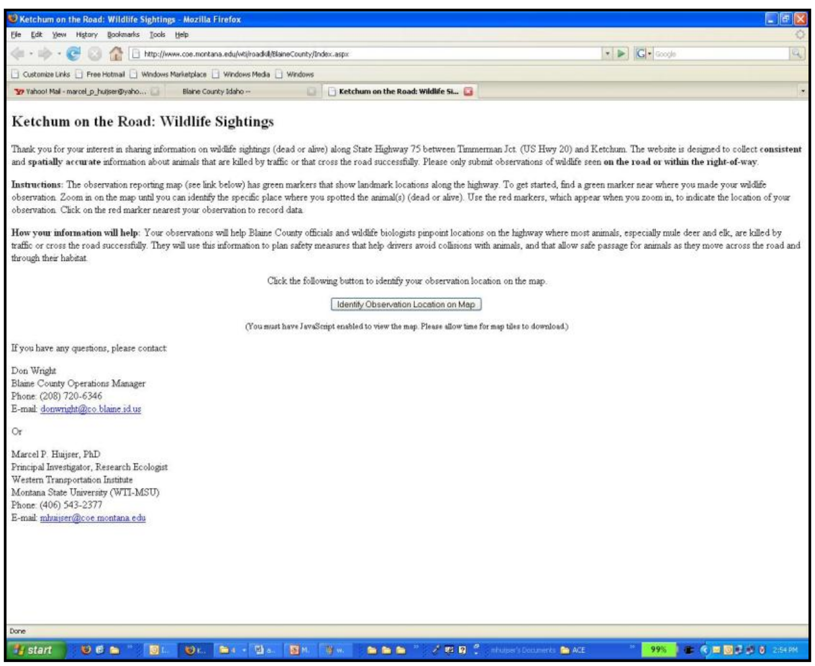
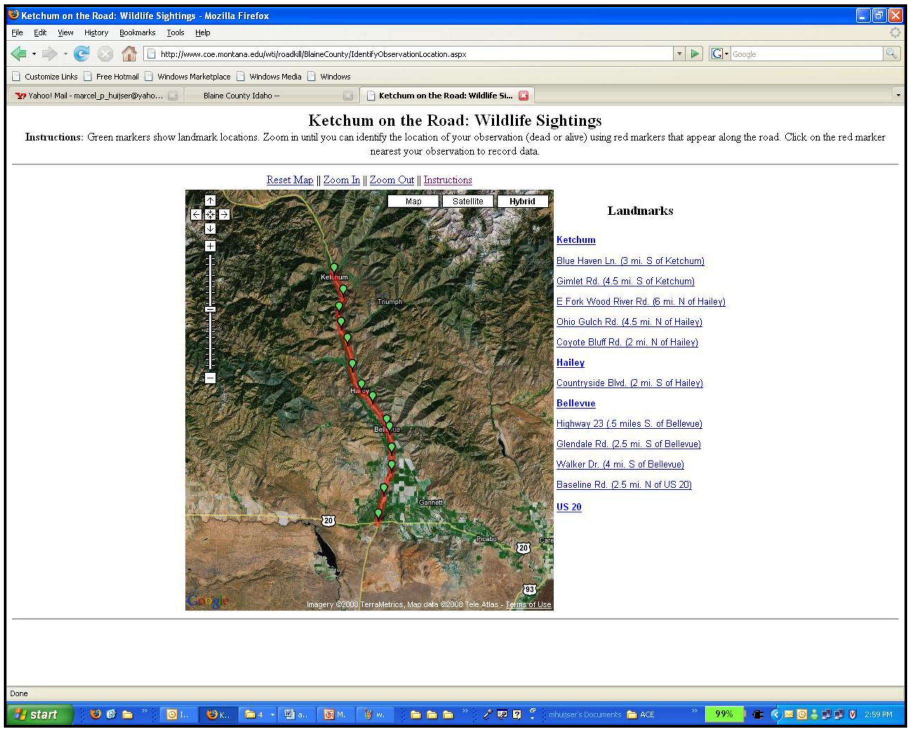
Appendix A: Screenshots of the "Ketchum On The Road" Wildlife Reporting Website

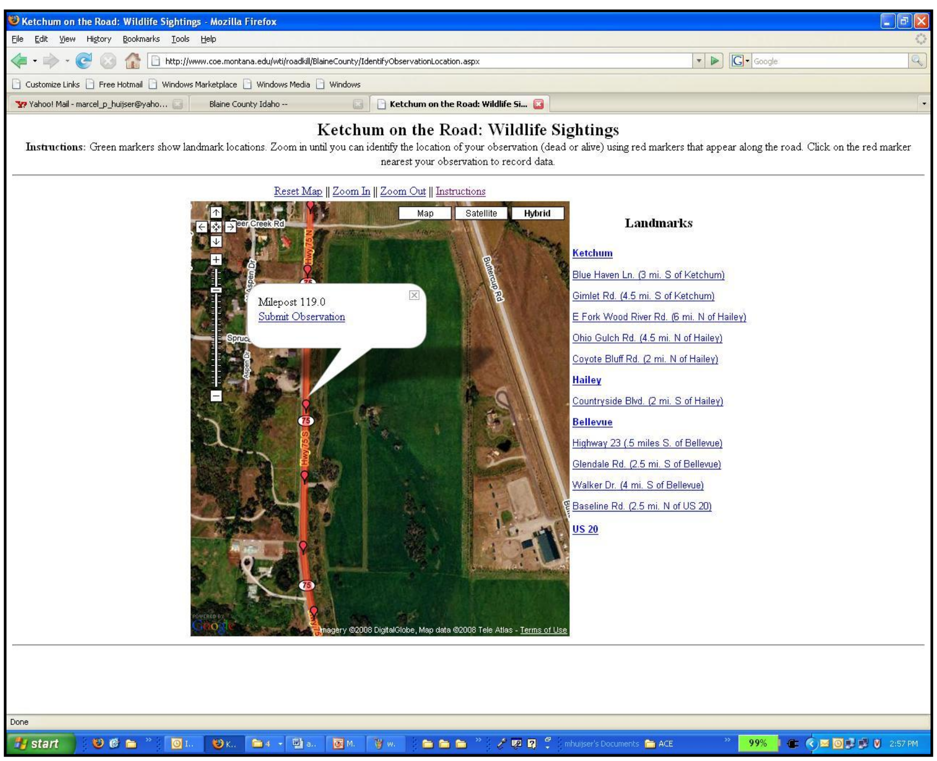
1. Blaine County's website with a button link to "Ketchum on the Road: Report Highway 75 Wildlife Sightings" on left hand navigation bar.



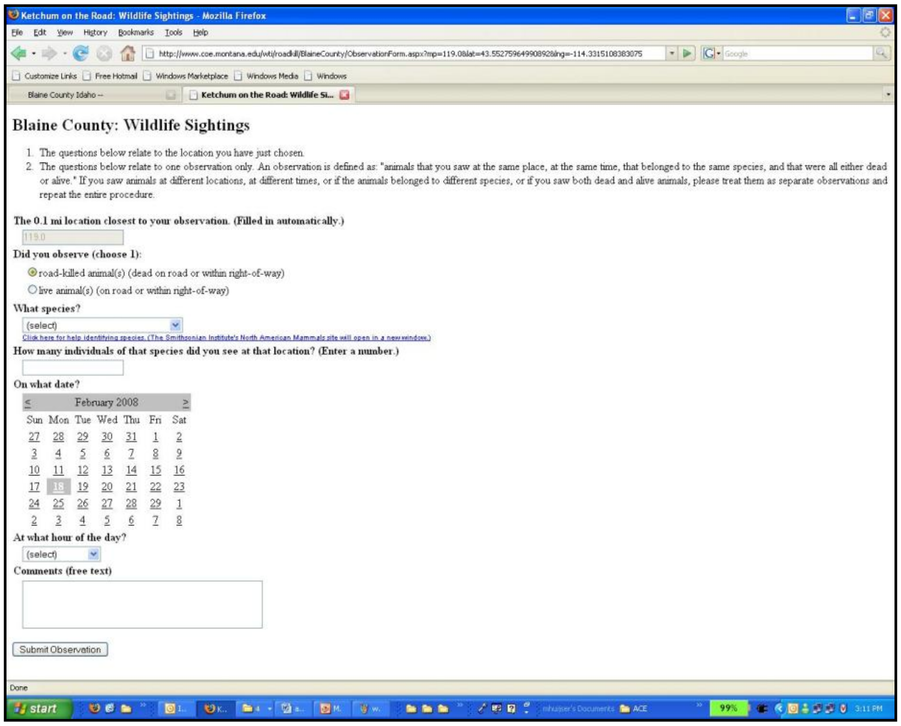
2. Introductory information about the database on WTI's website.



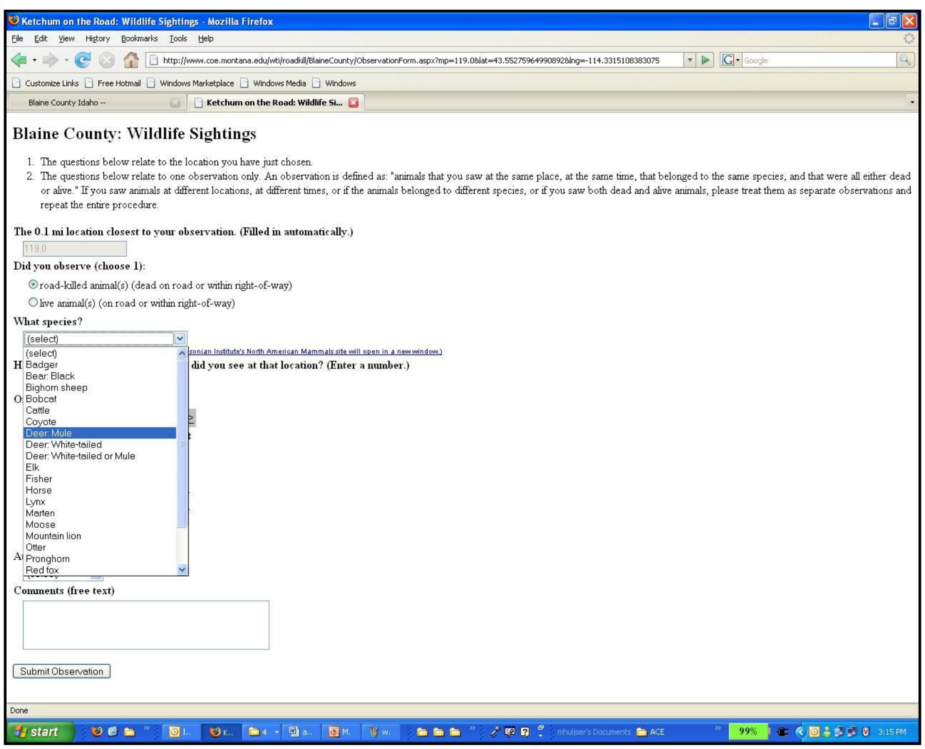
3. Google Earth map depicting landmarks in study area and surrounding topography. This allowed users to zoom in on the appropriate road section.



4. Google Earth map depicting landmarks in study area and surrounding topography. This screenshot shows 0.1 mi posts (red markers) around the 119.0 mi post.



5. Data form for submitting a live or dead animal observation. Note: the tenth of a mile location obtained when clicking on a red marker on the previous page was automatically stored in the data form.



6. Easy-to-use drop down menus and space for free form comments.

CAN CITIZEN SCIENCE REPRESENT WILDLIFE ACTIVITY ALONG HIGHWAYS? VALIDATING A MONITORING PROGRAM

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Abstract

Using volunteers for scientific data collection is increasingly recognized as a method to gather management-relevant environmental information. Citizen scientists can provide an inexpensive and potentially large long-term labor force that can amass large datasets in a relatively short time while covering large geographical areas. Although there is a distinct need for large, long-term datasets in road ecology to address the numerous effects of roads on wildlife, few projects involving wildlife and highways have incorporated citizens in their research or conservation efforts. The spatially and temporally explicit data on wildlife movement near highways that is required to improve our understanding of wildlife movement along and across highways has the potential to be collected by highway users as citizen scientists. Yet, in order to be integrated meaningfully into decision-making processes, citizen science must be valid and reliable. It is therefore essential to examine whether these programs can provide robust, reliable data.

Study Area

In this study, we examined *Road Watch in the Pass* (RW), a citizen science monitoring program providing information on wildlife activity on Highway 3 in the Crowsnest Pass in Alberta, Canada, as a pioneering example in using citizens for wildlife crossing data collection by assessing its ability to represent unbiased visible live wildlife activity along Highway 3. As is sometimes the case with citizen science programs, this program is based on opportunistic observations rather than systematic monitoring, making it susceptible to problems related to sampling effort. We developed a rigorous driving survey sampling method for collecting data systematically. We assessed RW methodology in its capability of providing statistically robust data, and by comparing the RW dataset to the systematic dataset, we analyzed the accuracy of spatial distributions of opportunistic wildlife observations using two spatial statistic approaches. We assessed spatial agreement along 1-km segments of the highway between the citizen and researcher datasets using a permutation modeling process. We also demonstrated the use of Ripley's L and L_{12} statistics as tools to examine live wildlife spatial patterns along transportation corridors. Additionally, we assessed the threshold number of wildlife observations needed to provide representative highway wildlife data, insight potentially useful to other highway wildlife monitoring programs. To assess this numerical threshold, we undertook a simulation analysis that quantified and compared the strength of spatial similarity of the citizen and researcher data in a variety of settings, including different sample sizes for the two spatial processes.

Conclusion

Due to its unsystematic nature and lack of sampling effort documentation, this citizen science program is limited in its ability to make some statistical conclusions. Despite these problems, the spatial distribution of citizens' wildlife observations corresponded with the systematic dataset; the number of citizen-collected observations within a specified distance of a researcher-collected observation was significantly larger than would be expected if the citizens' observations were distributed independently. The wildlife observations from the two datasets also had similar spatial distributions; the differences in relative frequencies of citizen and researcher observations by kilometer were not significant. Spatial similarity of the two datasets was detected at sample sizes of a minimum of 150 observations. This minimum number of observations was needed for RW and possibly other highway wildlife monitoring programs to provide representative information of spatial highway wildlife activity.

We recommend several modifications to enhance the scientific rigor of RW and provide guidance for groups aiming to use a similar citizen science highway wildlife monitoring program. We particularly focus on the importance of including sampling effort, and discuss how the driving survey methodology may not be effective for all large wildlife species.

Biographical Sketches

Kylie Paul earned her M.S. in environmental studies in 2007 from the University of Montana. She is on the board of the Ninemile Wildlife Workgroup in Huson, MT, which focuses on wildlife connectivity conservation. She has worked with stakeholders in the Northern Rockies on issues ranging from wildlife connectivity, road ecology, citizen science, private and public land use issues, and human/wildlife conflict.

Jon Graham is a professor in the Department of Mathematical Sciences at The University of Montana, which research interests in spatial statistics, Markov chain Monte Carlo methods, and applied statistics. He earned his Ph.D. in Statistics at North Carolina State University.

Len Broberg is the director of the Environmental Studies Program at the University of Montana. He received a J.D. from Wayne State University, practiced law for nine years, and then received his Ph.D. in biology from the University of Oregon. His research interests include land management policy approaches, biodiversity conservation planning, watershed restoration, and response of animal communities to management.

Michael S. Quinn is an Associate Professor in the Faculty of Environmental Design at the University of Calgary and the Director of Research and Liaison for the Miistakis Institute, an ecosystem management research institute affiliated with the University of Calgary. His research and teaching interests include landscape scale conservation, the effects of linear disturbances on wildlife and ecosystems, and interdisciplinary approaches to managing for social-ecological resilience.

Marcel Huijser received his M.S. in population ecology (1992) and his Ph.D. in road ecology (2000) at Wageningen University in Wageningen, The Netherlands. Currently Marcel works on wildlife-transportation issues for the Western Transportation Institute at Montana State University (2002-present). He is a member of the Transportation Research Board (TRB) Committee on Ecology and Transportation and co-chairs the TRB Subcommittee on Animal-Vehicle Collisions.

Adapting Agency Relationships in a Changing Regulatory Environment

INTERAGENCY PARTNERING FOR THE DEVELOPMENT OF STREAM CROSSING STANDARDS IN NEW YORK STATE

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Abstract

Highway stream crossings pose unique concerns for both the environmental and transportation engineering communities. Construction of a static highway crossing over a dynamic, flowing waterbody must address the risks of flooding, erosion, normal channel migration, and structure deterioration; this is essential to maintaining the safety and stability of the highway. At the same time, crossing structures – particularly culverts – may fragment aquatic habitat or alter stream channel form. Stream crossings in New York State are often designed to take environmental concerns into account, however there are currently no crossing standards or design guidance to encourage statewide consistency.

Development of standards and design guidance for stream crossings in New York State has been undertaken by a group of engineers, environmental professionals, and regulators known as the Interagency Aquatic Connections Team (InterACT). Assembled in 2007, InterACT is comprised of ten federal, state and local agencies that are committed to ensuring that stream crossings are designed, installed and maintained in a manner that protects the ecological integrity of aquatic systems, while accommodating practicable technology, engineering criteria and human safety. To accomplish the team's tasks with efficiency, four subcommittees were established. The Ecological Performance Standards subcommittee was charged with identifying those characteristics and processes of streams to be achieved, restored, or maintained when a stream crossing is constructed or replaced. The Engineering Design and Specifications subcommittee was charged with development of design guidance to facilitate meeting the ecological performance standards. The Outreach and Education subcommittee was charged with developing a strategy for the delivery of InterACT's products. Lastly, the Regulatory Streamlining subcommittee was charged with developing regulatory tools that minimize processing time and facilitate permitting for projects meeting the new design standards and protocols.

One basic premise of InterACT has been that its products must represent a fair and reasonable balance of its members' concerns. This presents a challenge at times, as concessions are required by all parties. Additional challenges result from the team's size. With over sixty members, it becomes difficult to provide a forum in which all opinions can be expressed and all options vetted. Despite these challenges, the dedicated members of InterACT continue to make substantial progress toward the completion of stream crossing standards and design guidance that will protect and enhance the aquatic resources of New York State.

Introduction

The diverse landscape, geography and climate of New York State, combined with its population distribution and associated transportation infrastructure, pose challenges to the New York State Department of Transportation. This challenge becomes particularly evident in addressing aquatic connectivity needs and transportation infrastructure needs at stream crossings (i.e., bridges and culverts). Considering that NYSDOT is the state's largest public works agency, the Department recognizes its obligation and responsibility to the people of New York State to protect, improve and enhance the environment in the course of its business of planning, building and maintaining a transportation system. Like all states in the northeast, New York faces challenges to restoring its extensive transportation infrastructure to a state of good repair and maintaining it at that level. Aging infrastructure, harsh weather conditions and heavy utilization are ongoing problems for transportation operators (NYSDOT, 2006).

Highway stream crossings pose unique concerns for both the environmental and transportation engineering communities. Construction of a static highway crossing over a dynamic, flowing waterbody must address the risks of flooding, erosion, normal channel migration, and structure deterioration; this is essential to maintaining the safety and stability of the highway. At the same time, crossing structures may fragment aquatic habitat or alter stream channel form.

The impacts of transportation infrastructure on species and ecosystems are well documented (Forman et al., 2003). As long linear ecosystems, rivers and streams are particularly vulnerable to fragmentation. A number of human activities can disrupt the continuity of river and stream ecosystems. There is growing concern about the role of road crossings – especially culverts – in altering habitats and disrupting river and stream continuity (Jackson et al., 2007). Effects of culverts and bridges on stream ecology can include altered flow regimes and scoured sediments, which may result in increased sedimentation, barriers to fish and wildlife movement, and reduced habitat for fish and other biota (Forman et al., 2003).

Within New York, roads, dams, and culverts, have been identified as threats to biodiversity in more than 15 conservation action plans, including the Hudson River Estuary, Adirondack Mountains, Western Finger Lakes, Delaware River Basin, Long Island Central Pine Barrens, Tug Hill Plateau, Allegheny Forests, Lake Champlain, Catskill Mountains, French Creek Landscape, and Montauk Peninsula, among others (ConPro, 2007).

Environmental and Social Setting

New York State possesses remarkable natural diversity and a storied history, both of which are woven into its modern identity. New York was the first state to (1) preserve an historic site (Washington's Headquarters at Newburgh); (2) establish a state park (Niagara Reservation); and (3) declare land "forever wild" (the Adirondack and Catskill forest preserves) in the State Constitution (NYSDED, 2008).

Landscape

New York's 47,000 square miles (121,729 sq km) of land area is drained by more than 70,000 miles (112,654 km) of streams within ten major river systems. These ultimately flow into the Atlantic Ocean, Delaware Bay, Chesapeake Bay, Gulf of Mexico, and Gulf of St. Lawrence. Elevation ranges from sea level to the 5,344-foot (1,629 m) peak of Mount Marcy in the Adirondacks. Approximately 40% of the state lies at an elevation of more than 1,000 feet (305 m) above sea level. It has some 450 miles (724 km) of seacoast, and borders on two of the Great Lakes. With 18.6 million acres (7,527,183 ha) of forest cover, New York State is 62% forested, however this predominance belies the state's long history of intensive timber harvesting and agriculture. The past fifty years have seen a substantial shift from agriculture to forestland. Agriculture is presently the second greatest land use, occupying 25% of the total land area (NYSDEC, 2009).

Climate

The climate of New York State is broadly representative of the northeastern United States, but its diversity is unique. Distribution of precipitation within the state is greatly influenced by topography and proximity to the Great Lakes or Atlantic Ocean. Average annual precipitation amounts in excess of 50 inches (127 cm) occur in the western Adirondacks and the Catskills. Areas of least rainfall, with average accumulations of about 30 inches (76 cm), occur near Lake Ontario in the extreme western counties, in the lower half of the Genesee River Valley, and in the vicinity of Lake Champlain (NYSCO, 2009). Mean wintertime temperatures range from about 20˚F to 32˚F (-7˚C to 0˚C), with summertime means from 67˚F to 77˚F (19˚C to 25˚C); the record extremes are -52˚F (-47˚C) and 108˚F (42˚C).

Natural Resources

Diversity in New York's topography, geology, and climate contributes to a wide range of habitat types. Seven ecoregions are represented, encompassing 173 unique natural community types including rare maritime beech forest, pitch pine-scrub oak barrens, and alpine meadow, as well as the more common Appalachian oak-hickory forest, spruce-northern hardwood forest, and beech-maple mesic forest (Edinger, 2002).

Much of New York's natural and cultural identity is a result of its richness in water resources. Water resources remain New York State's richest treasures and are critical to its future growth and economic vitality (NYOGLECC, 2009). This is well illustrated by the freshwater fishing industry. In 2006 alone, the total economic output of freshwater fishing in New York State approached $755 million (Southwick Associates, 2007). The Catskill Mountains are the birthplace of fly-fishing and a popular destination among anglers. However, this attraction hinges upon the presence of a robust trout fishery. While fingerling stocking helps to supplement the fishery, a self-sustaining natural population requires connectivity of spawning habitat found in headwater streams – streams that are particularly vulnerable to fragmentation.

Population Distribution

New York is the third most populated state, with nearly 19 million residents (U.S. Census Bureau, 2008). Population distribution varies throughout the state, requiring unique transportation strategies in different regions (NYSDOT, 2006). Major urban areas contain 48% of New York's population within 1% of the State's total land area, with 40% of the State's residents living in New York City (NYSDEC and OPRHP, 2009).

The six largest population centers in the state are New York City (18,323,002 in NY/NJ/PA), Buffalo/Niagara Falls (1,170,111), Rochester (1,037,831), Albany/Capital District (825,875), Syracuse (650,154), and Poughkeepsie/Hudson Valley (621,517) (U.S. Census Bureau, 2009). These cities share a common thread in that they are connected by the Erie Canal, Mohawk River, and Hudson River, which together formed a major transportation and trade route in the nineteenth century. This corridor continues to function in much the same way today, although use of the water route has been largely replaced by the faster and more convenient land route provided by Interstates 87 and 90.

Transportation Infrastructure

Today, the New York State transportation network includes a state and local highway system that annually handles over 100 billion vehicle miles. This total system encompasses more than 15,000 centerline miles (24,140 km) of State-owned highway and nearly 100,000 centerline miles (160,934 km) of locally-owned highway, with more than 17,000 bridges, and approximately one million culverts. As of 2007, 42% of centerline miles were located in urban areas and provided for 75% of vehicle-miles traveled (VMT). Fifty-eight percent of centerline miles were located in rural areas and provided for 25% of VMT.

The juxtaposition of a diverse landscape, abundant natural resources, extensive surface transportation infrastructure and competing financial demands pose ongoing challenges to NYSDOT in achieving its mission to ensure "a safe, efficient, balanced and environmentally sound transportation system." This difficult balance became more strained by the proposal and ultimate issuance of regulatory changes specific to culverts. The impact of these changes on NYSDOT's capital and maintenance programs is expected to be substantial.

Regulatory Changes Affecting NYSDOT Culvert Program

In March 2007, the U.S. Army Corps of Engineers (USACE) reissued its suite of Nationwide Permits (NWPs) which are intended to streamline authorizations for certain activities with relatively minor environmental impact on waters of the United States. Individual Corps districts may impose special regional conditions that tailor the NWPs to the unique environmental issues in their region. Both districts encompassing New York State had developed proposed regional conditions, issued by Public Notice in October 2006; however, the issuance of these regional conditions was delayed such that they were not issued with the NWPs in March 2007. After a lengthy internal administrative process, the Buffalo District's final regional conditions for Nationwide Permits went into effect on August 27, 2008. To date, the New York District's regional conditions have not been officially issued, but they are being voluntarily implemented on NYSDOT projects.

The Public Notice of Proposed Regional Conditions for Nationwide Permits issued in October 2006 included ecologically-based design requirements applicable to new and replacement crossing structures in fish-bearing streams. The USACE's primary concern was maintaining connectivity of aquatic habitats upstream and downstream of the crossing. The proposed conditions attempted to achieve this by imposing requirements with respect to natural streambed sediment, span length, and culvert gradient. As a result, new structures would frequently be larger and more expensive than those designed in the past.

Though NYSDOT agreed with the intent of these conditions, the agency had serious concerns regarding implementation, constructability and cost. NYSDOT asserts that decisions regarding culvert design must remain flexible and be guided by the principles of fluvial geomorphology and habitat connectivity, rather than being dictated by prescriptive requirements which may or may not fit the given situation.

The magnitude of NYSDOT's culvert program makes meeting the regional conditions a serious logistical and financial challenge. New York State owns 9,110 large culverts (5 ft < span ≤ 20 ft) (1.5 m < span ≤ 6.1 m) and an estimated 128,000 small culverts (span ≤ 5 ft) (span ≤ 1.5 m). Large and small culverts are replaced at rates of approximately 55 per year and 1,600 per year, respectively. Additionally, an average of fifteen bridge-sized culverts (span >20 ft) (span >6.1 m) are replaced annually.

The State highway culvert program, as it existed before the proposed NWP regional conditions, was estimated to cost $90M annually. NYSDOT investigations have determined that ecologically-based design of highway stream crossings, if applied indiscriminately, could increase the overall cost of the culvert program by as much as 80%, with a disproportionately large cost increase in the small culvert size class (300%). Similar cost increases are expected within County and Town culvert programs which, in total, encompass five to six times as many culverts as the State program.

This cost increase may be justifiable at a particular location based on environmental benefits, but sometimes it will not, such as in streams with severe, systemic impairments or where streams are naturally fragmented by falls. For this reason it is imperative that a method of prioritization be developed. This prioritization will require collective understanding of the broad range of issues associated with culvert repair, replacement and installation, as well as stream dynamics and characteristics of the natural resources. Research funded in part by NYSDOT aims to prioritize sites for ecologically-based crossing design through predictive habitat models for species of greatest conservation need.

Interagency Aquatic Connections Team

NYSDOT provided comments on the proposed regional conditions during the public comment period in late 2006, as did the New York State Department of Environmental Conservation (NYSDEC) and the United States Fish and Wildlife Service (USFWS). Due to the obvious interest and stakeholder status of these three agencies, the USACE and the agencies agreed that a collaborative approach be employed to draft mutually acceptable regional conditions for culverts.

The first interagency meeting on this matter was held on January 18, 2007, with twenty-three attendees representing five agencies (those mentioned above and the Adirondack Park Agency). NYSDOT representatives included environmental scientists as well as hydraulics, design and maintenance engineers. Through open and frank discussion, the group made much progress toward the goal of developing revised regional conditions for culverts. Through these discussions, it became evident that the varying perspectives presented both opportunities and challenges.

It was also recognized that New York State is deficient in consistent guidance on the ecological aspects of culvert design. As a result, this interagency group decided that it would undertake the development and dissemination of such guidance upon completion of the Nationwide Permit regional conditions. Thus began the Interagency Aquatic Connections Team.

The Interagency Aquatic Connections Team (InterACT) is an interagency, interdisciplinary team formed to address aquatic connectivity at highway stream crossings. It is comprised of thirteen agencies that are “committed to ensuring that stream crossings are designed, installed and maintained in a manner that protects the ecological integrity of aquatic systems, while accommodating practicable technology, engineering criteria and human safety.”

Following the kickoff meeting, InterACT made numerous revisions to the regional conditions based on member input and dialogue, finally reaching consensus in July 2007. During this time period, there was a concurrent effort to establish the Team’s goals, organization and work plan.

InterACT Subcommittees

As the interest in the collaborative effort grew, the team expanded from five agencies to thirteen agencies with more than 60 members. To manage the size and scope of the team, four subcommittees have been established to address the overall charge. This allows for meaningful contributions from all team members in a more manageable group setting. Each subcommittee has representation from the ecology and engineering communities. The Ecological Performance Standards Subcommittee charge is to identify those characteristics and processes of streams to be achieved, restored, or maintained when a stream crossing is constructed or replaced. The Engineering Design and Specifications Subcommittee is charged with development of necessary design guidance to meet the ecological performance standards. The Outreach and Education Subcommittee serves to raise awareness, and will be responsible for delivery of the products of the other InterACT subcommittees. Lastly, the Regulatory Streamlining Subcommittee is working to develop regulatory tools that minimize processing time and facilitate permitting for projects that meet the new design standards and protocols.

When forming the subcommittees, the team was challenged to overcome the temptation to assign only the experts of the given topic on each subcommittee. Rather than charging the biologists to develop ecological performance standards, to then hand off their requirements to the engineers on the engineering design and specification subcommittee for implementation, the InterACT leaders changed the paradigm and assigned both engineers and biologists to each of the subcommittees. Each subcommittee has representation from the ecology and engineering communities, the regulators and the regulated, the reviewers and the implementers.

Subcommittee Progress and Products

Development of New York's Ecological Performance Standards for stream crossings began with identification of the characteristics and functions of stream corridors that should be preserved or maintained at crossing sites. These fall into the broad categories of aquatic organism passage, terrestrial organism passage, woody debris passage, hydrogeomorphic stability, native riparian vegetation, and floodplain continuity.

The physical capabilities that determine aquatic organism passage through a crossing are highly variable depending on species and life stage. Therefore, rather than dictate necessary flow conditions on a species-by-species basis, the Ecological Performance Standards are based on the premise that aquatic organism passage is accommodated by matching conditions within the crossing to representative conditions found in the adjacent stream reaches.

The standards are organized into three tiers - Optimal, General, and Minimal - to allow varying degrees of ecologically-based design. This gives the crossing designer flexibility to choose design elements that are reflective of the quality of the stream resource.

Currently, the InterACT Engineering Design Specifications Subcommittee is developing engineering guidance as a means of implementing the Ecological Performance Standards. This guidance will address site data requirements, hydrologic and hydraulic parameters, channel substrate, and grade control. Appendices will provide a glossary of terms and definitions, typical details (where needed to illustrate concepts), and a technical reference list.

InterACT has been highly active in providing education and outreach regarding the potential environmental impacts of stream crossings and mitigative design measures. A wide variety of audiences have been targeted, including transportation engineers, environmental professionals, and contractors, totaling approximately 1,700 people.

Handling Challenges through Collaborative Problem Solving

There are many challenges and potential conflicts in managing a large, multi-disciplinary, multi-agency team. Collaborative problem-solving skills needed to be continually used and honed. As recognized in FHWA's Collaborative Problem Solving manual (USDOT, 2006), conflict can be positive, such as: addressing conflict in a forthright manner can produce positive results; conflict forces the recognition of differing perspectives, and provides opportunities to arrive at new understandings; struggling to accommodate diverse interests can be rewarding; addressing conflict also provides the option of responding in either a competitive or a cooperative fashion. If a competitive posture is chosen, damaged working relationships and a lack of progress in achieving goals is often the result (USDOT, 2006). Essential to the success of the effort, the InterACT leaders modeled strong collaborative problem solving skills throughout the effort.

The differing perspectives required the team leaders to revisit and reinforce definitions and understandings throughout the team's tenure. There have been, and continue to be, some challenges regarding terminology and definitions. Terms such as "bankfull," "fish-bearing," and "practicable" generated extensive discussions between the agencies and the disciplines. Also, the intent of the end-products needs continued reinforcement. Though it was agreed upon early in the formation of InterACT and the team's charge that the products are not regulatory in nature and that their function is to provide guidance, this understanding needs ongoing reiteration as it is fundamental to the end-user as well as to the format and details of the products.

Looking back at the effort, the InterACT members should be proud that, as a whole, they routinely demonstrated what USDOT, 2006 has listed as "Attitudes that Can Promote Unassisted Problem Solving." These are:

1. All agencies are mandated to serve the public interest.
2. Every agency should respect the mandate of the other agencies.
3. Public interest has many facets, and all are important.
4. It takes a team effort to address the full range of public interest.
5. Comments that identify problems carry a responsibility to offer recommendations for overcoming those problems or by providing useful information or guidance.
6. An objection is driven by an underlying unmet need. The goal is to understand and meet that need in order to remove the objection.
7. Effectiveness is enhanced through mutual understanding of agency mandates and procedures.

Conclusions

Traditionally, guidance and standards are developed by a primary agency (generally the agency with regulatory authority or the greatest stakeholder), soliciting input and review by other stakeholders. Under this model, however, the primary agency generally does not share or relinquish control of the product. Oftentimes the core team is comprised of or dominated by a particular discipline (e.g., biologists, engineers, planners).

What makes the InterACT effort noteworthy is its true team approach. InterACT is not only multi-agency, with representatives from thirteen agencies (resource, regulatory and transportation agencies), it is multi-disciplinary, with more than 60 representatives from various disciplines. There are fisheries biologists, materials engineers, permit reviewers, hydraulic engineers, aquatic ecologists, maintenance engineers, terrestrial ecologists, and design engineers working together to develop ecological performance standards and engineering design specifications, to conduct outreach and training, and to develop regulatory streamlining products.

This collaborative effort on the one hand is energizing and informative, but on the other hand poses many challenges. Jacobson, et al. (2007) notes that fisheries biologists and wildlife biologists "view passage needs differently" and that "both wildlife and fisheries biologists have limited knowledge and training of passage needs for their discipline. This may result in unsophisticated or uninformed input, or overlooking important passage needs, on projects in the planning phase." Consider this struggle from within the science discipline and magnify the likelihood of conflict when adding in the various engineering perspectives, including hydraulics, civil, maintenance and materials.

Admittedly, this multi-disciplinary approach caused some initial discomfort, as the members were asked to contribute to discussions outside of their area of expertise. The concept, however, was to discuss and resolve the major conflicts within the subcommittee to avoid "fatal flaws" in the end products and recommendations. This collaborative approach prompted in-depth and insightful discussion wherein all parties became better informed about the others' discipline or perspective. To ensure continuity of the discussions, several key members of each discipline serve on multiple subcommittees. These bridging agents bring the understandings reached from the various subcommittees to the next level of discussion to ensure that work is not undone and to avoid redundant or conflicting efforts.

In applying collaborative problem solving, the team was not following a manual or instructions, per se; rather, through years of developing trust and interagency relationships, several of the key players have practiced these skills in their interagency interactions. Some of the team members, however, had not previously experienced the same level of interagency relations, particularly if their dealings were limited to project-level negotiations. Consequently, the key InterACT leaders needed to set the tone of the relationship and dialogue, emphasizing to members that the agencies shared objectives and mutual goals. The overall result has been improved relations and a long-term benefit to the involved agencies. This benefit is transferrable from process to projects.

There are several recent examples of transportation projects that have reaped the benefits from this improved understanding by agency staff. In these cases, the InterACT members that represented the project proponents and regulators followed the tenets of Fisher, et al. (1991), in that they separated the people from the problem, focused on interests, not positions, sought options for mutual gain, and developed objective criteria. Together they developed mutually-agreeable solutions after identifying mutual interests.

Developing positive and collaborative working relationships takes time. Many of the InterACT members are product-driven and are recognized for their effectiveness in meeting tight schedules. The first several months of the InterACT efforts were focused on developing a dialogue and reaching understanding of the different perspectives and mandates. This may have been frustrating for some, in that initially there were no clear end-products. However, the InterACT leaders feel this was time well spent in that subsequent dialogues have been more effective and sophisticated after having established the collective set of interests.

The oft-cited Albert Einstein quote "You can never solve a problem on the level on which it was created" seems appropriate to the efforts of the Interagency Aquatic Connections Team. Rather than approaching a far-reaching environmental and transportation challenge on the level on which it was created, the transportation, resource and regulatory agencies came together to share their expertise and resources in developing solutions. The support of management is essential to the success and continuance of the InterACT effort; however, it is the willing, cooperative participation of the agency staff that has ensured the continued positive momentum of this effort. The team members include program managers, permit reviewers, field staff and practitioners with grounded experience and knowledge, well-poised to implement the outcomes and to apply the new approaches to their work. This collaborative approach has been heralded by the involved agencies and the jointly developed end products are anticipated to ensure that "stream crossings are designed, installed and maintained in a manner that protects the ecological integrity of aquatic systems, while accommodating practicable technology, engineering criteria and human safety."

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ENDANGERED SPECIES ACT SECTION 7 CONSULTATION AND THE U.S. FISH AND WILDLIFE SERVICE'S INFORMATION, PLANNING, AND CONSULTATION (IPAC) SYSTEM

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Abstract

Section 7(a)(2) of the Endangered Species Act requires Federal agencies (and their applicants) to consult with the Fish and Wildlife Service regarding any actions to be authorized, funded, or carried out that may affect listed species or designated critical habitat. One of the most effective methods of streamlining the consultation process and reducing the need for project modifications is for action agencies, applicants, and the Service to engage in early coordination during the project design phase to develop methods of integrating proposed activities with the conservation needs of listed species. The Service is currently developing an internet-based information, planning, and consultation system, the IPaC system, that can be used to obtain natural resource information screen out projects that will not affect listed species, construct needed consultation documents, complete the requirements of informal section 7 consultation, expedite formal section 7 consultation, and better integrate section 7 consultation with action agencies' other environmental review processes, such as NEPA. System development is currently supported by the Department of Homeland Security through Customs and Border Protection. The first phase of IPaC is currently being tested and employed along the Mexico border for Customs and Border Protection activities.

Discussion

Balancing the needs to improve our nation's transportation infrastructure and those of threatened and endangered wildlife and plant species (listed species) can be a delicate dance. Certainly, the country needs to address its growing transportation needs, but at the same time, we have a duty to protect the ecosystems that support listed species such as whooping cranes, Indiana bats, and Chiricahua leopard frogs for future generations. There are several mechanisms within the Federal Endangered Species Act that help to accomplish this goal. For example, under Section 7(a)(2) of the Act, Federal agencies and members of the public that require funding, authorization, or assistance from Federal agencies must consult with the Fish and Wildlife Service (or the National Marine Fisheries Service, if appropriate) regarding the effects of their actions.

Some have described Section 7 consultation as a long, frustrating process often involving what practitioners sometimes refer to as the "bring me a rock" syndrome: "Bring me a rock and I'll let you know if it's the rock I'm looking for. If it's not, then you can bring more rocks until the correct rock is found." However, when Congress created Section 7 they appeared to have loftier goals in mind, anticipating that the consulting agencies and applicants would work together to address potential conflicts that arise between project impacts and listed species conservation. Hence, they titled Section 7 of the Act "Interagency Cooperation." Indeed, one of the most effective methods of streamlining the Section 7 process is for the action agency, applicant, and Services to cooperate early in the project design phase to ensure the incorporation of measures to make projects compatible with listed resources conservation. Engaging in this process early allows project proponents to make informed decisions regarding their projects and can allow for project adjustments to be made while there is the maximum project design flexibility. This latter point is particularly important as the Service is often brought into processes at the last moment after all or most other permits and financing have been obtained. In many of these cases Service biologists request what appear to be relatively minor project modifications only to find that the changes have cascading effects for the project proponent, sometimes requiring them to go back through their other processes again.

To combat this problem, the Service prefers to engage project proponents as early in the design phase of project development as possible. However, recently the Service has faced shrinking budgets and increasing workloads, forcing its biologists to focus on projects that are on the verge of implementation rather than on the ones that are in the early planning phase when flexibility is greatest. The Service's solution to this issue is the development of the Information, Planning, and Consultation system, or IPaC. IPaC is an internet-based system now in the early stages of development. The goal of the system is to provide access to natural resource information and the Service's guidance on ways to avoid or address potential impacts to these resources when project proponents need it rather than when Service staff are available.

The first phase of IPaC, which is almost complete, allows project proponents to come onto the system, identify a project location, chose from a "pick-list" of potential project activities, and instantly receive a list of Service trust resources (including federally listed species) that may be affected by the project. Within the context of Section 7 consultation you may recognize this as the “species-list” step, a process that typically requires project proponents to write the Service a letter and then wait 30 days for a response. IPaC will allow for this process to be completed within seconds. In addition, the lists returned by IPaC contain links to “species profiles” that inform the user on important aspects of the species’ life history, threats, and conservation needs (similar information will also be returned for the other Service trust resources addressed in IPaC, for example, national wildlife refuges, migratory birds, wetlands, coastal barrier resource units, invasive species, etc.). This information will allow project proponents to begin the process of evaluating the potential for their proposed actions to affect listed resources, a step that now typically requires multiple meetings with the Service. The system will also contain links to bibliographies of resource information that will provide guidance on where additional information regarding listed resources may be obtained. It will inform project proponents of any special needs such as the timing of species surveys so they can plan their activities as early as possible, and it will provide project proponents with a series of “best management practices” (BMPs), or design recommendations, that can be incorporated into project designs to eliminate, minimize, or mitigate potential effects whenever practicable.

The ability to provide BMPs is key to avoiding the “bring me a rock” paradigm and providing the predictability desired in planning processes. To be effective, the BMPs should possess three primary attributes: (1) they should be based on sound conservation principles; (2) they should be carefully coordinated with those who will use them; and (3) they should lead to long-term conservation solutions. To address the first attribute, the BMPs are being founded on “conservation frameworks.” Conservation frameworks are documents used to synthesize information regarding the conservation needs of species and threats to those needs in order to develop “conservation objectives.” One of the common complaints of project proponents is that they sometimes think that they are being asked to implement measures that don’t make a real difference. Conservation objectives are used to better focus BMPs on aspects of the problem that affect species conservation, thus ensuring that the BMPs contribute to conservation solutions. Another goal of using conservation objectives is to remove emotion from the process. At times it appears to some as if project design recommendations may be based on what someone “feels” is the right thing to do or is comfortable with. However, there are often multiple ways of achieving a given conservation result. Project proponents should have the flexibility to use whatever methods work best for them, as long as they achieve the identified conservation objectives. Indeed, future phases of IPaC will provide project proponents with different options for achieving the conservation objectives.

The second phase of IPaC, which is under construction right now, will include “project-builder” and reporting and monitoring functions. The project-builder will allow project proponents to come on and enter into a “Turbo-tax” style system that asks the user a series of questions and makes design recommendations. For highway projects, project proponents will be able to test out different alignments to evaluate their effects on natural resources. This will allow for the refinement of project designs while the system constructs the needed consultation documents behind the scenes (the project-builder will construct biological assessments to be used for section 7 consultation, environmental assessments to be used for NEPA review processes, as well as documents for other environmental review and permitting processes). In the case of Federal highway projects, IPaC will exchange information with the Federal Highways Administration’s “web-BA” system, increasing its effectiveness. As the project design is being developed, IPaC will also construct a customized reporting module. This will allow project proponents to come onto the system after their project is completed and fulfill any reporting requirements. This information will be supplied to an environmental baseline tracking module that will allow for the evaluation of listed species progress towards recovery and help to inform future cumulative effects analyses.

IPaC will eventually include additional components including the ability to submit consultation information on-line, and obtain required approvals on-line as well. Thus, IPaC is becoming the future of Section 7 consultation with the Fish and Wildlife Service, and the future is almost here. The Service is currently implementing a series of IPaC pilot projects around the country, and the first phase of the system is currently being tested and employed along the Mexico border for Customs and Border Protection activities. As progress continues to be made on IPaC we anticipate environmental planning and approval processes becoming much more streamlined, something that is eagerly anticipated by both project proponents and Service biologists.

Biographical Sketch

Michael Horton has been in the Fish and Wildlife Service for 19 years: six as a field biologist in the Sacramento Field Office, two as the northeast region's habitat restoration coordinator, and the last 11 as the Service's National Section 7 Coordinator in the Washington Office. For the last two years he's been actively heading up the Service's effort to develop and implement the Information, Planning, and Consultation, or IPaC, system, and he has recently become the Service’s National IPaC Program Coordinator.

INTERCOUNTY CONNECTOR (ICC): ENVIRONMENTAL COMPLIANCE MANAGEMENT USING INTEGRATED TECHNOLOGIES TO PROVIDE CONTEXT SENSITIVE SOLUTIONS

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Abstract

Currently the only east/west limited access highway is Interstate 495 (Capital Beltway) where gridlock is the norm resulting in significant safety and economic impact to the rapidly growing region. Public debate over the Intercounty Connector (ICC) $2.4 billion 18.8-mile new alignment design/build (D/B) project to relieve congestion in the northern suburbs of Washington D.C. has spanned 50 years, resulting in three separate Federal NEPA studies, culminating with ROD approval in January 2006. As one of the most environmentally regulated project in Maryland's history, obtaining the necessary approvals required the Maryland State Highway to commit to unprecedented levels of environmental management, review and oversight plan. For the 5 separate contracts, the project structure includes a General Engineering Consulting team (GEC) which provides primarily environmental design and construction quality assurance reviews, Independent Environmental Monitor team (IEM), and an environmental management team providing environmental permit compliance and quality oversight for design/build contracting team. To encourage natural resource avoidance and minimization, and successful erosion and sediment control performance, monetary incentives and disincentives are included. To many this level of environmental oversight would seem over-the-top and a waste of taxpayers' funds but on a $2.5 billion dollar, 18.8-mile new alignment D/B highway project, the efforts are paying considerable environmental dividends including shifting the paradigm of an industry.

As pioneers on this new approach for the first ICC contract, the Intercounty Constructors (IC) Environmental Compliance Team (ECT) found itself developing new environmental processes, approaches and systems as a member of the contractor team and in partnership with the client and regulatory agencies. As part of the contractor D/B team, our role is to ensure the D/B team meets the project permits, compliance requirements and commitments, obtain maximum incentives for avoidance/minimization efforts and for Erosion & Sediment Control (ESC) compliance along with providing full time design environmental reviews and construction quality control oversight. The ECT had to develop a system to track design and construction processes that could integrate with multiple systems and programs, could easily transfer data in real-time, would be a valuable tool in compliance and avoidance/minimization analysis and would keep the contractor and reviewing agencies informed to avoid critical time delays.

We found that the use of an integrated environmental documentation management system that integrates web-based and GIS technologies, and allows for real-time data sharing both in office and in field has resulted in a net reduction of design modifications, reduced environmental impacts during both design and construction and has avoided critical time delays as a result of environmental issues. This presentation will discuss some of the challenges and uniqueness associated with providing this level of environmental oversight working for the D/B contractor and the system put into place to keep the project in compliance during this fast paced and constantly changing project.

Introduction

Project History

The Intercounty Connector (ICC) was first proposed in the 1950s as part of the outer beltway around Washington, DC. Planning documents were updated by Maryland National Capital Park and Planning Commission (M-NCPPC) and Montgomery and Prince George's county governments and presented in three separate federal National Environmental Policy Act (NEPA) studies completed by the Maryland State Highway Administration (SHA) Draft EIS and public hearings in 1983 and 1997 were abandoned over agency and public concerns of environmental impacts. A real need for increased mobility became paramount as the area was experiencing congestion and increased population growth and the only east-west highway (I-495) that encircles Washington, DC is stop-and-go much of the time, even on weekends. Only the current NEPA study resulted in a Final Environmental Impact Statement (FEIS) and Record of Decision (ROD). The current NEPA study focused on interagency coordination, public scoping and involvement, and environmental and planning agency coordination and resulted in a focused purpose and need, comprehensive avoidance and minimization and cumulative impact studies, and a substantial mitigation and environmental stewardship package.

Selected Alignment

The 18.8 mile east-west managed highway is a controlled access highway with electronic toll collection at highway speeds. There are three traffic lanes in each direction. Due to the magnitude of the design/build scope, the highway project is separated into five contracts; A-E.

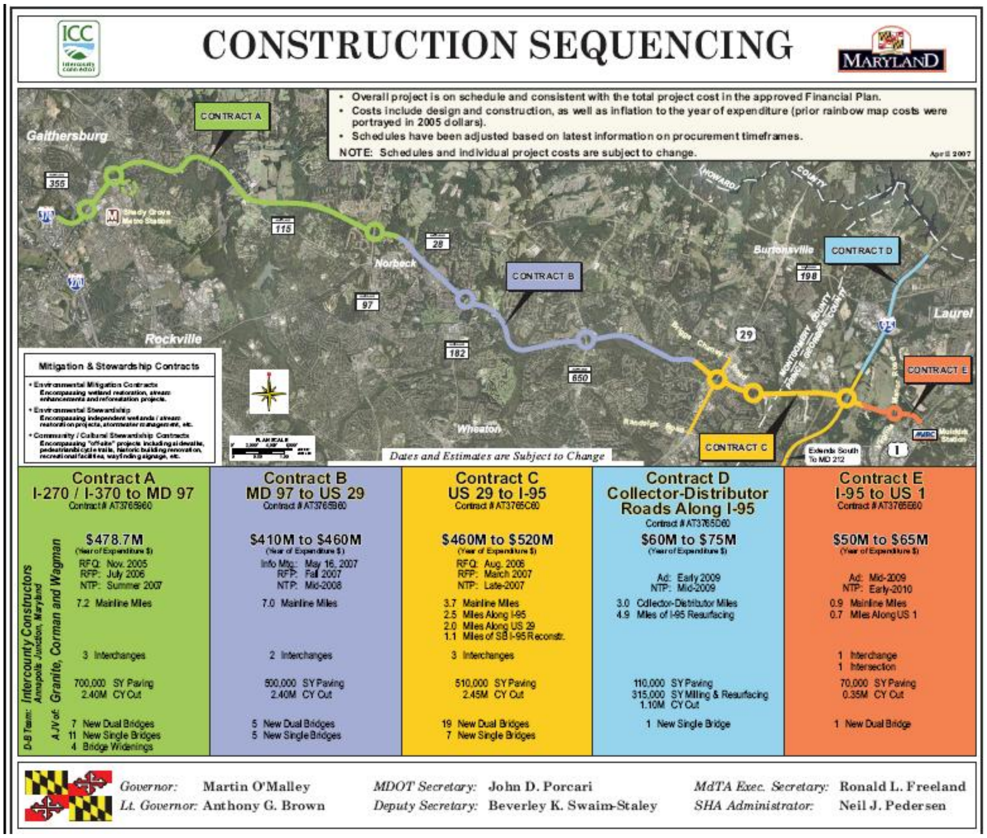


Figure 1 - ICC Contract Construction Sequencing

Mitigation and Environmental Stewardship Package

The $370 Million mitigation and environmental stewardship package consists of:

- 29,700 LF stream restoration
- 3 fish blockage removals
- 83 acres of wetland creation
- 25 wildlife passage improvements
- 776.6 acres of new parkland for the approximate 88 acres of impact
- 7 reforestation sites
- Stormwater management retrofits
- Vernal pool replacement
- Community improvements including:
    - Additional screening using earthen berms, walls, vegetation or combination
    - Dedication of lands to community homeowner associations (HOAs)
    - Pedestrian access
    - 11.4 miles hike/bike trails
- Eastern Box Turtle collection/relocation program

Required Project Environmental Oversight

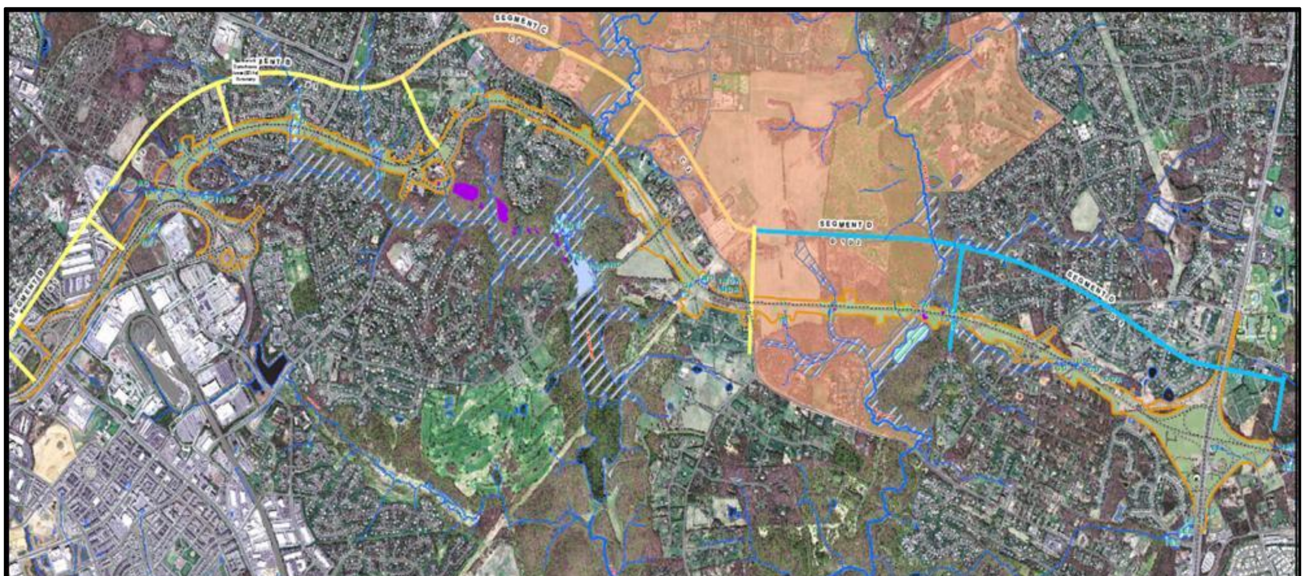
The State of Maryland made a promise to deliver the most environmentally sensitive project ever constructed and plan to leave the area in better condition than before the project onset. To meet this commitment, an aggressive environmental compliance program was needed. In order to ensure the ICC project stays in compliance with all permit conditions and project commitments, the owner established the following mechanisms for quality control and assurance:

- Memorandum of understanding (MOU) between federal, state and local agencies to address details of coordination, monitoring and enforcement of commitments
- Creation of a commitment tracking database (CTD)
- Hiring of an independent environmental monitor (IEM) to report directly to and make recommendations to the regulatory and lead agencies
- Hiring of a general engineering consultant (GEC) to coordinate all of the Contracts (A-E). Require the GEC to provide project wide environmental management.
- Require the design/build contractor to provide environmental compliance management and quality control

ICC Contract A

Contract A extends from the western nexus of the ICC at the I-370/I-270 interchange and the Metro Access Road to Georgia Avenue (MD 97) and is 7.2 miles long. Contract A crosses Mill Creek, Rock Creek (RC), North Branch Rock Creek (NBRC) and tributaries as well as associated wetland and forest resources. These areas are also located in protected Montgomery County Parks. A Montgomery County Special Protection Area (SPA) is located in NBRC.

ICC Contract A was awarded to the Intercounty Constructors (IC) design/build team on March 27, 2007 and the Full Notice to Proceed was issued on November 13, 2007. The limited access 7.2 mile highway must be open to the public and generating revenue by October 2010.



ICC Contract A - I-270/I-370 to East of MD 97
Environmental Features

Figure 2 - ICC Contract A Alignment

The IC is a joint venture team comprised of Granite Construction Inc., Corman Construction Inc., and G.A. & F. C. Wagman, Inc. for construction and Parsons Inc. and Jacobs Inc. for design. KCI Technologies, Inc. (KCI) was contracted to provide environmental compliance management and quality control for the design/build team.

Intercounty Constructors Approach to Environmental Compliance Management

The stringent requirements for environmental management, oversight, environmental resource avoidance, minimization and protection during the design and construction of the ICC calls for context sensitive design solutions and a flexible management system to ensure project success. KCI needed to develop an environmental management system that could document daily design and construction interaction for avoidance and minimization purposes and provide permit and commitment compliance standards in order to lead the environmental aspects of the design/build project to a successful end. The system also needed to be flexible enough to incorporate modification capabilities for unforeseen events as well as be able to provide coordination features so the owner could review data.

This was the first time the state required the contractor to include environmental compliance management as part of their team. They were also assigned the non-traditional role of quality control monitoring. Therefore, it was up to KCI to develop a system that would change the traditional way the contractor approached business processes and move towards a more flexible, environmentally sensitive approach. We knew it was going to be very challenging as contractors deal with cost codes, volumes and schedules. They are typically uncomfortable with the many normal, but often unknown factors of reviewer/comment/revision/re-submittal procedures, negotiating changes in environmental permit conditions, natural resource impact avoidance and minimization tracking, environmental re-evaluation summaries related to NEPA and wildlife protection issues.

Contract requirements of key personnel included an Environmental Manager and Environmental Specialists. Since the permit conditions and project commitments on the project were so numerous and the project was so sensitive, KCI added an Environmental Compliance Specialist position to the Environmental Compliance Team (ECT). This value added position strengthened the overall approach towards making sure the design/build team maintained environmental compliance standards.

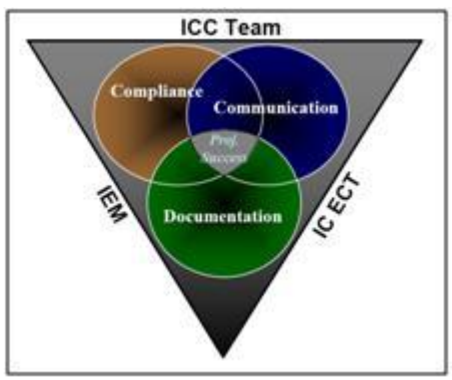


Figure 3 - Three Key Principles in ECIP Implementation

Environmental Compliance Components

Environmental Compliance Process

The ECT approach to achieve full compliance of project commitments and considerations, permit conditions and approval requirements for design and construction consists of three key elements; compliance, communication and documentation. The ECT developed an Environmental Compliance Implementation Plan (ECIP) that outlined how the IC was going to meet and exceed environmental compliance standards. The ECIP is comprised of a document control and data management system, interactive design review processes and protocols, resource management programs and contractor/subcontractor training/continuing education program. The three main components integral to the day to day design and construction functions include:

- *Compliance* which includes the knowledge of the project history, effective resource management and successful performance of project commitments.
- *Communication* includes making sure that everyone understands their role, responsibilities, project protocols and know what to do when the unexpected happens in a design/build environment. Also to make sure the project remains on a successful path.

- *Documenting* the design and construction processes using the latest in field computing and document management technologies combined with an integrated review process and quality control tracking to make sure that project compliance is met.

The environmental compliance process ensures that the project goals are met, permit conditions and record of decision commitments are followed. Stakeholders are kept informed throughout the design and construction phases of the project and are aware of all activities and any modifications. This process allows the ECT to systematically track, monitor and document activities throughout the design and construction phases of the project with an emphasis on stewardship/enhancement and mitigation as well as maintenance and post construction activities. Figure 4 depicts the design elements B, C and D and the earth disturbance areas 1 through 14 in relation to the environmental compliance process.

In the design phase the ECT actively participated in weekly task-force meetings where design and constructability, impact avoidance and minimization, permit conditions and project commitments issues were raised and addressed. If additional information was required, the ECT attended breakout meetings and informal over-the-shoulder review meetings. The ECT also conducted official design reviews utilizing the commitment tracking database (CTD) at key design milestones.

During construction, the ECT provide daily field compliance and erosion and sediment control (E&S) reviews, water quality monitoring of pumping operations, natural resource inventory in accordance with yearly and/or seasonal requirements and wildlife collection and relocation.

Figure 4 - Environmental Compliance Process

Environmental Compliance Implementation Plan

KCI developed a web based document and GIS system that integrates with multiple systems and programs that easily transfers data in real-time to track design and construction processes. This system is a valuable tool in compliance and avoidance and minimization analysis and keeps the designers, contractor and reviewing agencies informed during the construction. This progress has avoided critical time delays. KCI dedicated an Environmental Specialist (ES) position to conduct the document management, GIS data management and analysis, water quality tracking and CTD reviews for impact avoidance and minimization (A&M).

The ECIP consisted of the following chapters:

- ECIP Overall Process
- IC Environmental Compliance Team Structure, Staff Experience
- IC Environmental Compliance Team General and Incident Communication Process
- Commitment Tracking Database
- Avoidance and Minimization Plan
- Water Quality Monitoring Plan
- Wildlife Management Plan
- Forest Impact Plan
- Air Quality Plan
- Spill Prevention Control and Countermeasures plan & Stormwater Pollution Prevention Plan
- Hazardous Material Plans
- Noise Monitoring Plan
- Vibration Monitoring Control Plan
- Construction Access and Mobility Plan

Commitment Tracking Database

The State compiled the entire ICC project federal, state and local environmental permit conditions and project commitments and entered them into a Commitment Tracking Database (CTD). The database could be queried by individual Contract for specific environmental regulations and commitments that govern that project area for avoidance and minimization and environmental compliance purposes. KCI took the CTD provided by the state and added a more specific key word list and tagged highway stationing so the user could query the database on a specific station or structure basis attached to GIS and use it as a verification tool for detailed avoidance and minimization of natural resources and permit/project commitment tracking. The CTD was used for each design milestone review to ensure that all compliance standards were met and/or exceeded.

Central Information and Documentation System

The web based document and GIS management system integrates document, business processes and records management. The system records documents, data and designs and is integrated with GIS technology. The flexible system allowed the ECT to provide a central interactive document control that was useful for compliance tracking for both the user and owner. Key components that were essential for ICC project compliance included:

- Provides the manager customization & client access for viewing
- Create customized forms for environmental compliance tracking
- Workflow customization
- Conduct design reviews
- Conduct QA/QC
- Permit tracking
- Create map book
- Bookmarks
- Hyperlinks to other documents
- Geo-reference design plans
- Add notes, points, line polygons into GeoPDF documents
- Real time data entry and retrieval
- Ability for document histories and queries
- Features can be exported into shape files to load into GIS back into an office environment

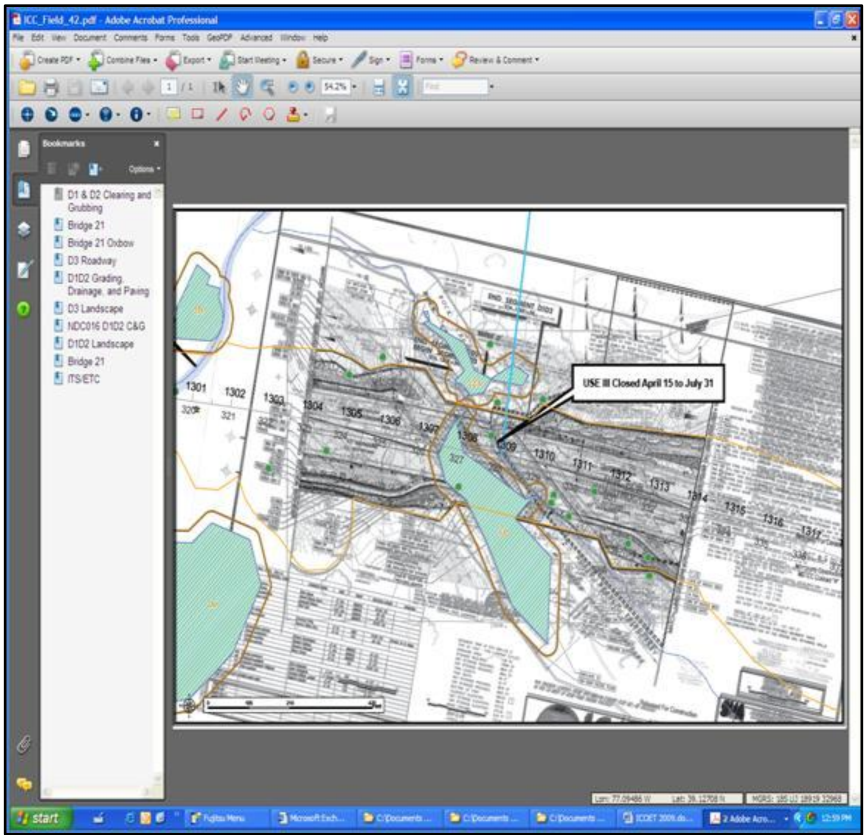


Figure 5 - Web-based Geo-PDF System with GIS Data Attributes

Environmental Keys to Regulatory Compliance

Environmental compliance of the ICC Contract A fell into four main categories including communication and documentation, erosion and sediment control and water quality, natural resource avoidance and minimization and wildlife management. The ECT found that staying in compliance involved daily interaction with the design team to discuss and resolve avoidance and minimization issues, the contractor management team making structural, earthwork and pumping operation modifications, the owner to discuss and resolve any permit modification or other natural resource issues and the quality assurance inspection team to discuss any erosion and sediment control or environmental regulatory permit issues.

Communication and Documentation

In order to educate the design and contractor team of the environmental sensitivity of the ICC project and how the traditional construction practices had to be modified to incorporate redundant and tighter erosion and sediment control, stringent water quality best management practices and wildlife management strategies, the ECT develop an Environmental Compliance and Environmental Awareness Training program (ECAT). The ECAT was primarily developed for the construction work force and presented pertinent information on the ICC Contract A project regarding specific best management practices used on the project to stay in environmental compliance for cultural and natural resources. All people working within the ICC limit of disturbance (LOD) were required to attend the ECAT program. As construction got underway and water quality issues arose, the ECT found that additional training and education was needed to stay in compliance with the State's stringent regulatory water quality standards for turbidity and pH. Continuing education programs were developed to inform workers of changing pumping protocols especially in regards to concrete pouring operations, pH management and noxious weed control. A pocket field guide of the best management practices and specific environmental regulations governing the ICC project was developed and provided to all supervisors and foremen.

The Environmental Specialists (ES) walk their portion of the construction corridor with the erosion and sediment control team member on a daily basis to document any erosion and sediment control issues that need maintenance or modification. They also coordinate on an as needed basis for pumping operations, mud or dust maintenance, or any other issues that may arise. The ES complete daily Inspector daily reports (IDR) for each area and structure within their designated segment within the ICC. All construction activities, erosion and sediment control issues and supporting photographs are included in the IDR. Pumping operation monitoring forms are also submitted daily.

Since the owner and IC share space in a centrally located office, general coordination occurs at the convenience of the both teams which has stream-lined the review and comment process. One example of stream lining, is the use of the SHA E&S 00C62 form. This is where erosion control design modification is made with an email form and line drawing that is submitted via email. The owner can review and approve and forward the email to the regulatory agency for approval. Generally approvals are received within a day and sometimes within hours which has greatly streamlined the whole traditional design modification process for minor E&S design changes.

Erosion and Sediment Control and Water Quality

Dust on a construction site is an environmental concern, especially when existing communities are in close proximity to the ICC crossing. ECT personnel including sediment and erosion control field engineers and the environmental compliance specialist obtained Opacity certification and a yearly re-certification to determine the percentage of dust particles within the LOD and at the right of way (ROW).

Fugitive dust must be 0% at the ROW therefore, stringent strategies for dust control are followed. Water trucks and tractor fitted with scrapper box maintain tight schedules in areas where there are high volumes of earth movement or vehicular traffic. Tackifiers such as sodium chloride used in areas where earth is not being moved for several days and temporary seeding is used on all stockpiles and areas that are not scheduled for disturbance for extended periods.

The ICC Contract A crosses three stream valley parks, one of which is a designated Special Protection Area (SPA), numerous wetland systems, large contiguous forested tracts as wells as congested residential communities. Protection of adjacent and receiving natural resources and regulated water quality standards in turbidity, pH and temperature are a major concern. The ECT developed an extensive water quality monitoring program to track the in-stream and surface water environments, and researched and developed new methodologies to further reduce impacts from adverse water quality affects.

The ECT installed automated water quality data loggers in all streams at both upstream and downstream locations of the ICC crossing. The data loggers collect continuous data and allow remote access to the unit. Direct communication with the units in the field is accessed for calibration, downloading, and system setup. A hand held PC automatically synchronizes data with a personal PC. Telemetry® remote systems is used to access real-time data from the datacenter, allowing capability of accessing multiple units, downloading files, and storing and archiving data. Each unit can alert the IC team of any adverse water conditions the moment a parameter exceeds the set, acceptable range. Alarms are sent via text message. This permits the ECT to respond and implement required corrective measures immediately.

Figure 6 - Water Truck

Hand held data loggers, the same as those used for in-stream monitoring, are used to monitor water quality parameters, specifically turbidity and pH in sediment traps, sumps or other dewatering areas. The ECT monitors all surface water on a daily basis. All pumping operations are monitored for water quality standards prior to discharge to any waters of the US. To be in compliance with the Code of Maryland Regulations (COMAR) standards, the turbidity may not exceed 50 NTUs and pH must be within the range of 6.0-8.5. When a concrete pouring operation is underway, special attention is paid to pH as it will immediately rise when in contact with water.

Maryland typically has “flashy” storm events where water quickly falls and runs offs before having the chance to infiltrate. This results in the need for dewatering operations in an accelerated timeframe. Full sediment traps that have high turbidity often do not have time for the sediment to settle before they need to be pumped down and in many cases the turbidity will not drop to within COMAR standards due to clay or coluvial sediments. IC researched and gained approval for the use of the flocculent enzyme Chitosan, which adheres to the sediment and forces a quick reduction in turbidity. This greatly increased the rate of dewatering on the construction site.

Figure 7 - Rain for Rent® Unit Using Flocculents

Getting the right amount of moisture in the soils to meet compaction standards was difficult due to the soil characteristics and excessive amounts of rain in the spring of 2009. Soil amendments such as lime and Portland cement increase pH as does the use of limestone based stone. All of these components are common materials used on a roadway construction site. Due to the sensitivity of the adjacent receiving waters, testing and approval for use of methods to neutralize pH was investigated. Hardwood mulch in clean water swales, rock salt in sediment bags when discharging sump water and the use of carbon dioxide gas were all tested and used to reduce pH. Also, when feasible, water was allowed to settle in sediment traps since pH gradually neutralizes if left undisturbed.

As part of water quality protection and safety commitment to the local communities, IC needed to make sure that construction vehicles did not trail dirt and mud onto the public roadways. The stabilized construction entrances were extended to 100 feet and power wash stations were added on days after storm events. Personnel are stationed at the stabilized construction entrances (SCE) to brush and/or scrape the road crossings and sweeper trucks regularly seep the crossings to keep the public roadways dirt free.

Thermal discharge in the SPA was a major concern which required special stormwater management design. IC will install underground storage tanks along with innovative deep storage dry stormwater ponds for cool water discharge to minimize the thermal impact from roadway storm water runoff. IC plans to install thermal monitoring stations to monitor the inflow and outflow data in order to determine the effective ratio of the storage tanks and stormwater management ponds.

Natural Resource Avoidance and Minimization

Avoidance and minimization of impacts to the cultural, natural and socio-economic environments were integral components of the selection and permitting process of the ICC alignment. As part of the Contract A Segment, IC was mandated through permit conditions as well through incentives and disincentives to further avoid and minimize natural resource impacts. Innovative design techniques such as the bottomless arch culverts were used to avoid and minimize impacts with successful results. The avoidance and minimization did not stop with design, but continued in the construction phase of the project. Construction best management practices (BMPs) are used to further avoid and minimize impacts with even greater results.

Tree avoidance and minimization along the LOD was a concern as there are many considerations including ownership, size, species requirements, sun scald, wind throw and root pruning requirements. The Maryland Department of Natural Resources approved the removal of 209.1 acres of forest with the condition that IC would avoid as many trees as possible, specifically specimen size trees. Special consideration was paid to minimize impacts to trees along edges through communities, sensitive natural resource habitats and parkland. The owner is providing incentives to encourage the contractor to make preservation of trees a priority.

The IC Maryland certified Arborist made the determination of which trees along the LOD should be saved or removed based on proximity to the LOD, species health, habitat requirements and access in the future for removal if it dies. IC also conducted additional reviews with M-NCPPC personnel along parkland LOD to obtain concurrence for the removal of any trees along their LOD. Avoidance and minimization was so successful that IC reduced their onsite reforestation requirements by 34+ acres (46 percent).

Other avoidance and minimization efforts to protect natural resources included design modifications to avoid or minimize impacts, the addition of redundant erosion and sediment control measures and enhancement measures of existing resources.

The landscaping design is a large part of the aesthetic and habitat reconstruction along the ICC corridor. The landscaping uses native species and an aesthetic design palette that complements the communities and park systems that the ICC crosses. The plant zones were separated into various habitat designations including community gateways, bridge abutment and embankment areas, bike trail areas, historical and specific community areas, forest edge, interchanges/gateways, medians, roadside screening, reforestation, riparian buffer, street tree, stormwater management, wetland, bioretention, embankment and sound barrier/retaining wall. A naturalistic drift was used to reduce the appearance of the standard “landscaped” appearance. The highest densities ever specified in Maryland and large caliper size trees (1 ½-2” caliper and/or 6-10’ high) and shrubs (2-3’ high) were used to soften the initial constructed view. Perennials and grasses were specified in quart or gallon size containers. The landscaping design is an enhancement to the existing habitat throughout the ICC corridor.

Wildlife Management

The ICC crosses three stream valley parks and the main design goal for wildlife is to reconnect the habitat corridors using the most sensitive designs possible for both aquatic and terrestrial wildlife passage. The ICC designs include bridge and culvert structures that specifically incorporate wildlife corridor connectivity and protection features. Fencing is corridor wide and is designed for amphibian as well as large and small mammal safety. Specific protection strategies were developed for strategic wildlife crossings to encourage species diversity and reduce wildlife roadkill potential.

Bridges are located in the large stream valley parks and are greatly oversized to encompass not only the required hydraulic requirements, but the entire 100 year floodplain. Culverts are strategically placed in habitat corridors and in several locations use a “bio sensitive” bottomless arch culvert design. In several locations pipe culverts are designed and installed specifically for small mammal passage.

Figure 8 - Culvert Z: Bio-Sensitive Bottomless Arch Culvert

The wildlife fence system is a double layer fence. The outer layer is an eight foot high metal chain link fence to deter deer from entering the roadway and the inner fence that is attached to the deer fence is a three foot high quarter inch diameter fence that is vinyl coated. This fence will deter small mammals from entering the highway and will protect the sensitive skins on amphibians. Both fences are buried to deter wildlife from burrowing under them. To reduce roadway mortality, earthen escape ramps will be installed approximately every quarter mile in case a deer does get into the roadway system.

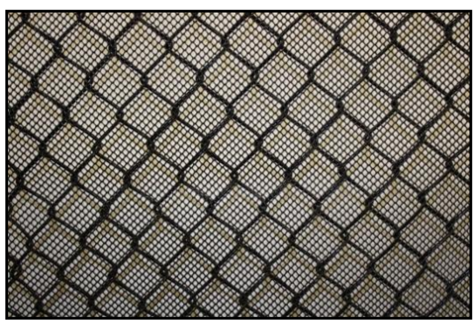


Figure 9 - Wildlife Fencing for Deer, Small Mammals and Amphibians

Stream segments that were re-constructed through culverts or pipes were restored with fluvial geomorphic principals to ensure aquatic passage. Natural substrate using remnant materials where possible were used including adjusting designs to incorporate slope and flow adjustment when bedrock was encountered.   Many innovative approaches to stormwater management are implemented especially in infiltration and thermal reduction best management practices. These practices will have a net benefit to water quality, will improve fish habitat for all species of fish including temperature sensitive trout species and the Comely Shiner, a State threatened species. In order to protect the existing fish population, a fish relocation program is performed where fish are relocated downstream of the work area prior to any in-stream construction activity. This is conducted by net passes in shallow water conditions or by electro-fishing in deeper water conditions. Block netting is placed upstream and downstream of the work area to keep fish from re-entering the work area.

Adherence to stream closure dates for in-stream construction activities to allow for fish spawning is an important construction scheduling tool. Best management practices for stream diversions and tie-ins are strictly followed and any construction activity in the vicinity of streams, uses stringent construction practice protocols.   A specialized mix of stone and sand was used in the bottomless arch culverts, box culverts and pipe culverts sized for deer passage. The deer mix substrate was a minimum of one foot deep.

IC monitors vernal pool locations during construction starting in March and, if viable, continues through June when the pools are vacated. IC also created 764 square feet of vernal pools within the ICC LOD. IC verified the presence of one vernal pool in 2008 that had wood frog (*Rana sylvatica*) egg masses and spotted salamander (*Ambystoma maculatum*) egg masses. In 2009, IC had wood frogs and American toads *(bufo bufo*) egg masses in many sediment traps and depression areas created construction. In efforts to preserve the wood frog species from high pH in the sediment traps, IC moved the egg masses to viable vernal pools in offsite locations and monitored those pool locations to determine the success of the egg relocation effort.

The IC developed a management plan to collect and relocate the eastern box turtle (*Terepene carolina carolina*) from the construction limit-of-disturbance (LOD) area. The environmental stewardship effort was developed to promote the protection and preservation of a species that is currently declining in the eastern United States. As some existing habitat areas along the ICC will become extremely limited or non-existent in post-construction conditions, some of the collected turtles must be permanently moved to new habitat areas. Collaboration between the IC, SHA and members of the Box Turtle Advisory Group (BTAG) which is comprised of federal, state and county agencies as well as non-government organizations and consultant groups, occurred to develop a strategy for the turtle relocation effort. The BTAG provided diverse expertise on biological, herpetological, and wildlife habitat issues. Protocols were developed on the handling of turtles, attachment of transmitters to turtles, and relocation of hibernating turtles. For turtles that needed to be permanently moved outside of their original habitat area, locations on where the turtles would be moved were also determined.

A combination of turtle tracking dog teams and human tracking teams were used to locate existing turtles within the ICC corridor.

Figure 10 -
John Rucker with his turtle tracking dog and friends

Figure 11 -
Eastern Box Turtle

Figure 12 -
Box Turtle Study Sign

Collection of turtles began prior to the formal NTP and after turtles began to hibernate, a solution was required for what to do with the turtles once they were found. IC was not authorized to install the proposed exclusion fence prior to NTP, therefore transmitters were purchased and attached to a 145 turtles in order to relocate them again after entering hibernation. Prior to the clearing and grubbing of an area, the turtles were located using radio telemetry and GPS, then relocated outside of the LOD. When a turtle was located, a GPS survey point and photographs were taken and a data sheet was completed with habitat, weather, turtle activity and biological data. The turtle was permanently marked with an individual marking and a transmitter attached. The turtle was then released outside the LOD. A GPS survey point was also taken of the turtle release point.

Due to the success of collection of turtles, a temporary holding facility was constructed within the ICC LOD. The area was approximately one half acre in size (approximately 150' square). All turtles collected in 2007 beyond the 145 transmitters were relocated into the temporary turtle enclosure to hibernate for the winter. In the spring after emergence, they were either released to locations outside the LOD but near their original capture point or relocated to new locations if originally found in the area where habitat was to be eliminated. Prior to turtles coming out of hibernation in the spring of 2008, exclusion fence was installed in areas along the ICC LOD.

Due to the success of the IC turtle collection/relocation program, Towson University was very interested in continuing the initial data collection of the ICC turtles and is continuing to monitor 90 of the IC "collected/relocated" turtles in the North Branch Rock Creek Park. Their three-year study will gather new data on the effectiveness of on-site relocations of box turtles and the success of viable populations. The Humane Society of the United States (HSUS) is also conducting an eastern box turtle study relocating turtles from the ICC habitat elimination area to three separate off-site locations. This study will gather data for the success of viable populations for off-site relocations.

Environmental Management Success Based on Avoidance and Minimization and Incentive Performance

Contractor Incentives

One way to ensure the design/build team approached the project with the impetus to strive towards making the maximum effort in avoidance and minimization of natural resource impacts was to provide incentives. Incentives are provided for erosion and sediment control and avoidance and minimization to wetland, stream, forest and parkland impacts.

Erosion & Sediment Control Incentives:

- Maintain E&SC average SHA E&SC rating of "A" each quarter and for environmental permit compliance and receive $250,000
- Maintain E&SC average SHA E&SC rating of "A" overall for the project and get $1,000,000 bonus
- Maximum potential incentive for each Contract is $4,000,000

Natural Resource Avoidance and Minimization Incentives:

- Additional compensation in increments of 0.25 acre for wetland impact reduction ($100,000 per acre outside Special Protection Area (SPA), $150,000 per acre inside SPA)
- Additional compensation in increments of 25 feet inside limit of disturbance (LOD) and 0.25 acre for forest impact reduction ($75,000/acre outside SPA, $100,000/acre inside SPA)
- Additional compensation in increments of 100 LF stream impact reduction ($150 LF outside SPA, $225 inside SPA)
- Additional compensation in increments of 0.25 acre for forested or wetland areas in parkland ($50,000 per acre)

ICC Contract A Avoidance and Minimization Success

Environmental Management using the real-time, web-based management system is making impact and compliance tracking in a very complicated, fast paced and highly sensitive project very successful. To date there have been no project shut downs, IC has received positive feedback from the owner, regulatory agencies, adjacent communities and media. The environmental management also continues to be rated highly in partnering. The regulatory agencies are recognizing the effort the contractor has taken to be in compliance and are quick to discuss and resolve new issues quickly. A prime example of this is after conducting the research and presenting the idea and monitoring protocols for use of flocculents to reduce turbidity, the owner gave authorization for the use of Chitosan.

The total projected cost for the Contract A design/build contract is $480 Million with the environmental management portion of the contract is approximately $4.8 Million or 1.0 percent. With 1.5 years to project completion, environmental management has already earned $1.5 in erosion and sediment control incentives. To date, natural resource impact reduction has earned over $2 Million with the potential to earn more by the project completion.

Presuming IC maintains the erosion and sediment "A" rating and continues to earn the quarterly incentive, the potential to earn in excess of $4.8 Million and is certainly feasible. This proves that environmental management provided by the contractor on a large contract is extremely beneficial and can pay for itself over the life of the project. Communication, documentation and education of regulatory processes and avoidance and minimization and compliance techniques and standards using web based interactive technologies for data sharing in a true partnering atmosphere has made the difference between a compliant project and a greatly successful project.

Lessons Learned

Key positions from the Owner and Contractor working on the ICC Contract A were interviewed to get a collective view and establish trends on the environmental management of the project. Based on the answers, it is hoped that project planners will learn valuable lessons from the ICC project and will modify the way the environmental management is structured for future design/build projects.

ICC Contract A Natural Resource Avoidance and Minimization											
Natural Resource	Perennial/ Intermittent Stream	Ephemeral Stream	Wetland	Wetland Buffer	Open Water	Floodplains	FIDS Habitat	Forest	Parkland	SPA Forest	Specimen Trees
	(LF)	(LF)	(Ac)	(Ac)	(Ac)	(Ac)	(Ac)	(Ac)	(Ac)	(Ac)	(#)
Avoided	1,764	482	1.10	0.81	0.11	3.7	5.8	36.6	5.1	2.5	24
Restored	2475										
Incentive Increment	100 LF @ $150/LF	0	0.25 Ac @ $100,000/Ac	0	0	0	0	0.25 Ac @ $75,000 Ac	0.25 Ac @ $50,000/Ac	0.25 Ac @ $100,000/Ac	0
Incentive Totals	A: $270,000 R: $360,000	0	$75,000	0	0	0	0	$806,250	$250,000	$250,000	0
E&S Incentive Totals	$1,500,000										

Table 1 - ICC Contract A Natural Resource Avoidance and Minimization

The owner and contractor personnel were asked the following questions:

- ***Do you think the RFP accurately reflected the expectations*** for environmental compliance?
- Should this project be a design/build? Or design/bid/build?
- With the Environmental Management QC being led by the Contractor and not by the owner or an independent, do you think it is beneficial to the project success? If so/not why?
- Do you feel there has been a "cultural change" in the way the environment is thought about and planned for in the contractor point of view?
- Do you feel that a change from reaction to pro-action is occurring?
- Has partnering been a key component to success?
- What do you see as a major roadblock(s) in the project process/progress?
- Do you feel that the public view has changed/is changing on how the ICC is being handled because of environmental sensitivity from the contractor?
- What key lessons have you learned to date?
- If you had to start this all over again, what would you do differently?

The answers are broken into two categories; Pro; listing the environmental management structure areas that are working well and Con; listing the environmental management structure areas where modifications should be made on future projects to be more effective.

Pro

Both the owner and the contractor agree that design/build is still the right solution as it allows for the risk to be spread between the owner and contractor and it expedites the permit review and modification process. The process of design/build is still faster than the traditional design/bid/build.

Key items that the contractor must consider on a daily basis include time, mobility, sequencing, resources, manpower and project end schedule. There has been a slow change in the way the contractor has approached the environmental management of the ICC as they typically assign cost codes and time allotments to items. They traditionally have not dealt with adjustments for stream closure periods, negotiations for new standards in water quality, personal preferences in design standards and wildlife habitat requirements. The contractor began this project with the knowledge that the project had more permit conditions and project commitments than most, and they recognized that they had to meet the compliance requirements, but they did not expect the level of scrutiny and oversight. After they got used to the level of environmental oversight and discovered that it might be possible to meet erosion and sediment control and impact avoidance and minimization incentives, they started to take pride in the excellence of environmental commitment.

There has been a change from a reactive approach to environmental issues to a more proactive approach. At the beginning of the project, when an environmental issue arose, the contractor met with the environmental compliance team, discussed and resolved the issue and corrected the problem to stay in compliance. Now when the same environmental issue rises, the contractor takes a proactive approach and resolves the issue prior to it becoming a non-compliance issue. New issues are discussed and resolved immediately rather than waiting for a non-compliance to be issued. A prime example of a proactive approach is the erosion and sediment control crews are actively working during storm events to correct any issues that might arise rather than waiting until the storm event is over to make all necessary corrective actions.

Partnering has been extremely helpful during design and construction when the interactive form is used. Examples of good partnering are task force meetings, over the shoulder reviews, erosion and sediment control checkpoints, Maryland Department of the Environment (MDE) checkpoints, and SHA E&SC design modification 00C62 forms which is a stream lined review and approval process.

Considering the ICC project has been in planning for 50 years and in the negative spotlight for many years, the public has changed from trying to stop the project to asking how long until it will be complete. The people who are educated in environmental issues have been impressed with the effort made by the contractor in maintaining good water quality, quick response time to any environmental issues that arise and polite manner in dealing with the public. The people who are not educated in environmental issues will never understand the good efforts made by the contractor. In general, both the owner and the contractor feel that we do not promote how well we are doing. We should be marketing our success across the nation.

Con

There was a fundamental difference in the way the owner intended the project to be managed and how the contractor viewed the RFP intent. The owner outlined the environmental concepts not the expectations and the contractor was not informed of the level of effort that would be required to maintain compliance standards to meet incentive goals. The contractor had no way of knowing that outside interest group stakeholder coordination would be required. It also may have been more beneficial if the regulatory permits were in the contractor's name as they would have strived from the beginning of the project process to avoid and minimize impacts as the risk would have been all theirs. They would have taken a more pro-active approach by policing themselves to stay in compliance.

One issue is the contractor finds with a design/build project is the add-ons for extra coordination, especially in relation to erosion and sediment control requirements and public relations, are not paid for by the owner under a design/build contract. Only out-of-scope modifications are paid changes.

It would be better if the environmental management contract reported to either the owner or an executive committee comprised of board made up of owner, designer and builder. This would be more like a P3; a public, private partnership that is established for the duration of the project. This would eliminate the "conflict of interest". Contractually, the environmental management was approximately 1% of the project and reports directly to the D/B project manager which provides little authority and control to the ECT. While the environmental manager of the ECT is one of two people given the authority to shut the job down, the ability to do so without significant consequences is significant. To date the environmental manager has used the authority to shut down portions or specific locations of the project when violations are occurring and for the most part received support from the D/B project manager. Project wide shut downs have not been an issue so testing the limits has not occurred. The owner in the QA role on this project have more authority in relation to erosion and sediment control guidance as they control the erosion and sediment control ratings and incentives.

The partnering form and forum continues to be held with a level of mistrust as comments are often taken out of context, the underlying facts are not represented and there can be repercussions on comments made. In partnering meetings, people often do not speak up as their superiors are present and they are held accountable for what is said. There is a fundamental disconnect between comments made and the various category ratings.

The entire ICC project employs many thousands of professionals and laborers in the engineering, environmental, resource supply and labor support industries. Major roadblocks on the project include the lack of qualified personnel and resources due to companies spreading individuals and materials between the active contracts. This leads to the potential for an overly conservative approach to cover company liability, missing key information due to lack of experience and material that is not meeting quality standards. Personal preference of design reviewers and quality control inspectors also impedes progress. The process can be cumbersome when common sense does not prevail and traditional processes can't be expedited when minor modifications are made.

Design was separated into small packages that often phased construction between roadway, culvert and landscaping activities. This in turn phased the erosion and sediment control devices and LOD. This made for confusion between packages and set up the potential for the LOD or erosion control features to not match in subsequent packages resulting in awkward sequencing. Numerous field design changes (FDC) and 00C62 forms were a result of this and the contractor would prefer to combine the design packages if they could do it all over again. They also would install the final LOD the first time instead if interim LODs as this would eliminate the need to root prune trees at changing LODs and have the arborist review changing tree edges.

The NEPA process does not work well within the design/build context. The time needed for natural resource review, coordination of archeological and historical review, and state and federal highway review and approval processes is a long and cumbersome process for often small and changing LOD modifications design modifications (as compared to the FEIS) due to utilities, maintenance of traffic (MOT) and signs outside the mainline project LOD. While everyone on the ICC project team worked diligently to modify the NEPA process for the D/B environment more work should be done to further evaluate the process for future projects. There should be some way to expedite the review and approval process for minor project activities in areas such as existing roadway shoulders that have been previously disturbed.

<u>Summary</u>

Great environmental management success is achievable on a large scale project that has extreme natural resource and cultural sensitivity coupled with extensive agency, private interest group and community organization coordination. Sound management techniques including an interactive web-based management system assisted our environmental compliance and erosion and sediment control team in day-to-day compliance and avoidance and minimization impact tracking. Collaborative partnering and a solid training program that followed through with innovative design principals and best management practices is changing industry standards in construction especially in water quality methods used for erosion and sediment control.

Inclusion of the owner into documentation access of the web-based system allowed immediate review of environmental data in a desk top setting to ensure that compliance standards were being met and this open data sharing further enhanced the owner-contractor relationship and forged a partnership that helped expedite issues related to field design changes and modifications when construction issues such as sequencing and construction methods arose.

The most effective contractual means for the environmental management team is to have them report to an executive committee or the owner rather than to the contractor. The environmental management contract could be paid for by the contractor. The issue is the placement of accountability, responsibility and authority. This can be done through the executive committee and would give the environmental management team greater authority for quality control. This in conjunction with the contractor holding the regulatory permits in their name will further ensure that environmental compliance is met and exceeded.

The ECT is demonstrating on the ICC Contract A that though the system still is a work in progress, through compliance, communication and documentation and solid partnering, great success can be made to meet both NEPA and permit requirements to further avoid and minimize impacts throughout the entire design/build process.

TRAFFIC VOLUME AS A PRIMARY ROAD CHARACTERISTIC IMPACTING WILDLIFE: A TOOL FOR LAND USE AND TRANSPORTATION PLANNING

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Abstract

Based on an analysis of current literature, we developed a Traffic Volume Wildlife Tool that identifies different levels of traffic volume as a means to assess risk to various wildlife species groups, including amphibians, reptiles, birds, and mammals. Each level includes an assessment of when impacts to different species groups begin and when they become a serious threat. Traffic volume, or the amount of traffic using a road, poses substantial negative consequences for many wildlife species, especially as traffic levels increase. Road location and traffic volume are the two most important factors to assess when evaluating a road's potential impacts. Increases in traffic volume alter species composition, impedes animal movement, causes direct mortality, and fragments habitat. Based on the existing studies that quantify traffic volume and measure impacts to wildlife, we developed guidelines for use in planning. We discuss how changes in traffic volume affect habitat quality and animal behavior, and which types of species are most vulnerable. We recommend using these data and guidelines in land use and transportation planning and permitting.

Introduction

Roads play an increasingly important role in both supporting our social and economic welfare and determining the success of our conservation work. Roads enhance human social interactions and contribute to economic development by creating safe and efficient transportation routes for the goods and services we all need and use. They also provide access to jobs, our families, and recreation sites including remote areas.

On the other hand, roads have an enormous impact on wildlife and wildlife habitat. Although direct loss of habitat appears small from a landscape perspective, taking up only 1% of the U.S. land, the ecological impact is much greater affecting15-20% of the landscape (Forman and Alexander 1998). One of the most significant impacts of our road network on wildlife is habitat fragmentation (Forman 2006, Gibbs 1998, Vos 1997, Merriam et al. 1989). Animals move across the landscape to access the various habitat types needed for foraging, breeding, and resting. Roads can destroy established ecological connections, prevent necessary genetic exchange by isolating populations from each other, and for sensitive species increase the risk of extinction (Jaeger et al. 2007). In the White Mountains of New Hampshire, an analysis done for the U.S. Department of Agriculture Forest Service indicated that loss from highway kills was a factor in the extirpation of Canada lynx from the state (Brocke et al. 1993). Road mortality also was an important factor in the failure of an attempted reintroduction of Canada lynx to the Adirondack Mountains of New York in 1991 (Hoving et al. 2005).

Roads also reduce the size of core habitat and increase the amount of edge habitat, resulting in smaller wildlife populations (Raty 1979, Maine Department of Inland Fisheries and Wildlife 2003, Fleischman et al. 1997, Forman et al. 2003). Expanding edge habitat is detrimental to certain wildlife species because increased predation and human disturbance lowers breeding success and reduces habitat use. In addition, changes in microclimate occur far from the edge of the road and degrade habitat (Environmental Law Institute 2003).

Direct impacts of roads on wildlife include habitat avoidance (Forman and Alexander 1998) due to traffic noise interfering with breeding calls and songs (Reijnen et al. 1995, Reijnen et al. 1996), lights, and inhospitable surface; and wildlife-vehicle collisions (Lalo 1987, Ashley and Robinson 1996, Gonzalez-Prieto 1993 *In* Seiler 2003). Indirect impacts include changes in land use due to increased human access, chemical contamination from vehicle exhaust and road treatments (Trombulak and Frissell 2000, Buech and Gerdes U.S. Forest Service, Forestry Sciences lab, Grand

Rapids, Minn., unpubl. data *In* deMaynadier and Hunter 2000); and the spread of invasive plant species (Forman and Alexander 1998). Both the direct and indirect impacts of roads threaten wildlife populations and their persistence on the landscape.

The conflict between our need for safe and efficient roads and conservation of wildlife and wildlife habitat points out the need for tools that measure the potential risks to wildlife associated with roads and the development that goes with them. Roads through wetland areas are known to have impacts to water quality and wildlife. We have developed a tool to help planners and regulators determine where new roads should or should not be located or relocated, and determine which roads should or should not be upgraded for higher traffic levels.

Discussion

Measuring Road Impacts on Wildlife

We used the current available literature to assess what factor(s) would be most appropriate to use in developing a tool to predict impacts of roads on wildlife and wildlife habitat. Studies were taken predominately from Europe and North America and included a variety of habitat types. Although the science of road ecology is still emerging, we found original source data to evaluate impacts of road location, road surface (paved vs. unpaved), road width, road speed, and traffic volume on wildlife.

Road width and speed have an impact on wildlife but have not been found to be as significant as traffic volume (Jaeger et al. 2005). In general, narrower roads and roads with lower traffic speed have fewer impacts than wider roads or roads with higher traffic speed (Forman et al. 2003, Jaeger et al. 2005). Oxley et al. (1974) found road surface was not a critical inhibiting factor for mammals.

Road location was repeatedly found to be important in determining impacts of roads on wildlife (Compton 1999, Gonzales-Pretio et al. 1993 *In* Seiler 2003). The highest collision rates occur in undisturbed areas where development is not significant (Gonzales-Pretio et al. 1993 *In* Seiler 2003). Impacts from roads adjacent to or near wetlands are especially pronounced (Ashley and Robinson 1996, Glista et al. 2008). The number of species of plants, reptiles, amphibians, birds, and mammals declined between 12-19% as the density of roads increased near wetlands and the effects can extend between 1600 and 6500 feet (approx. 488 – 1,980 m) (Findlay and Houlahan 1997). In Maine, riparian habitats are used by 85% of the vertebrate species (Krohn and Hepinstall 2000) and are considered the skeleton or backbone of the landscape that, if protected will ensure that approximately 50% of Maine's wildlife will continue to persist (Krohn and Hepinstall 2000). Species often live, nest or den in the riparian habitat while others take advantage of the rich life in these areas for feeding or use them as travel corridors.

Traffic volume is especially important when evaluating road impacts to wildlife. Jaeger et al. (2005) conducted a quantitative analysis of impacts of various road characteristics on population persistence. Although vulnerability varies among species, he found that traffic volume had the greatest effect on population persistence (Jaeger et al. 2005) and was also an indicator of habitat fragmentation (Jaeger et al. 2007). Based on a review of 30 different papers that studied traffic volume impacts to various wildlife species (Table I) and Jaeger's work, we conclude that traffic volume is a key factor in determining impacts to wildlife.

Traffic Volume	Traffic Count Collection Method	Species	Level of Impact[1]	Location	Reference
120	AADT estimated by authors[2]	Southern Leopard Frog	Onset	Florida. USA	Palis 1994.
>100	Vehicles/lane/day[3]	Land turtles (includes Box, Spotted, Blanding's, Wood, Gopher Tortoise)	Substantial	Eastern & central regions, USA	Gibbs and Shriver 2002.
>200	Vehicles/lane/day[4]	Snapping Turtle	Substantial	Eastern & central regions, USA	Gibbs and Shriver 2002.

[1] Level of Impact increases from Onset →Substantial→Major Habitat Avoidance→Near Complete Barrier
[2] Calculated by Charry/Jones from study reporting 12 families on dead end road using estimate of 10 trips/single family home from ITE Trip Generation Manual (Institute of Transportation Engineers 2003)
[3] Density dependent (based on areas with > 1 km of roads/kmsq)
[4] Density dependent (based on areas with >2 km of roads/kmsq)

Traffic Volume	Traffic Count Collection Method	Species	Level of Impact[1]	Location	Reference
>250	Vehicles/lane/day [5]	Spotted salamander	Substantial	Massachusetts, USA	Gibbs and Shriver 2005.
300	Vehicles/day provided by landowner on private road	Salamanders	Onset	Maine, USA	deMaynadier and Hunter 2000.
300-500	Vehicles/day winter[6] only	Carnivores (includes coyote, wolf, cougar, lynx, marten, wolverine)	Onset	Central Canadian Rocky Mountains	Alexander et al. 2005.
300-2200	AADT	Snakes (primarily, gopher snakes, western rattlesnakes)	Substantial	Southeastern Idaho, USA	Jochimsen 2005.
336	Vehicles/day collected by traffic counter during study	Common Toad (Bufo bufo)	Onset	The Netherlands	van Gelder 1973.
500-3500	AADT	Frogs and Toads	Onset	Ottawa, Canada	Fahrig et al. 1995.
500-5000	Vehicles/day winter[7] only	Ungulates (includes elk, moose, sheep, deer)	Onset	Central Canadian Rocky Mountains	Alexander et al. 2005.
576-960	AADT estimated by authors[8]	Common toad (Bufo bufo)	Substantial	Germany	Kuhn 1987 *In* Reh and Seitz 1990.
624	Calculated from 26 cars per hour	Common Toad	Substantial	Germany	Heine 1987 *In* Reh and Seitz 1990.
700-3000	per 24 hour (methods unknown)	Birds, 4 species Tetraonid (grouse)	Onset	Finland Forest	Raty 1979.
835	AADT personal communication from author[9]	Amphibians	Substantial	New Brunswick, Canada	Mazerolle 2004.
1000	AADT Noise rises over 50 dB(A) at this traffic volume	Birds	Onset	The Netherlands	Forman 2003 based on studies by Reijnen 1995, 1996, 1997.
1068-3231	Summer AADT	Mammals, birds, amphibians	Onset/Substantial	Alberta, Canada	Clevenger et al. 2003.
1440	1 car/minute (extrapolated to 24 hour day)	Toad (Bufo bufo)	Substantial	The Netherlands	van Gelder 1973.
1900-6287	AADT	Primarily amphibians, reptiles, also birds, mammals (carnivores included coyote, mink, masked shrew, red fox)	Substantial	Indiana, USA	Glista et al. 2008.
2000-4000	AADT	Moose	Substantial	South-central Sweden	Seiler 2005.
2400	AADT estimated by authors[10]	Elk	Substantial	Arizona, USA	Gagnon et al. 2007.
3050	Average summer daily from Ontario Ministry of Transportation	Amphibians (Northern Leopard frog most common,) reptiles (Garter snake and painted turtle most common), birds (Red-winged blackbird most common), mammals (carnivores included short-tailed shrew, little brown bat, red bat, long-tailed and short-tailed weasel, mink)	Substantial	Ontario, Canada	Ashley and Robinson 1996.
3200	24 hour counts (April 1 – July) by Danish Road Directorate	Amphibians	Substantial	Northern Denmark	Hels and Buchwald 2001.

[5] Density dependent (based on areas with >2.5 km of roads/kmsq)
[6] AADT for these roads were reported as 3000 and 5000 but did not assess impacts to wildlife during peak/summer seasons.
[7] AADT for these roads were reported as 5000 and 14,000 but did not assess impacts to wildlife during peak/summer seasons.
[8] Calculated by Charry/Jones from study reporting 24-40 cars per hour
[9] Night traffic volume collected by traffic counter 13.6 vehicles/hour, range 5-26 vehicles/hour at night
[10] Calculated by Charry/Jones from permanent traffic counter recording mean traffic volumes of 100 vehicles/hour.

Traffic Volume	Traffic Count Collection Method	Species	Level of Impact[1]	Location	Reference
4000-6000	AADT	Moose	Substantial	South-central Sweden	Seiler 2005.
4560	Cars per average weekday	Grassland birds (lapwing & godwit)	Substantial	The Netherlands	van der Zande et al. 1980.
4700	AADT	Wolf	Substantial	Wisconsin, USA	Unger 1999 *In* Kohn et al. 2000.
5000	AADT Steep increase in noise level at this traffic volume	Birds	Substantial	The Netherlands	Forman 2003 based on studies by Reijnen 1995, 1996, 1997.
5000	Cars per day	Grassland birds	Substantial	The Netherlands	Reijnen et al. 1996.
5000-6000	AADT	Frogs and Toads	Substantial	Ottawa, Canada	Fahrig et al.1995.
6000 +/-	AADT estimated by authors[11]	Turtles including, fully or semiterrestrial, small-bodied and large-bodied pond turtles	Near Complete Barrier	USA	Gibbs and Shriver 2002.
7000 - 20,000	Number of vehicles entering the park in July and February respectively, underestimate	Snakes (Ribbon snake, Garter snake, Florida water snake, Cottonmouth)	Near Complete Barrier	Florida, USA	Bernardino and Dalrymple 1992.
7311	Vehicles per average weekday	Grassland birds (lapwing & godwit)	Substantial	The Netherlands	van der Zande et al. 1980.
8000-15,000	AADT	Grassland birds	Substantial	Massachusetts, USA	Forman et al. 2002.
8200	AADT calculated by authors[12]	Turtles	Near Complete Barrier	Florida, USA	Aresco 2005.
8500-13,000	AADT	Frogs and Toads	Substantial/Near Complete Barrier	Ottawa, Canada	Fahrig et al. 1995.
10,000	Vehicles/day	Terrestrial vertebrates	Near Complete Barrier	Europe	Seiler 2003. Many references cited.
10,000	AADT Nearly 70 dBA at this traffic level, then gradual increase in dBA as traffic volume increases level	Birds	Major Habitat Avoidance	The Netherlands	Forman 2003 based on studies by Reijnen 1995, 1996, 1997.
10,000	Vehicles/day	Woodland birds	Major Habitat Avoidance	The Netherlands	Reijnen et al. 1995.
10,000	Vehicles/day	Birds, woodland & grassland	Major Habitat Avoidance	The Netherlands	Reijnen et al. 1997.
10,000-100,000	Vehicles/day	Migrating salamander	Near Complete Barrier	Massachusetts, USA	Gibbs and Shriver 2005.
11,000	AADT	Small mammals	Near Complete Barrier	Ontario, Canada	McGregor 2003.
14,000	AADT	Mammals, birds, amphibians	Near Complete Barrier	Alberta, Canada	Clevenger et al. 2003.
14,400	AADT estimated by authors[13]	Elk	Major Habitat Avoidance/ Near Complete Barrier	Arizona, USA	Gagnon et al. 2007.
15,000	Vehicles/day used in model to represent busy highway	Amphibians	Near Complete Barrier	Northern Denmark	Hels and Buchwald 2001.

[11] Calculated by Charry/Jones based on assumption that "several thousand vehicles/lane/day" equals 6000+/-
[12] Calculated by Charry/Jones based on 162% increase AADT occurring from 1977 to 2001.
[13] Calculated by Charry/Jones based on permanent traffic counter recording mean traffic volumes of 600 vehicles/hour.

Traffic Volume	Traffic Count Collection Method	Species	Level of Impact[1]	Location	Reference
15,000-30,000	AADT	Grassland birds	Major Habitat Avoidance	Massachusetts, USA	Forman et al. 2002.
21,500	AADT	Turtles	Near Complete Barrier	Florida, USA	Aresco 2005.
>=30,000	AADT	Grassland birds	Major Habitat Avoidance	Massachusetts, USA	Forman et al. 2002.
50,000	Cars per day	Grassland birds	Major Habitat Avoidance	The Netherlands	Reijnen et al. 1996.
50,000	Vehicles/day	Birds, woodland & grassland	Major Habitat Avoidance	The Netherlands	Reijnen et al. 1997.
54,000	Cars per average weekday	Grassland birds (lapwing & godwit)	Major Habitat Avoidance	The Netherlands	van der Zande et al.1980.
60,000	Cars per day	Woodland birds	Major Habitat Avoidance	The Netherlands	Reijnen et al. 1995.

Table I: Levels of Impact to Wildlife from Various Traffic Volumes (Ranked Low to High) on Species or Groups of Species.

Traffic Volume as a Tool for Measuring Road Impacts to Wildlife

Traffic volume is regularly measured by state transportation departments to assess the need for road improvements and is therefore often readily available. Traffic engineers use Average Annual Daily Traffic (AADT) to measure traffic volume. True AADT volume is measured at permanent stations and counts every car, every day, and calculates the average for the year. AADT volumes can also be estimated by sampling (e.g. counting during certain times) and then adjusting the count using various factors (seasonality of use, type of use - urban vs. rural etc.). Finally, traffic volume can also be estimated into the future, albeit with less certainty, using various assumptions and data collected on similar types of roads from across the United States and reported in the ITE *Trip Generation Manual* (Institute of Transportation Engineers 2003).

Although AADT is the most easily collected and comparable measure of traffic volume, it is not available for all roads. Therefore, many studies that measured impacts of traffic on wildlife populations collected their own information on traffic volume using traffic counters during their studies (Mazerolle 2004, van Gelder 1973) while others simply did not identify whether or not the measure was AADT (Raty 1979, Reijnen et al. 1995, Reijnen et al. 1997, deMaynadier and Hunter 2000). While traffic counts are not true AADT, it is a useful measure of traffic volume observed during the study period and was included as part of our analysis to determine impacts to wildlife and wildlife habitat. It is important to note that traffic volume can vary greatly by season and time of day, as can wildlife movements. Our analysis used all types of traffic measures in order to include the most information on impacts.

We identified different levels of impacts to wildlife based on traffic volume (Table I). The risk of impacts was assessed for various groups of wildlife species, including amphibians, reptiles, birds, and mammals. Each level of risk included an assessment of when impacts to different species groups would likely begin and when it was likely to become a serious threat.

Amphibians

Many amphibians, such as the spotted salamander and wood frog, travel regularly between wetlands, where they breed, and uplands, where they live during the non-breeding season. This movement pattern makes them vulnerable to road mortality and habitat fragmentation. Amphibians are particularly vulnerable to road mortality at relatively low traffic volumes (van Gelder 1973, Kuhn 1987 *In* Reh and Seitz 1990, Heine 1987 *In* Reh and Seitz 1990), are killed in large numbers on roads going through or adjacent to wetlands (Ashley and Robinson 1996, Glista et al. 2008), have been documented to avoid crossing roads (deMaynadier and Hunter 2000), and are highly sensitive to chemical contamination (Buech and Gerdes, U.S. Forest Service, Forestry Sciences Lab, Grand Rapids, Minn., unpubl. Data *In* deMaynadier and Hunter 2000).

Reptiles

Snakes and turtles are particularly vulnerable to impacts from roads. They have similar life histories, including terrestrial travel between breeding and nonbreeding habitats, and relatively long life with slow reproduction rates. In one study, 73% of the snakes observed on the road were found dead or injured at traffic volumes of 7,000 to 20,000 (Bernardino and Dalrymple 1992). According to Gibbs and Shriver (2002, p. 1649), it is likely that "as little as 2-3% additive annual mortality is more than most turtle species can absorb and still maintain positive population growth rates". Compton (1999) found that, for Maine wood turtle populations, loss of only two adults from a population can devastate that population and are they are especially vulnerable to being killed by vehicles (Klemens 1989 *In* Compton 1999). Gibbs and Shriver (2002) concluded that land-use planners should perhaps consider near roadlessness as a criterion for habitat suitability for land turtles. "This perhaps places land turtles and, in some situations, large-bodied pond turtles in the company of grizzly bears and gray wolves as fauna for which road networks may be a key limiting factor to population recovery efforts" (Gibbs and Shriver 2002, p. 1651).

Birds

Mortality from bird-vehicle collisions is a significant issue. It is estimated that 80 million birds are killed annually in the United States (Erickson et al. 2001). For example, Glista et al. (2008) found 34 dead chimney swifts along a road bisecting a bog which were probably the result of low-flying birds striking vehicles while pursuing insects. Many bird species have been documented to avoid habitat adjacent to roadways at increasing levels as traffic intensity increases. At traffic volumes of 1000 AADT, breeding populations of woodland birds begin to decline, and at traffic volumes of 10,000 AADT, breeding populations of birds in coniferous habitat were reduced as far as 30-1500 m from the road. (Reijnen et al. 1997).

Mammals

Wide-ranging mammals such Canada lynx, gray wolves, moose, bear, bobcat, fisher, and American marten have large home ranges in which to find food, breed, and raise their young. They often must cross and re-cross roads to access all parts of their home range and to disperse to new territories, making them vulnerable to collisions with vehicles (Ashley and Robinson 1996, Glista et al. 2008). For example, a study from 1970-2005 in Wisconsin showed a high percentage of wolf mortality was associated with human causes (70.6%), with vehicle collisions higher than any other cause (31.2%) (Wisconsin Dept. of Nat. Resources 2007). Moose-vehicle collisions peak at traffic volumes between 4000-6000 vehicles per day (Seiler 2003). Due to habitat fragmentation and mortality to carnivores, wildlife crossing structures are recommended at traffic volumes of 2000-3000 AADT (Ruediger et al. 1999). Many species of both carnivores and ungulates have also been found to avoid crossing roads (Alexander et al. 2005) or locate breeding activities away from major highways (Unger 1999 *In* Kohn et al. 2000). Fisher were found to use roads as the perimeter of their home ranges (Arthur et al. 1989). As traffic volume increases, habitat adjacent to roads is avoided by elk (Gagnon et al. 2007).

Determining Impact Thresholds

We reviewed the studies summarized in Table I to identify the severity of impacts to wildlife at different traffic volumes. Although impacts from increasing traffic volumes actually occur along a continuum (Figure 1), we identified thresholds to provide clear guidance to land use and transportation planners.

Studies were organized by increasing traffic volume (Table I) and then assessed for severity of impacts and categorized as one of the following; onset, continuum of substantial impacts, major habitat avoidance, and near complete barrier. Although individual species exhibit unique responses to traffic volume, for the purposes of this paper each species was evaluated as a part of a species group (amphibians, reptiles, carnivores, ungulates, and birds). The severity of the impact was used to determine natural breaks in traffic volume that could function as thresholds. These breaks are summarized in Table II. Impacts we assessed included road mortality, wildlife-vehicle collisions, extent of population reduction, barrier effects, and adjacent habitat avoidance.

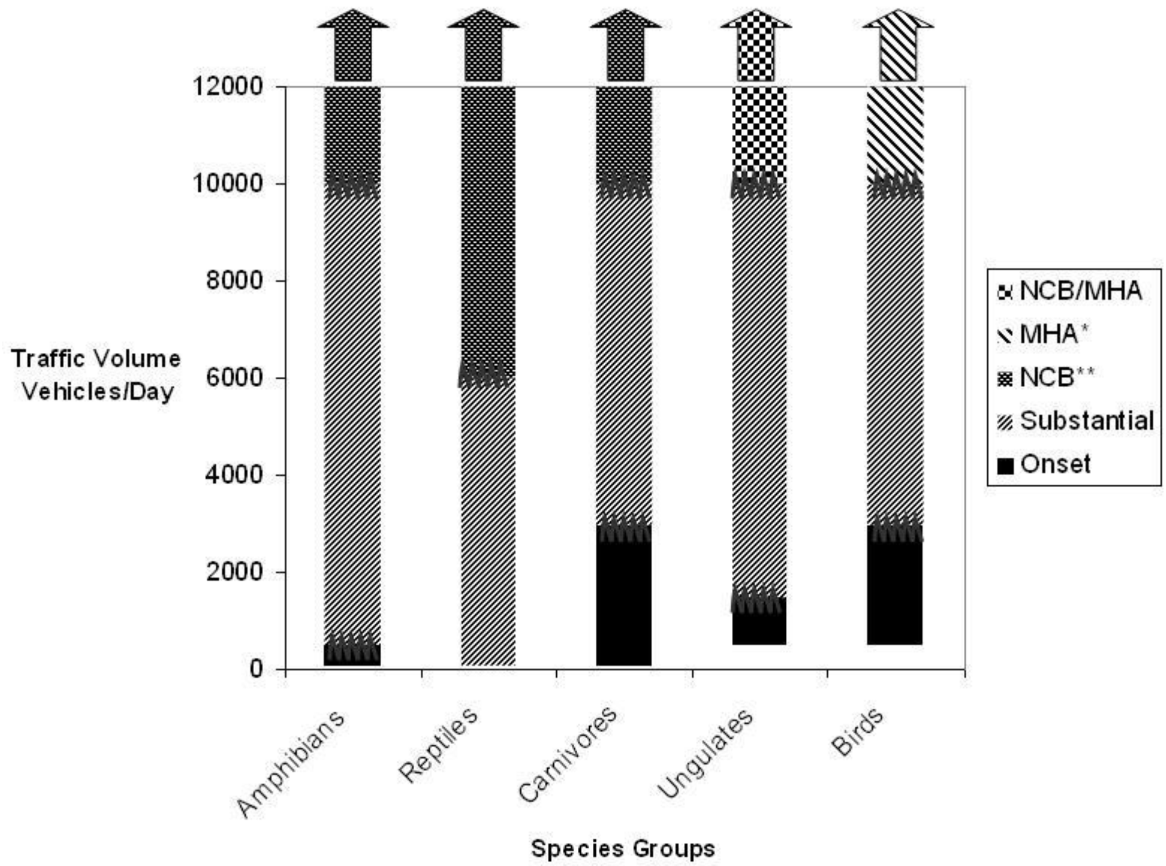

Figure 1: Continuum of Impact to Species. Impacts for five different species groups (Amphibians, Reptiles, Carnivores, Ungulates and Birds) are shown for different traffic volumes (vehicles/day). Impacts for each species group occurred across a continuum but include thresholds for five different levels of severity; Onset, Substantial to Severe impacts, Major Habitat Avoidance (MHA) and Near Complete Barrier (NCB). [^^^] thresholds are provided for guidance and occur over a range of traffic volumes.

Vehicles/Day	Onset of Impacts	Continuum of Substantial Impacts	Major Habitat Avoidance	Near Complete Barrier
100-500	Amphibians Carnivores	Amphibians[14] Reptiles		
500-1500	Ungulates Birds	Amphibians (increases for reptiles)		
1500-3000		Ungulates (increases for amphibians & reptiles)		
3000-6000		Carnivores Birds (increases for amphibians, reptiles, ungulates)		
6000-10,000		Increases for amphibians, carnivores, ungulates, birds		Reptiles
10,000+			Birds Ungulates	Amphibians, Reptiles, Carnivores, Ungulates Small mammals

Table II: Traffic Volume Impacts on Wildlife at Different Thresholds

[14] Road density dependent

Onset of Impacts

Onset of adverse impacts for amphibians began at traffic volumes of 100 AADT. In this traffic volume range, mortality of up to 50% of amphibians was observed on the road (Palis 1994, van Gelder 1973), or was a significant barrier to amphibians (deMaynadier and Hunter 2000). Onset for carnivores and ungulates was defined as detectible reduction in habitat permeability (change in rates of animal movement) and began at traffic volumes of 100-500 AADT (Alexander et al. 2005). Alexander et al. (2005) used winter tracking studies and found that roads began to present a barrier effect for carnivores (coyote, wolf, cougar, lynx, marten, and wolverine) and ungulates (elk, moose, sheep, deer). As groups, these species were less likely to cross and more likely to make multiple approaches to roads in an attempt to cross at winter traffic volumes (Alexander et al. 2005). Woodland birds were documented as starting to avoid habitat (i.e. reduced densities) at 42 dB(A) (Reijnen et al. 1995). We determined the onset of impacts for woodland birds at traffic levels of 1000 vehicles/day because Forman et al. (2003) reported that noise levels over 50 dB(A) occur at this traffic volume. Impacts to grassland birds occurred at lower traffic volumes than with woodland birds. Avoidance is caused by traffic noise which is louder as traffic increases and travels farther through grasslands than woodlands.

Continuum of Substantial Impacts

Impacts within this category generally increased along a continuum from substantial to more severe with increasing levels of traffic volume. We looked for a change in severity of impacts within a species group to determine the beginning of a new threshold of impact (Table II).

Impacts to reptiles were determined significant when annual adult mortality rates resulted in a population decline for turtles (Gibbs and Shriver 2002). For snakes, Jochimsen (2005) compared 15 studies that counted snakes found dead-on-road (DOR) and then determined snake mortality within his study area as “intermediate” which we considered a significant impact.

Significance was identified for amphibians in studies observing successful versus unsuccessful road crossings with >= 50% mortality (Kuhn 1987 *In* Reh & Seitz 1990, Heine 1987 *In* Reh & Seitz 1990, Mazerolle 2004), studies documenting >= 6.7 individuals DOR/km/day (Glista et al. 2008, Ashley and Robinson 1996), or population studies documenting >=25% road mortality of moving breeding adults (Gibbs and Shriver 2005, van Gelder 1973, Hels and Buchwald 2001). Migrating spotted salamanders were unable to sustain road mortality levels of 20-30% of moving adults, leading to local population extirpation within 25 years (Gibbs and Shriver 2005).

Increased impacts as traffic volume increases as a continuum for amphibians was demonstrated in several studies. Fahrig et al. (1995) compared traffic volume ranges of 500-3500 to 5000-6000 to 8500-13,000 AADT and measured populations of frogs and toads and found significant negative impacts on local density and mortality based on three factors; 1) the number of dead and live found per km decreased as the AADT increased; 2) the proportion of dead increased as the AADT increased; and 3) the density decreased with increasing AADT. Mazorelle (2004) found that American toads were found DOR in larger number with increasing traffic during night driving surveys. These increases are apparent in road mortality studies that documented road mortality on roads adjacent and through riparian habitat. Road cruising surveys documenting all species encountered (>60 species), found that 95% DOR were amphibians and reptiles (Glista et al. 2008). At traffic volume of 1900 AADT, 4.6 herptiles were found DOR per km per day and at traffic volume of 6287 AADT 36 herptiles were found DOR per km per day. A similar study through a wetland in Ontario using walking and bicycling surveys, documented 100 species DOR of which 92.1% were amphibians and averaged 11.65 amphibians DOR per km per day at 3050 AADT (Ashley and Robinson 1996).

Ungulate impacts were considered significant when collisions were greater than10 moose-vehicle collisions per 100 km at 2000 AADT (Seiler 2005) or when the average probability of elk occurrence within 200 m of the road was approximately 40% (Gagnon et al. 2007). This probability of habitat use decreased as traffic volume increased. Highest frequencies of collisions were 16.7 moose-vehicle collisions per 100 km at traffic volumes of 4000-6000 AADT (Seiler 2005).

Road mortality of carnivores was particularly high between 3000-6000 AADT in habitats adjacent and through wetlands. Glista et al. (2008) and Ashley and Robinson (1996) both documented carnivore mortality, including coyote, mink, shrew, weasel, fox and bats, on roads adjacent to wetland habitats on roads ranging from 1900-6287 AADT. Clevenger et al. (2003) documented a higher vulnerability to road mortality for mammals, including coyote, American marten, and mink, on a road with traffic volumes of 1068-3231 summer AADT than a major highway with traffic volumes of 14,000 AADT. In addition, wolves located their dens in the center of their territories away from roads with traffic volumes of 4700 AADT (Unger 1999 *In* Kohn et al. 2000).

For grassland birds, a steep increase in road noise occurs at about 5000 vehicles per day (Forman et al. 2003) resulting in a reduction in breeding density and reduction of populations in habitat adjacent to roads within 20-1700 m (Reijnen et al. 1996, van der Zande et al. 1980). Population loss was estimated to be 12-56% within 100 m of roads for most species studied, and beyond 100 m population loss was estimated to be > 10% (Reijnen et al. 1996). Black-tailed godwit population declined 22% from 0-500 m and oystercatcher declined 44% from 0-500 m and 36% from 0-1500 m. Although one study (Forman et al. 2002), did not find a significant impact on the distribution of grassland birds at traffic levels of 3000-5000, densities and population declines have been documented elsewhere (Reijnen et al. 1996). Road mortality for birds was also documented on a continuum on roads with lower traffic volume (1068-3331 summer AADT) to higher traffic volume (14,000 AADT), with roadside foragers most frequently killed (Clevenger et al. 2003).

Major Habitat Avoidance

Birds and ungulates respond to increased traffic volume through major habitat avoidance (MHA), which is a decrease of habitat use and/or reduced population densities in habitats adjacent to roads (Table I). As the traffic volume increases, bird population density continues to decline farther from the road (Forman et al. 2003) and the probability of habitat use by ungulates declines (Gagnon et al. 2007). We used this impact to define MHA for these two species groups (Table II).

In grassland birds, noise is also an important factor but visual stimuli cannot be excluded for certain (Reijnen et al. 1997). Forman (2003) reported noise levels increase to nearly 70 dB(A) at traffic volumes of 10,000 AADT. At this traffic volume, grassland bird species had population reductions at a distance of up to 2180 m from roads (365 m when probable unrealistic values are excluded) (Reijnen et al. 1997). At traffic volumes of 50,000 vehicles/day there were increasing impact distances to a maximum of 3530 m (930 when probable unrealistic values are excluded) from roads (Reijnen et al. 1997) and an estimated population decrease of 12-52% within 500 m from the road and five species had population reductions of 14-44% up to 1500 m from the road (Reijnen et al. 1996). These findings are supported in other studies (Forman et al. 2002, van der Zande et al. 1980).

In woodland habitats, noise is the most critical factor causing reduced densities of birds along roads (Reijnen et al. 1995). Sixty percent of the woodland species studied had reduced densities of 20-98% within 250 m of road (Reijnen et al. 1995). MHA for woodland birds was defined as occurring at traffic volumes of 10,000 AADT when researchers observed a reduction in breeding bird densities at distances of 40-1500 m from the road (305 m when probable unrealistic values are excluded) (Reijnen et al. 1997). Impacts continued to increase with increasing traffic volume and at 50,000 AADT MHA occurred up to 2800 m from road (810 m when probable unrealistic values are excluded) (Reijnen et al. 1997).

MHA for ungulates occurred when the mean probability of habitat use within 200 m of road declined to <20% (Gagnon et al. 2007).

Near Complete Barrier

For most species, roads with traffic intensity over 10,000 vehicles per day become a near complete barrier (NCB) for movement. Though an individual animal may be able to safely cross a high volume highway one or more times, the odds of a successful crossing are slim. Time of day, time of year, the speed and behavior of the animal, and its ability to make intelligent crossing decisions all influence the outcome. However, one safe crossing does little to counter the cumulative multiple negative impacts to local and regional populations that occur on and adjacent to the road, in some cases hundreds or thousands of meters.

Seiler (2003, p. 29) identified roads with traffic volumes of 10,000 AADT as an “insurmountable barrier” and cites several sources. Gibbs and Shriver’s (2005, p. 288) model found these roads to be “wholly lethal” to migrating salamanders. Hels and Buchwald (2001) calculated a 0.89-0.98 probability of mortality when amphibians attempt to cross a 15,000 AADT road and essentially a complete barrier (probability of mortality reaching 1.0) at traffic volumes above this level. For terrestrial and semi-terrestrial, small and large-bodied pond turtles, modeling work identifies roads with traffic volumes of 10,000 AADT or more as essentially impenetrable (Gibbs and Shriver 2002). Using Gibbs and Shriver’s model (2002) modified from Hels and Buchwald (2001), Aresco (2005) estimated approximately 68% probability of mortality for turtles on a road with a traffic volume of 8200 AADT. Traffic increased to 21,500 AADT (a 162% increase) from 1977 to 2001 resulting in a probability of 98% mortality of turtles. The results were verified by field surveys in the same location documenting 100% mortality (Aresco 2005). Clevenger et al. (2003) concluded that lower bird and mammal road-kills on the road with traffic volume of 14,000 AADT was probably due to avoidance of the highway. No relocated small mammals returned across a road with traffic volume over 11,000 AADT whereas some successfully returned on roads with as much as 7000 AADT (McGregor et al. 2003).

Recommendations for Use of the Traffic Volume Tool in Land Use Planning

Traffic volume and road location were the two most important factors in determining impacts to wildlife. Traffic volume can be readily measured and used to determine how various patterns of development will impact wildlife and wildlife habitat. Although we have identified thresholds of impacts, it is important to note that impacts increase over a continuum and thresholds may need to be adjusted to avoid impacts to wetland-dependant species or endangered species.

It is also important to recognize impacts occur beyond the immediate access roads of a proposed development or beyond road segments scheduled for upgrades. Ruediger et al. (1999) recommended that highway agencies should increase the planning scale to at least the entire highway length in the northern Rocky Mountains and in other areas where carnivores are a concern. Traffic impacts will occur miles beyond a proposed development and should be taken into consideration. For example, assessment of impacts from resorts and lodging development within remote areas should include roads used for travel to and from airports, major highways, and recreation destinations that are likely to be visited by potential customers of the resort.

We offer the following concepts and recommendations to assist land use planners, conservationists, and developers in minimizing road impacts to wildlife and maximizing conservation benefits.

Land Use Planning Concepts for Avoiding Impacts of Traffic on Wildlife:

1. Avoid road building in large undeveloped habitat blocks and remote areas (*consider road closures*)
2. Avoid increased traffic volumes on roads in rural and remote areas (*prevent development that requires access through large undeveloped habitat blocks and remote areas*)
3. Concentrate traffic on existing highly traveled roads
4. Avoid locating new roads near wetlands, ponds, lakes, rivers, and streams

Recommendations for Implementing Traffic Volume Tool into Land Use Planning:

1. Concentrate new traffic on existing high volume roads (particularly roads approaching 10,000 vehicles/day)
2. Avoid increasing traffic to 3000-6000+ vehicles/day range
3. Limit new traffic on low use roads (e.g. 500-1500 vehicles/day) in rural and remote areas to less than 2000-2500 vehicles/day
4. Limit new traffic on remote/logging roads to less than 300-400 vehicles/day
5. On existing roads that bisect or occur near wetlands, ponds, lakes, rivers and streams, avoid increasing traffic volume above its current threshold range
6. On existing roads, use wildlife-crossing structures to facilitate animal movement. (*NOT a solution to allow poorly located roads*)

These concepts and recommendations incorporate road location and traffic volume in order to minimize the impacts to wildlife and to help avoid fragmenting habitats of species vulnerable to increased traffic.

Conclusions

Most species are impacted by traffic volume, however different impacts are present at various traffic volumes. Traffic volume can be used as a tool to assess overall risk to wildlife and wildlife populations in order to help planners and regulators make informed decisions on how to better conserve species across the landscape. Traffic volume has the clear advantage in that it is readily measured and can be realistically used to compare roads and predict changes and determine baseline volumes. In addition, this measure is often readily available from state transportation agencies at least on many roads, is a tool regularly used by traffic engineers, and is broadly used by the scientific community to estimate impacts to wildlife. We recommend that researchers, in future studies, include AADT or estimates of AADT in addition to seasonal counts or counts taken during a study. AADT estimates will allow studies to be easily compared and can assist in further refining the thresholds determined in this paper.

Biographical Sketches

Barbara Charry is a Wildlife Biologist and GIS Manager at Maine Audubon with 20 years experience in endangered species management, natural history information, and information management. She holds a B.A. from Grinnell College and an M.S. from Antioch New England Graduate School. She has worked as an interpretive naturalist, wildlife rehabilitator, field biologist, and grassroots activist coordinator. Over the last 10 years, the focus her work has been the impacts of sprawling development on Maine's wildlife. Much of her work on road ecology has involved researching and synthesizing scientific information and sharing it with local, regional and state decision-makers. She became a state leader in this work in 2001 when Maine Audubon became a founding partner of Maine's nationally acclaimed Beginning with Habitat program, an innovative public/private partnership that provides practical tools for Maine communities to incorporate wildlife and habitat conservation into local land use planning. Under Barbara's leadership, Maine Audubon convened the first-ever state-wide conference on road ecology in Maine. She has also presented at the International Conference on Ecology and Transportation. She presented expert testimony on road impacts at public hearings on Plum Creek's massive development proposed for Maine's Moosehead Lake region. She has written several guides for land use decision makers and community members on the impacts of development on wildlife including a community conservation guide, "Conserving Wildlife On and Around Maine Roads".

Jody Jones is a wildlife ecologist with experience in policy issues regarding endangered and threatened species, migratory birds and bats, ecology of coastal beaches, wetland and riparian habitats and toxics in the environment. She also directs the recovery of endangered Piping Plovers and Least Terns in Maine. Jody holds a B.S. in natural resources and a M.S. in wildlife ecology and management from the University of Michigan, where she conducted research on the wintering ecology of waterfowl. She has taught courses in ornithology, mammalogy and the coastal ecology of Maine. In her tenure at Maine Audubon, Jody has provided expert testimony before the Board of Environmental Protection, Land Use Regulation Commission, U.S. Fish and Wildlife Service and the Maine legislature on a variety of issues including impacts of wind power on wildlife, risks associated with coyote snaring to rare species, dune and beach habitat protection and the recovery of Atlantic salmon, Canada lynx and wolves.

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INTEGRATING ENVIRONMENTAL CONCERNS WITH THE PLANNING AND CONSTRUCTION OF THE SOUTH EXTENSION OF INTERSTATE 355 INTO WILL COUNTY, ILLINOIS

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Abstract

Highway agencies face environmental challenges in achieving responsible growth while simultaneously protecting the environment. On September 30, 2004 the Illinois Tollway Board of Directors approved a $6.3 billion dollar capital program which included the highway extension of Interstate 355 from Interstate 55 to Interstate 80. The new 12.5 mile extension serves Will County, one of the fastest growing counties in Illinois and would potentially impact some of the most environmentally sensitive species in the region. The I-355 South Extension included the construction of a 6 lane, 1.3 mile long bridge over the highly sensitive Des Plaines River Valley. In an effort to address agency concerns, the Illinois Tollway established an environmental team consisting of University of Illinois and South Dakota scientists, the U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, the Illinois Department of Natural Resources, Will Cook and DuPage County Forest Preserve Districts and the ecological and engineering firm AECOM.

The Des Plaines River Valley is home to several federal and State protected species including but not limited to the state threatened Blanding's Turtle, the federally endangered Hine's Emerald Dragonfly and the federally endangered Leafy Prairie Clover. In order to avoid and minimize the impacts on these species the Tollway developed nine ways to build an environmental team. The I-355 environmental team worked to successfully address issues such as wetland mitigation, species mitigation and research, regional multi-use trail connections as well as identified new ways to coordinate and communicate issues along the corridor. The environmental team building approach helped the Tollway deliver a new 12.5 mile, $730 million dollar, six lane Tollway facility, on time, within budget all while minimizing impacts to the natural and physical environment.

Disclaimer: The contents of this paper reflect the views and experience of the author while employed at the Illinois State Toll Highway Authority (Illinois Tollway). This paper is not an official agency statement.

Introduction

The construction of a new interstate creates an enormous transportation challenge: achieving responsible growth by providing an opportunity for safe and efficient travel and simultaneously protecting the environment. As part of each political administration or with the passage of a state capital program, a comprehensive transportation plan is developed for modernizing and rebuilding the state's transportation network. As in every state, Illinois' construction activities cannot move forward without approval from various Federal and State resource and regulatory agencies as well as support from environmental advocacy groups and the general public. The Environmental Unit for the Illinois State Toll Highway Authority (Illinois Tollway) works to meet this challenge in an effort to demonstrate stewardship, comply with environmental regulations and secure environmental permits necessary for highway construction. However, the lack of flexible environmental regulations, current scientific research coupled with a general mistrust of transportation agencies prohibits the creation of working agency partnerships in order to incorporate environmental benefits into a highway project.

The Federal Highway Administration (FHWA), the Army Corps of Engineers (ACOE) and the U.S. Fish and Wildlife Service (FWS) encourage the avoidance of sensitive habitats and aquatic areas, including wetlands but unavoidable impacts caused by road construction must be mitigated. In essence, replace, restore and enhance the environment that has been destroyed as a result of the transportation project. Although this concept appears easy to understand and implement; it is a very difficult undertaking due to complex agency dynamics, geographic constraints and the negative public perception of a highway agency. Addressing governmental and public concerns while meeting environmental regulations is a challenging task. Transportation and environmental planners responsible for these functions must develop ways to strengthen agency relationships by demonstrating system-wide stewardship, accountability and incorporating agency and community recommendations into highway improvements.

The strengthening of these relationships requires creative thinking, courage, monetary resources and the ability as well as support to follow through with commitments. Traditionally, transportation agencies address their immediate needs on a project-by-project basis. This approach results in a large number of roadway permit applications submitted within the same county, corridor and project vicinity. Thus, a new proactive strategy is needed to educate involved parties and encourage open, interactive collaboration and consultation as part of a streamlined approach to plan, design and construct highway projects.

The approval of the Tollway's $6.3 billion dollar program required a new way of doing business in order to meet the agency's schedule for construction. As a result, the Environmental Unit created nine ways to build an environmental team in an effort to effectively secure permits, avoid sensitive resources and develop an acceptable mitigation strategy approved by state and federal resource and regulatory agencies. By the creation of environmental teams, agencies and advocates are invited to learn about a project, highlight areas of concerns and build positive relationships with involved parties. Environmental team building is the first step to improve efficiency, streamline the permitting process, learn from past experiences and create a trustworthy working atmosphere. Environmental team building has become a way of doing business at the Illinois Tollway. As a result of the team building process, the South Extension of Interstate 355 received roadway permits in a timely fashion, incorporated measures to protect adjacent resources and in the process, agency representatives established an improved working relationship.

Discussion

Traditional Environmental Approach

Unfortunately, environmental issues are currently addressed and discussed in the context of legislation created in the 1960's, the National Environmental Policy Act (NEPA). NEPA covers a broad range of important but limited environmental and community issues. A product of the NEPA process is an Environmental Assessment or Environmental Impact Statement; a document that describes ways to avoid, minimize and mitigate impacts to the environment and surrounding communities relative to the proposed project. The NEPA process allows transportation agencies to integrate environmental values into their decision making processes by considering the impacts of proposed actions and reasonable alternatives to those actions. The NEPA process began at a time when meeting the transportation needs of urban areas generally meant providing enough highway capacity to accommodate the increasing demand for automobile travel (Meyer and Miller, 1984). As a result, highway projects continue to be assessed with a rigid linear approach to environmental and transportation planning.

Upon the initiation of a roadway project, the highway agency's planning and environmental staff immediately begins dialogue with adjacent property owners, communities, local elected officials, state and federal agencies. All parties are engaged early in the process with hope to build support and to explain the impacts of a transportation project. Throughout the planning and design processes various engineering alternatives are reviewed while agency and community concerns may be incorporated into the roadway design (NCHRP, 2002). In addition, sensitive environmental resources are identified and methods to avoid, protect and mitigate impacts are discussed. Unfortunately, this process of transportation planning and design are flawed because the environmental impacts are addressed on a project-by-project basis and the assessment of non-linear environmental resources begins after a project alternative is in mind.

In Illinois, highways are often viewed as the engines of economic growth and development. Environmental resources are often viewed as constraints on the expansion of the transportation system; they also have been seen as potential brakes on economic growth. Too often a debate occurs between local communities, transportation agencies and the environmental agencies once a highway project is proposed. One side seeks to implement a roadway improvement in terms of capacity expansion and new interstate construction and the other side seeks to protect natural resources within the project area. The situation can lead to bad feelings, mistrust and unwillingness to work together. Decision-makers drag out the process in fear of public backlash, environmental entities may threaten to sue and more often than not the tension escalates. This can be avoided by integrating traditional environmental and transportation planning processes with environmental team building and a new collaborative approach. Environmental planners charged with leading and guiding the team building process must focus the discussion on the agency representatives and the concerns of their organizations. The team building process is and should always be about people and their concerns not solely the highway project and its impacts.

Environmental Team Building

The successful design and construction of a transportation project depends on each entity's participation but also their willingness to play an unfamiliar role in a new collaborative process. Federal, state and local agencies are asked to form unconventional relationships in an effort to implement changes, meet commitments and adhere to environmental regulations. Local planners and environmental groups must work side-by-side with the resource, regulatory and transportation agencies. Oftentimes, each agency differs in its policy perspective however issues such as wetland mitigation and species impacts require the knowledge and experience across disciplines in order to address the needs of a transportation agency and ultimately gain the approval or support of environmental agencies.

Environmental team building creates opportunities where relationships amongst transportation stakeholders should strengthen. Local communities and environmental advocates are encouraged to provide input early in the planning process by creating an open working environment throughout the duration of a project. Providing input and creating opportunities for discussion is just the beginning of the process. Academic and funding resources must be identified for species and habitat surveys and research. Financial resources must also be dedicated for environmental protection during and post construction. Transportation engineers as well as management officials must be educated so they understand the importance of research, avoidance, protection and quality mitigation. This process must extend into plan development, alternative analysis, construction and maintenance as well as long-term monitoring. An open and continuous dialogue is essential to developing agency and community partnerships. Building and fostering these relationships requires a continued level of trust and commitment not only from the transportation agency and its professionals, but also from the environmental planner who leads this effort. Ultimately, it is the person/representative that people come to know and trust, not the organization. The environmental team building approach helps develop a transparent process in which people may openly and freely collaborate and make decisions.

Role of the Planner

As part of the team building process, the working relationships among transportation stakeholders must strengthen not because of a new collaborative trend but because working together is no longer an option. Agencies, collectively or individually, have the ability to stop the permitting process or request that several special conditions be included as part of a permit despite the ability of a transportation agency to carry out and implement those conditions. Environmental agencies and advocacy groups may pursue a legal route causing a transportation agency significant delays, fees and fines. The fragile relationship between transportation agencies and environmental entities must change to include mutually beneficial opportunities for habitat and species enhancement and scientific research.

Gathering and sustaining a working group or an environmental team is the role of the environmental planner. This particular type of planner must focus on collaboration by recognizing and respecting the people in the group as well as the agencies and ideals in which they represent. The scope of the highway project must be a lower priority. Successful collaborations require that organizations and people alter their current decision-making framework and become more flexible. Team building creates a new operating structure that always shares risks and rewards however the results may not be distributed in an equal fashion. To say it another way, working together on collaboration requires new kinds of relationships. When changed, these new working relationships are powerful forces for environmental change that could never be achieved by one organization working alone.

Environmental agencies often see partnerships as an avenue of last resort and the only avenue out of their current situation, which sometimes leads to the objections of a particular action. The process of transportation environmental planning must encompass human qualities as well as strategic ones. The ability to work together comes when members realize for themselves that working together is not only better, it’s the only real option for creating change to include environmental enhancements. The environmental team building approach will not be successful unless all parties are willing to set aside differences and become part of the process.

Local communities, agencies and environmental advocates are encouraged to provide input early in the planning process but what happens when the individuals/agencies providing the input feel overlooked and their recommendations fall on the deaf ears of transportation professionals? Empowering people to recognize and listen to the ideas that others have to offer is a critical first step even if those ideas conflict with mission and goals of the entity you represent. Governmental agencies, whether it is a federal, state and/or local entity, should work together for the benefit of the constituents they serve. Good government should collaborate, communicate and make decisions based on the best available data and with the best interest of people in mind.

Nine Ways to Build an Environmental Team

The planning, communications and coordination efforts involved in an integrated and collaborative approach requires an extensive commitment and dedication from all entities for project success. The goal of environmental team building is to establish a team of federal, state, and local agencies and advocates whose knowledge and experience across disciplines may be applied to best protect environmentally sensitive areas, threatened and endangered species, habitats and wetlands. The list below recommends nine ways, when combined, form an environmental team designed to strengthen the level of trust and commitment among agency representatives. These recommendations work best when combined but also may be used in various groupings depending on the context and scope of the project. The extension of Interstate 355 into Will County required new planning, design and construction processes in an effort to build a new highway within a sensitive river valley.

1) Request Key Agency Staff to be Assigned to Projects

In Northeastern Illinois several federal and state agencies are involved in the transportation and environmental planning process. Those agencies include: the Federal Highway Administration (FHWA), the United States Coast Guard (USCG), the United States Army Corps of Engineers (ACOE), the United States Fish and Wildlife Service (USFWS) as well as the Illinois Environmental Protection Agency (IEPA), the Illinois Department of Natural Resources (IDNR), and the Illinois Historical Preservation Agency (IHPA). Agencies assign staff from the various disciplines to work side-by-side with state and local entities on transportation improvements on a project-by-project basis. Several individuals are frequently assigned to a project, which complicates decision-making and the official position of the agency.

One contact from each agency was assigned to the Illinois Tollway in an effort to develop a consistent approach to address, permit and mitigate environmental impacts. As a result, the representative became the "face" of the agency and those individuals are responsible for communicating and coordinating back to their respective offices to clarify direction and seek guidance. The assigned representative was not always the "expert" in each discipline but they were often more open to flexible and adaptive environmental planning approaches. The assigned representative had an opportunity to separate themselves from the dynamics of their agency and speak freely, if comfortable, during meetings as well as consult with agency colleagues if necessary.

2) Develop a Flexible Schedule

At the conceptual level, scheduling is the process of thinking about what you want to accomplish, developing the steps to accomplish your goals, and obtaining the resources to carry out those steps. At the practical level, scheduling is the tool to identify problems, delays, changes, and obstacles and, sometimes, opportunities that surface during the course of a project. Scheduling aims to organize your thinking and identify potential problems. The development of an established and flexible plan ensures that you inform the team about options, alternatives and the needed response in an efficient and timely fashion. Presenting an agreed upon project schedule to upper management clearly and convincingly makes it easier to obtain support and financial resources when needed.

The environmental process must adhere to the project schedule if local, state and federal agency permits are required to be secured prior to construction. Transportation project schedules must be developed to reflect the environmental permitting and communication processes and each agency representative had an opportunity to review and comment on the I-355 project schedule. All representatives understood that failure to maintain the schedule would result in costly project delays, increased public scrutiny and broken commitments. The environmental agencies collaboratively developed the project schedule with the Illinois Tollway as well as provided an estimate of commitment and resources necessary to follow the agreed upon project schedule. Recognizing that numerous decisions are made as a result of a project schedule, potential setbacks and time delays jeopardize the project and relationships. As a result, flexibility and uncertainty, to some degree, were factored into the schedule while considering human as well as agency needs.

3) Clearly Explain the Project and What You Hope to Achieve

One of the first and most important, steps in identifying which transportation projects should be designed and constructed is making an assessment of the transportation needs. This helps identify what action is being pursued and for what reason. It demonstrates problems that already exist or which will exist if a project is not implemented. In a sense, it can be seen as the justification for action, and it helps to define what constitutes practicable alternatives and considers appropriate mitigation (NCHRP, 2002). The I-355 South extension project documented a clear purpose and need but the mitigation requirements were vague, unclear and had never been done before. Many of the mitigation requirements were new to environmental agency staff and were foreign concepts to the transportation professionals at the Illinois Tollway.

The open, honest and informative dialogue helped all agency representatives understand the intentions of the Illinois Tollway, the phasing of construction and the goals of the project. As a result of the open dialogue, information was provided to the environmental agencies in an effort to prioritize immediate project work areas and permits, assign staff and allocate resources. The project expectations and schedules were frequently communicated to team representatives so that they could make the best decisions regarding their level of involvement and commitment to the project.

4) Coordinate Early and Often

Transportation agencies, like the Illinois Tollway, historically focused their efforts on identifying transportation alternatives, with little thought given early in the process to the type of strategies that might be needed to enhance, protect and preserve the environment (NCHRP, 2002). The consideration of environmental factors early in the transportation planning process requires that transportation and environmental planners must be able to identify where possible effects as well as negative or positive consequences that could occur based on best available information. The Illinois Tollway identified the I-355 project as an opportunity to truly engage environmental agencies in the new collaborative process and sought their valuable input prior to an alternative analysis or merely informing them of a scope of work.

Environmental agencies and advocates contain a vast amount of data and have knowledgeable and experienced staff. Oftentimes, it is the same few staff members who are responsible for coordination and communication within the Northeastern Illinois region. Therefore, it seems that those key agency contacts would have a clear understanding of the regional environmental needs and encourage partnership opportunities to address agency concerns if they are informed of project goals early in the process. By early coordination and communication, areas of opportunity were identified and included, where feasible, in the I-355 project. Incorporating environmental factors earlier in the planning process lead to better decisions and shortened the time for roadway construction in addition to improving the relationships of agency representatives.

5) Highlight Project Uncertainty

Transportation projects are subject to political and public scrutiny. Transportation agencies must decide whether a project will be planned, designed and constructed and then must dedicate the funds for implementation. Funding a transportation project is a significant investment in a community and in the region. Environmental agencies, advocates and the general public often work for years to secure funding, lobby on behalf of a project or quite possibly against it. As a result, environmental entities are often asked and do take sides but are not always aware of project implications, scope, schedule and commitments. Additionally, transportation entities are not always informed of the available scientific data, research efforts and knowledge/experience of stakeholders and agencies. The lack of knowledge translates into an uncomfortable working environment with different sides wondering and worrying about what the others know. In order to establish a foundation of knowledge, a level of trust and strong working relationships, the Illinois Tollway project team verbalized all details of the project, including budgets, schedules, supporters, opponents as well as uncertainties and emergency scenarios.

6) Listen to Agency Concerns and Work to Address Them

The successful implementation of a transportation project is largely accredited to each agency’s participation and commitment to actively engage in a new collaborative and open process. Transportation agencies are more concerned with outcomes rather than process. Successful transportation projects not only include an environmentally sensitive “design” but also a construction, maintenance and operations regime. A successful project may be defined as promises and commitments that are maintained past any construction. Thus, projects solutions and decisions must reflect the functions and priorities of all agencies. This was achieved on the I-355 project first by listening to agency concerns, disregarding expectations and past negative perceptions and then by working together to develop strategies and solutions that best highlights the ideas and commitments of the group. Environmental agencies, advocates and those concerned with environmental issues met monthly or as often as necessary to receive project updates, discuss design/construction issues and identify the condition of environmentally sensitive areas as it related to the overall project.

7) See It in the Field

Visualizing geographical relationships between dissimilar and similar resources and transportation alternatives is essential to making sounds decisions. As a consequence, project study areas can be depicted using multiple graphics and data visualization tools. These tools are built on overlay techniques and facilitated by Computer Aided Drafting Design (CADD) and Geographic Information Systems (GIS). Computer models are an excellent tool and may save time and money but should not be the only resource to visualize a project, its impacts or alternatives. All projects should and can be seen in the field. Recognizing that topographic limitations may prohibit or impair mobility and access, this should not discourage the group from experiencing a project in reality. The I-355 project required that all environmental team members be able to work in the field. Agency representatives were able to experience the project, identify environmentally sensitive areas and see the wetlands, habitat and potential species that required attention. Frequent site visits allowed agency representatives to experience the project with one another as well as learn and understand the position and concerns of fellow team member.

8) Demonstrate System-Wide or Program Stewardship

As interested parties meet in larger rooms, seeking to identify collectively common issues and cooperative responses, you may begin to see how similar concerns and goals really are. The drainage systems, fish and wildlife resources, and management histories of environmental resources are distinct and not integrative. Yet we rely on these systems for a variety of purposes that range from drinking water provisions and recreation to interstate commerce and transportation. As a result, the environmental agencies of each region share a strong sense of identification with their respective disciplines and responsibilities thus, highlighting the difficulty of thinking outside of traditional environmental framework and limiting opportunities to work with a transportation entity.

The Tollway's environmental team building process was an excellent way to address a project or proposed improvement and will now be a tailored approach applied on all projects. The successful team building was quite an accomplishment but unless the same ideas, concepts, practices and openness are applied to all projects or at least those that require federal and state permits, the strength of the team building process never reaches its full potential. Team members must establish a continuous communication and information system that incorporates management as well as agency/advocacy staff into the process for future interaction. Environmental team building may be applied on a project-by-project basis but must be a systemic change affecting all elements of each organization. By demonstrating system-wide and program stewardship, this reflects that the work of the group is not "an extra requirement" but a way of doing business.

9) Try New Avoidance, Mitigation and Protection Techniques

Transportation agencies are more accustomed to building roads than studying, avoiding and creating living systems. Environmental agencies and advocates often recognize the limitations and inexperience of a transportation agency's ability to integrate wetlands, species and habitat assessment methodologies and mitigation into highway projects. Transportation entities become quickly frustrated when clear guidance and direction is not provided from environmental agencies or when the integration of environmental components is not an area of expertise controlled by the transportation professionals. This inexperience and frustration highlights the need to form environmental teams as well as to develop comprehensive mitigation plans to best protect and restore the physical and natural environment.
Mitigation banking has proven to be a reliable and verifiable market-based method of compensating for impacts to wetlands and streams and is the mitigation technique most preferred by transportation agencies (Cunningham, 2005). When credits are purchased from a mitigation bank and proof is provided to environmental agencies, transportation agencies have no further visible obligations, maintenance and responsibility. The challenge lies when credits are unavailable or the amount of bank credit needed is expensive. The end result is the creation of a mitigation, maintenance and monitoring plan subject to the approval and reporting requirements of the local, state and federal agencies.

A unique wetland mitigation plan was prepared and implemented in partnership with local, state and federal agencies on the I-355 project. The Illinois Tollway was willing to listen to regional priorities and try new mitigation techniques. Historically, transportation agencies, like the Tollway, were unlikely to partner with another entity for mitigation purposes. Fear of construction delays, lack of schedule control and fear of the agency approval process prohibits transportation agencies from developing larger mitigation sites and working with another public/private entity to develop a mitigation strategy. However, the fear and frustration were put aside as the environmental team guided the Tollway in an effort to satisfy mutual goals. Recognizing that mitigation projects will only succeed with the dedication of a long-term site manager and clear and obtainable mitigation performance standards, the Tollway partnered with the Forest Preserve District of Will County to acquire land and re-establish the Spring Creek corridor.

I-355 South Extension Case Study

The Illinois Tollway embraced the Environmental Team Building approach as part of the planning, design and construction processes associated with the I-355 South Extension in Will County Illinois. The passage of the Tollway's $6.3 billion dollar *Open Roads for a Faster Future Plan,* included a highway extension of Interstate 355 south 12.5 miles from Interstate 55 to Interstate 80. The new extension serves Will County, one of the fastest growing counties in Illinois and provides a regional connection that improves north-south mobility between two existing Interstates.

The I-355 South Extension required avoidance and minimization of the most environmentally sensitive areas in the region. The I-355 South Extension included the construction of a 6 lane, 1.3 mile long bridge over the highly sensitive Des Plaines River Valley, crossed 10 designated waterways and borders three different county forest preserve districts. The Tollway developed conservation measures to protect the State endangered Blanding's Turtle, the federally endangered Hine's Emerald Dragonfly, and the State protected Leafy Prairie Clover all of which made their home in the river valley. Project plans were modified to avoid impacts to the extent practicable, while supplemental environmental controls were incorporated to provide protective measures during and after construction.

Recognizing that state and local planning and environmental related agencies were working side-by-side with the Illinois Tollway new opportunities such as a regional wetland mitigation site, cutting edge environmental research and improved recreational features emerged as concepts worthy of development and implementation. The goals of the I-355 project were expanded from building a safe and efficient highway project to creating new recreational opportunities and environmental integration. A local community office was established and housed a team of project planners, engineers and scientists so that information was available to those that desired it. An environmental project team was created with staff from federal, state and local resource and regulatory agencies that used the field office and consulted with I-355 project staff to help assess impacts, secure permits and determine project mitigation.

The environmental team members collaborated in the field office with agencies such as the Forest Preserve District of Will County, the Woodridge Park District, Village of Woodridge, Forest Preserve District of DuPage County, Lemont Park District, Village of Lemont, Village of Homer Glen, Homer Township, City of Lockport, Chicago Metropolitan Agency for Planning, and the Chicagoland Bicycle Federation to promote and develop a ten mile trail along the I-355 South Extension in Will and Cook Counties. The Veterans Memorial Trail will connect existing trail systems in three counties and provide a vital link across the Des Plaines River Valley, which has been a major impediment to regional trail connections. It will connect the Centennial Trail System (20 miles long), the I&M Canal Trail Systems (120 miles long), and the Spring Creek Trail System (9 miles long), and create connections to cultural attractions, including the Isle a la Cache Museum in Romeoville and Pilcher Park in Joliet. The regional project promotes the development of alternate transportation facilities to reduce vehicular trips and promote an active and healthy lifestyle.

In an effort to address multi-agency concerns and utilize the expertise of state, federal and local agencies, the Tollway's I-355 environmental team included assigned agency representatives from the University of South Dakota, United States Fish and Wildlife Service, the United States Army Corps of Engineers, the Illinois Department of Natural Resources, the University of Illinois, and the Forest Preserve Districts of Cook, DuPage and Will Counties. This technical team has met monthly since 2004 and continues to meet post construction to advise the Tollway regarding the implementation of various mitigation strategies and to develop the regional trail concept. The ongoing collaboration with the Federal, State and local agencies for the past five years and the retention of state scientists resulted in cost-effective mitigation efforts, a unique contractor education program, new and innovative mitigation strategies all with the goal to reduce harm to sensitive species as a result of a new highway corridor.

Figures 1 and 2. I-355 South Extension: Environmental Agency and HEDWG Team Members
Photos courtesy of Angela La Porte

One of the many products of the environmental team building process was a partnership with the Forest Preserve District of Will County to design and construct over 40 acres of mitigation, thereby doubling I-355 mitigation requirements. The additional mitigation will provide advance mitigation for future Tollway projects and all land acquired by the Tollway for wetland mitigation will be turned over to the forest preserve upon completion of construction and initial maintenance and monitoring. The Spring Creek wetland mitigation site development compliments the County's long-term vision of creating, protecting and enhancing the Spring Creek Greenway that runs adjacent to, and under the Tollway. A complimentary multi-use trail facility was incorporated into the mitigation site design. The multi-use trail will ultimately be extended to the Tollway at which point it will intersect with the bikeway corridor and the underpass built under the Tollway. The teamwork approach to wetland mitigation was recognized by the esteemed *Chicago Wilderness* in 2008 with the dedication of the Excellence in Conservation Award!

The I-355 environmental team not only addressed wetland mitigation requirements but also the requirements in the Biological Opinion for the I-355 project, written by the USFWS, which outlined mitigation and conservation measures pertaining to the Hine's emerald dragonfly (HED). The dragonfly's habitat and life cycle requirements consist of the seeps and fens found at the base of the bluffs in the Des Plaines River Valley. These groundwater fed seeps and fens are some of the highest quality natural communities remaining in the Valley. Narrow channels (rivulets) where water flows slowly out from the bluffs through marsh vegetation provides additional dragonfly habitat. In order to plan, develop and implement ways to best protect the species, the Tollway and environmental team members gained an understanding of the Hine's emerald dragonfly's habitat and life cycle requirements. The diverse group of scientists and planners formed the Hine's Emerald Dragonfly Working Group (HEDWG) and provided this understanding through previous research as well as identified areas in need of research.

Figure 3. Hine's Emerald Dragonfly Habitat **Figure 4. Hine's Emerald Dragonfly**
Photos courtesy of Angela La Porte

The Hine's emerald dragonfly is in jeopardy due to expanding urbanization, a shrinking habitat and small population size; the Tollway developed three separate HED habitat management and conservation plan documents for habitat in Cook, DuPage and Will Counties. The Tollway also implemented the three plan documents to stabilize local populations and encourage additional reproduction. The plan documents detail the creation and restoration of natural and artificial Hine's emerald dragonfly habitat that has never been done before! This groundbreaking effort by the Illinois Tollway with the support of recognized scientists will be the first manipulated habitat created for this species. The efforts of the environmental team will continue to provide natural resource agencies the tools and data to implement similar conservation measures in other parts of the region in order to ensure the continued existence of this precious species.

Conservation efforts also were created for the Blanding's Turtle, a state-protected species that lives in the Des Plaines River Valley. The Tollway retained a staff of qualified herpetologists to be on-site throughout construction and track movement of the turtles with radio tags. Educational field seminars were held with the Tollway's construction management team and roadway contractors to spot Blanding's Turtles and avoid impacts to turtle habitat and travel patterns with construction equipment. A process was developed to alert workers and Tollway staff if a turtle was nearby or within the construction zone. These efforts successfully protected Blanding's Turtles located within this project corridor as they frequently crossed the construction haul road. Without the guidance of the Tollway's environmental team, the Blanding's Turtle population may have been unintentionally harmed. The avoidance and minimization measures were taken seriously as the Tollway worked aggressively to ensure the Blanding's Turtles were not impacted by construction activities.

The many planning, communications and coordination efforts involved in the environmental team building approach and species protection required an extensive time commitment and dedication to project success. After monthly meetings, all mitigation measures and ideas were reviewed in the field and discussed with project engineers and contractors. As a result of environmental team building approach, the working relationships among agencies strengthened and the knowledge and experience has been shared with interested agencies as the measures and mitigation strategies were selected to best protect the resources within the DesPlaines River Valley. The Illinois Tollway has adopted the environmental team building approach along other Tollway corridors and undoubtedly contributes much of the success regarding the I-355 South Extension project to the creation of the environmental teams.

In the End

Transportation professionals are trained to provide a certain quality of design using traditional engineering, planning and environmental approaches. As a result, highway projects and transportation agencies often face resistance from the public and community interest, when transportation projects are perceived as having clear, measurable adverse impacts on the communities as well as on the environment. No longer are these projects widely accepted or perceived, as worth the costs in terms of right-of-way, community disruption, environmental impacts. Highway agencies follow a prescriptive procedure with an emphasis on disclosure of impacts but lack the need for developing a strong environmental plan. The nine ways to build an environmental team changed the way the Illinois Tollway planned, designed and constructed a new highway corridor because working together was no longer an option and more importantly, it maximized public resources and knowledge to best protect the environment.

The ability of transportation agencies to adapt to a new approach towards environmental and transportation planning will, to a large extent, depend on their understanding of the importance of environmental issues and on how transportation can best incorporate these concerns from a process and a scientific point of view. Transportation agencies are more accustomed to building roads than studying, avoiding and creating living systems. By working with communities, engineers, architects and planners, the Tollway's transportation professionals were forced to simplify concepts, function as a planner and environmentalist in order to garner support for the I-355 project.

One way to gain environmental support and secure the roadway construction permits in accordance with the project schedule is by the creation of environmental teams. The goal of environmental team building process is to establish a team of federal, state, and local agencies as well as advocates whose knowledge and experience across disciplines may be applied to best protect environmentally sensitive areas, threatened and endangered species and associated habitats. By establishing environmental teams, representatives have to experience and understand each agency's way of doing business and reasons for concern in order to find effective ways to work together. Environmental team building requires the integration of goals, agencies, stakeholders, policies and most importantly, people.

The process of integrating people, science and transportation by environmental team building is one that is unclear and uncomfortable but yet may produce a transportation and environmental victory as well as build a level of trust among agencies typically opposed to transportation improvements. Additionally, transportation agencies are used to finding an engineering solution without input from environmental and community groups early in the planning process. The team building process is an easy concept but it takes much work and the dedication of time, monetary resources and key staffs are requirements for success.

In many ways, this paper suggests rethinking the way transportation and environmental planning is conducted. At the very least, it suggests a different mindset among most transportation and environmental planners as well as environmental agencies. It also focuses on ways to build environmental teams aimed to foster relationships and focus on people instead of a traditional highway planning process. This approach demands that we become more strategic and flexible. While challenges are daunting, the collaborative spirit grew among team members as part of the I-355 project as the participants continue to pave the way for innovative partnerships and new environmental/transportation initiatives. Rather than proceeding as we have, often with competing and isolated goals and objectives, we must embrace the opportunities that exist for transportation and environmental entities to unify around common challenges and shared solutions.

Acknowledgements

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Ecological Effects of Road Construction on Regional Ecosystems

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Abstract

The impact of road networks on regional ecosystems is often overlooked by transportation planners and civil engineers. Due to a lack of scientific data, the ecological impact a road has on adjacent areas is the topic of debate between conservationists and engineers in developing countries. The extent of ecological impact varies depending upon species and is not sufficiently studied for some endemic species.

Most research about ecological impact zones examines existing roads with adjacent ecosystems in a stable condition. Few studies have been carried out for roads under construction where dynamic and intense disturbances from construction may attract or repel animals from nearby natural areas. Those short term impacts may cause instant local extinction for some sensitive species and change local biodiversity. This study, performed on Kinmen Island, Taiwan, investigates the ecological impact of road construction.

The species studied are mainly rodents, invertebrates, and amphibians. It was found that the Brown Country Rat's (***Rattus losea***) edge habitat is broader next to farmland (35m) than it is next to the road (15m). The disturbance of construction also reduces the edge habitat area. Since the Ornate Rice Frog (*Microhyla ornate)* typically resides and forages in dim and humid environments, they instinctually avoid edges. The dry environment and brightness of the road side prevent them from entering the edge area. Most invertebrates captured were found at an edge depth of 15m along the road side and 35m along the farmland.

Our data suggests that road construction can decrease the edge habitat area within woodlands more so than farmlands, but the creation of new edges by a road can provide more edge habitats for edge species and, therefore, may lead to an imbalance within the ecosystem. Edge depth and ecological impact data found in this study can be applied to planning, designing, and building roads with more ecologically friendly guidelines and principles.

Introduction

Highly accessible transportation systems stimulate regional economic development but a high density of roads is greatly destructive to regional ecosystems. Extensive road networks may lead to habitat loss, fragmentation, and decreased habitat quality. Furthermore, the impact of newly constructed roads may be detrimental to the integrity of adjacent ecosystems and destroy an interior species' habitat (Reed et al., 1996).

The alterations of edge microclimate factors such as light penetration, temperature, humidity, wind speed, and disturbances from traffic and/or road construction create a strip of ecosystem along the road that is distinct from the original landscape. The depth of this edge ecosystem varies depending on latitude, vegetation, and species. The impacts of the edge on vegetation are less significant in tropical and diverse vegetation areas than in temperate regions and islands (Forman, 1995). The major impacts of an edge on adjacent vegetation are: direct damage to plants, changes in transvaporation, trophic circulation, and dissolution of materials; increase of pollen and plant seed dispersal, and disturbance of habitat soils (Harper et al., 2005). The edge many also change vegetation structures by: introducing alien species, increasing the density of seedlings, enlarging bush coverage, and enhancing species abundance therefore, affecting the sustainability of some species populations (Gehlhauson, et al. 2000).

Areas next to roads are ecologically special habitats with unique microclimates. Increased disturbances from traffic may attract edge species which can tolerate disturbances but expel interior and sensitive species. Without proper mitigation measures, populations of interior species may decrease considerably and, moreover, lead to local extinction. The depths of edge effects vary dependent on species, habitat types, geological environments and vegetation structure (Gehlhausen et al., 2000). The variations are summarized in the following table:

Target species or environment of edge	Depth of edge effects
Microclimate	50~80m [1][6][19]
Seeds of exotic plants invasion distance	Thinned treated vegetation 50m [2]
	Intact vegetation 30m [2]
Invasion of exotic plants	40~60m [19]
Invasion of exotic non-vascular plants	25m (In some circumstances it can reach 50m) [4]
Causes of death of trees in tropic rainforests	60~100m(Grassland edges) [5]
	40~60m(Newly revegetated forest) [5]
Impact on amphibians	25~35m(Forest habitat) [7]
	159~290m(Wetland habitat) [8][9]
Impact on reptiles	127-289m (Wetland habitat)[8][14]
Impact on avian species	Avian nest success 50~100m[3][13][15][16] Egg predation 100m[11]
Impact on small mammals	120-160m [6] 200m [10]
Impact on large mammals	3,000m[12]
The effects of land development on wetlands	Water nitrogen and phosphorous diffusion 2,250m [17] Phosphorous sedimentation 4,000m [17]
The effects of urban expansion on interior avians	200-1,800m [18]

[1] Young and Mitchell (1994), [2] Candenasso and Pickett (2001), [3] Deng and Gao (2005), [4] Aune et al. (2005), [5] Mesquita et al. (1999), [6] Stevens and Husband (1998), [7] Demaynadier and Hunter Jr. (1998), [8] Semlitsch and Bodie (2003), [9] Burke and Gibbons (1995), [10]Laurance (1994), [11] Burkey (1993), [12] Kinnaird et al. (2003), [13] Paton (1994), [14] Semalitsch (1998), [15] Manzer and Hannon (2005), [16] Rodewald and Vitz (2005), [17] Houlahan and Findlay (2004), [18] Dunford and Freemark (2004), [19] Gehlhausen et al., 2000.

Table 1. Depth of Edge Effects for Various Environments and Species (Forman et al., 2003)

A species' territory size and tolerance of edge disturbances reflects the extent of the edges for each species. Larger species are more sensitive to the edge and have larger edge depths. While, the ecological effect edge zone is less than 300m for small animals and exotic plants invade up to a depth of 60m. Salamander habitats, in a forest adjacent to forestry or abandoned logging roads, decrease in suitability by 28.6% to 36.9%, and the abundance of the species is affected up to 35m on either side of the roads (Semlitsch et al., 2007). However, the above surveys and studies were all conducted in ecologically stable environments with established edges. Although only temporary (1~2 years), road construction creates a broader edge effect zone and severely affects interior or sensitive species. Local extinction is more probable during road construction.

Few studies have been conducted with regards to the edge effect of road construction. With this data, engineers can devise proper ecological mitigation measures and construction practices. Proper mitigation measures can reduce animal mortality by 97% (McGuire and Morral, 2000). For example, animal passages connect habitats separated by roads (Bekker et al., 1995; Huijser and Bergers, 2000) and provide routes for gene exchange (Forman et al., 2003). Raised road beds guide avian species to fly high over the road and avoid collisions with vehicles (Clevenger et al., 2003). Blending these measures and ideas into civil engineering codes should be considered in each stage of planning, designing, construction, maintenance, and management.

The twinning project of the Trans-Canada Highway through the Rocky Mountain national parks is one example of the implementation of ecologically friendly practices (McGuire and Morrall, 2000). In this project, wildlife exclusion fences were installed to prevent most species from entering the job sites. Two metre berms were also used to reduce traffic noise and visual disturbance and guide runoff to nearby vegetation areas rather than separate bodies of water. Finally, seeds and cuttings were collected and marked from native plants along the construction sites and transplanted in greenhouses for further use as seedlings to rehabilitate the native vegetation.

These strategies are effective. However, the effectiveness of ecological mitigation measures can only be properly evaluated when edge effects have been studied thoroughly. This research will determine the ecological effects edge depths have on rodents, invertebrates, amphibians and other species while a road is under construction and establish the relationship between edge area and road density concerning regional development.

Scope of Investigation

On Kinmen Island, Taiwan - where the highway system is not elevated - vegetation rehabilitation during the Chinese Civil War (1950~1990) created an ideal habitat for various species, especially migratory birds. Over the last 15 years construction and development on Kinmen has caused the destruction of vegetation and woodland areas. The subject of our study will be Wuan Dau West Road (WDW), which is currently under construction (Figure 1). Construction commenced on June 27, 2006. The road is 337m long and 15m wide, including a pedestrian walkway on one side. The road bisects a 9.97 hectare area of woodland into two sections (Figure 2). The eastern section of the woodland is 4.04 hectares, and, the western section is 5.01 hectares. The ecological effect research was conducted in the western section.

The woodland canopy is mostly covered by Beef woods (*Casuarina equisetfolia*) with dispersed *Acacia confuse* and *Eucalyptus robusta*. Under the canopy there are *Melisa azedarach*, *Litsea glutinosa*, *Albizzia lebbeck*, *Celtis sinensis*, a few *Pinus massoniana*, *Cinnamomum camphora*, *Sapium sebiferum*, *Vitex negundo*, and *Dodoneae viscose*. The understory species are mainly *Lantana camara*, and *Murraya paniculata*, with dispersed *Asparagus cochinchinensis*, *Berchemia lineate*, *Elaeagnus oldhamii*, *Maytenus diversifolia*, *Pteris semipinnata*, *Lygodium japonicum*, *Cocculus orbiculatus*, and *Commelina auriculta*. Of the total 107 species, 72 are native, 1 endemic, 1 endangered, and 3 rare.

The western woodland was selected for study due to its large area in comparison to the eastern woodland. The eastern side of the section is under construction, the southern side is WDW road, and the west and northeast sides are farmland. The woodland is an ideal site to evaluate the effects roads and farmlands have on edge habitats. The survey was designed to measure the distance from the road to the spots where animals (target species being rodents, invertebrates, and amphibians) are captured or trapped. The subsequent results allowed us to evaluate the ecological effects road networks have on the regional ecosystem.

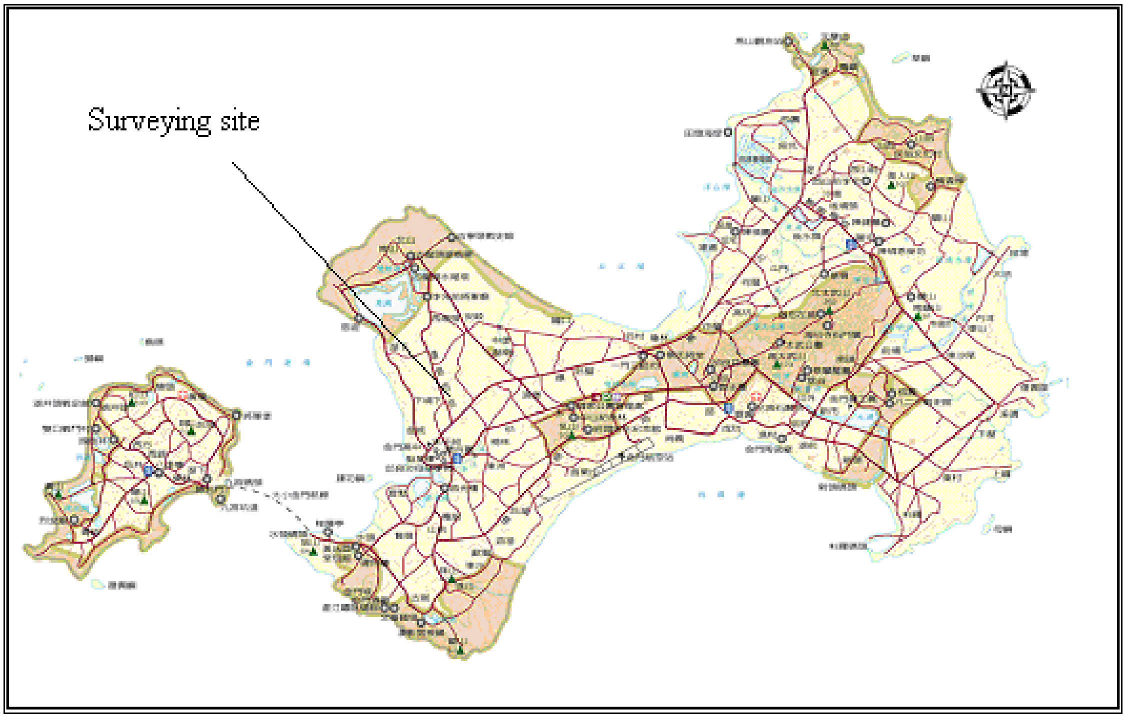

Figure 1. Location of the surveying site which is located at Jinning Township in the west portion of the main island

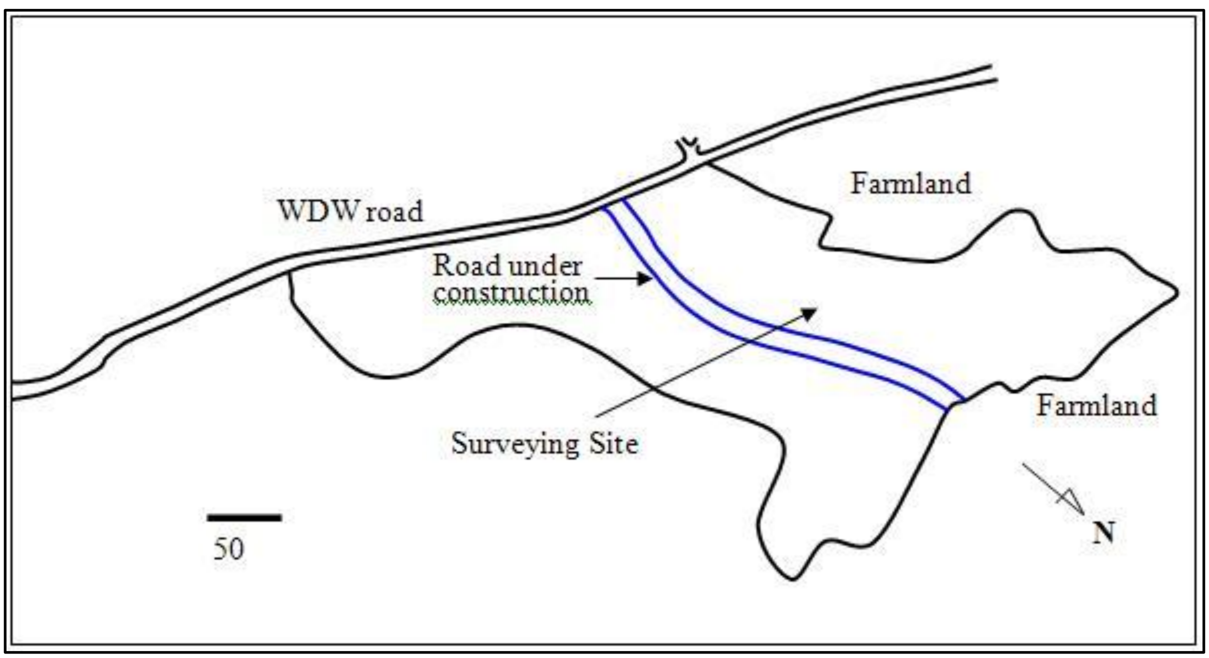

Figure 2. The road under construction runs North-South and bisects the woodland next to WDW road. The road under construction is on the East side; WDW road is situated on the South side; the West and Northeast sides are bordered by farmlands.

Methods

Ten routes with different lengths along the road were created by clearing some obstacles and dead woods (Figure 3). The interval between each route is 30m. Along each route one wire-mesh trap and pitfall were placed at 10m intervals from the roadside into the core of the woodland. The research commenced on July 1, 2006 and concluded on January 7, 2007. It was conducted 16 times. Three days were needed for each survey and animals were given a two week recovery period.

On the evening of the first day, bait was put into the wire-mesh traps and pitfalls were filled with fresh water. The next morning (around 7 AM), researchers checked for captured animals. The small mammals (mostly rodents) were marked with paint and then released. A large number of invertebrates trapped in the pitfalls died. They were marked and brought back to the laboratory for identification. After bringing back the captured animals, the wire-mesh traps were washed thoroughly to prevent unnecessary odours. On the evening of the same day, the traps were refilled with bait and the pitfalls were filled. The same procedures were performed on the morning of the third day. During the period of investigation, two routes (I and J) were greatly altered and shortened by construction and then abandoned. Since only a few routes were slightly altered, the research was carried out with little change.

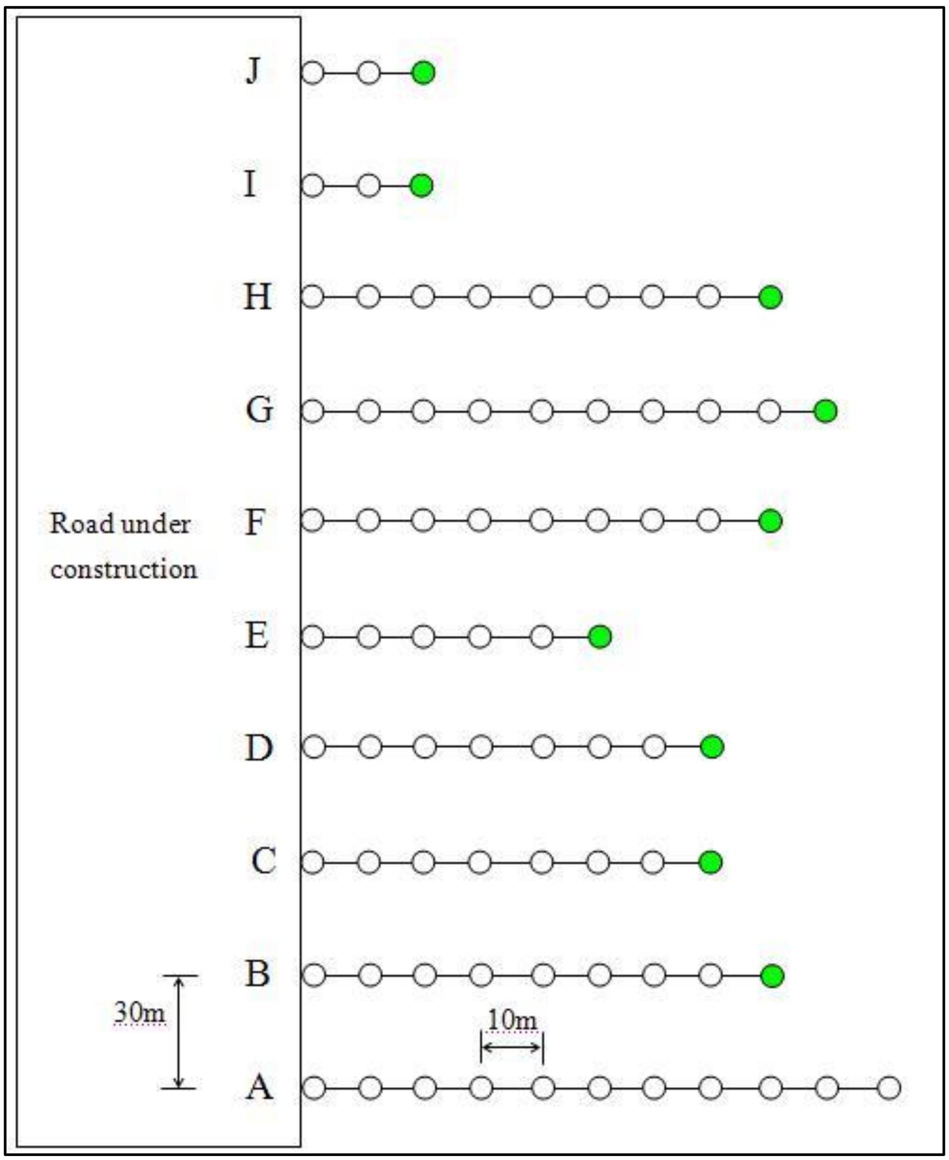

Figure 3. Distribution of Survey Sites. On the right of each site, a wire-mesh trap is placed. On the left, a pitfall is placed. The solid circle ( ) indicates the surveying site along farmland boundaries. It should be noted that the end spot of route A is still located inside the woodland.

Results and Analysis

Construction was scheduled to be completed in 210 days. However, due to design changes, the project had not yet been finished at the completion of this paper. Since some survey routes E, F, G were destroyed by construction, the survey in those areas had to be stopped. During the construction period, the most common mammals captured were the Brown country rat (*Rattus losea*), the House shrew (*Suncus murinus*) and the Red-bellied tree squirrel (*Callosciurus erythraeus*). Pitfalls collected a great number of invertebrates, spiders, and amphibians. Nine birds were also, unexpectedly, attracted by the bait in the wire-mesh traps and captured during the investigation. The results are listed in Table 2.

species	Invertebrate	Brown Country Rat	Red-bellied Tree Squirrel	House Shrew	Spider	Ornate Ricefrog	Spectacled Toad	Bird
Captivity	919	372	7	51	92	21	28	9

Table 2. Results for 16 survey periods

Ecological Edge Effects of Road Construction on Brown Country Rat Distribution

In Kinmen, the Brown country rat is the dominant small mammal in the field and it was captured with great frequency during our research. In calculating the collected data (shown in the Figure 4), we found a considerably higher rate of capture (the average number of capture per night) for rodents near the road and farmland edge as opposed to the inner area of the woodland. In this case, the resources and microclimate of the edge encourage the rodents to forage, where they are captured, by the wire-mesh traps. We, therefore, characterize Brown country rats as an edge species. However, the locations closest to the road (0m) have a lower frequency than the second closest locations (10m). This indicates that the constant and intense disturbance of road construction prevents the rodents from getting too close to the job site. To evaluate the depth of the ecological edge along the road (*d*), correlation analysis and *p*-value were calculated by taking d =5m, 15m, 25m with a 95% accuracy. Since route I and J are too short and route E falls into the edge area at the other end of the woodland, they are excluded from the following statistical analysis. The lengths of other routes are between 70m and 100m. Table 3 shows results of point-biserial correlation analysis for the edge along the road. A value (*d*) with the highest correlation coefficient (*r*) and lowest *p*-value is the most accurate representation of an edge's depth. Statistically, d =15m with highest r= 0.423 and lowest p=0.0026 can be defined as the edge depth as a greater number of individuals maintained an association with road edge.

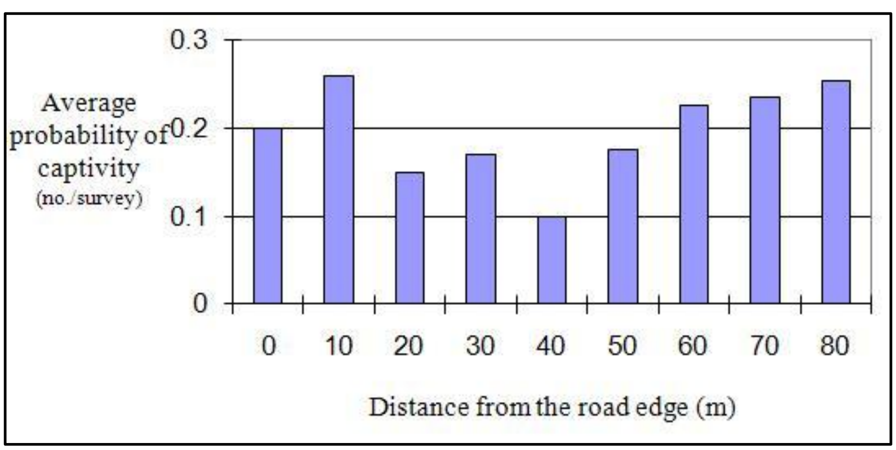

Figure 4. Average probability of Brown country rat capture along the road edge

d(m)	r	*P*
0~5	0.183	0.1229
0~15	0.423	0.0026
0~25	0.336	0.0149
0~35	0.324	0.0182

Table 3. Results of correlation analysis for edge effects on Brown country rat

The farmland on the opposite ends of survey routes forms a gradient edge and attracts rodents. Figure 5 shows the rate of capture distribution for the woodland-farmland edge. A similar pattern of distribution shows that more rats were caught along the woodland edge. Utilizing the same statistical analysis method but excluding route A (because one end of route A falls inside the woodland), six routes were analyzed with *d* = 0m marking the boundary between woodland and farmland. Table 4 shows the results and analysis for the 50m-from-boundary survey location. Where *d* = 35m the *r* and *p*-value are highest (0.478) and lowest (0.002) respectively. This result illustrates that for rodents, the scope is broader in a low edge gradient habitat as opposed to a road edge habitat. Even though edges provide a favourable environment for rodents, the abrupt change of landscape (i.e. road/woodland) ecologically discourages the Brown country rat's entrance (Forman, 1995). On the other hand, the edge adjacent to a gradual change of landscape (i.e. farmland/woodland) provides better habitat quality for the rodents. Although the Brown country rat is a generalist, the disturbance of road construction can reduce the depth of edge habitat for the species. Our depth edge numbers for the Brown country rat differ from those for small mammals (120~200m) found by other researchers (Stevens and Husband, 1998; Laurance, 1994). This is due to the fact that edge size is highly dependent upon landscape, vegetation, geology, road condition, and species; survey site vegetation cover and species characteristics of the small mammals studied in this research are distinct from the other two.

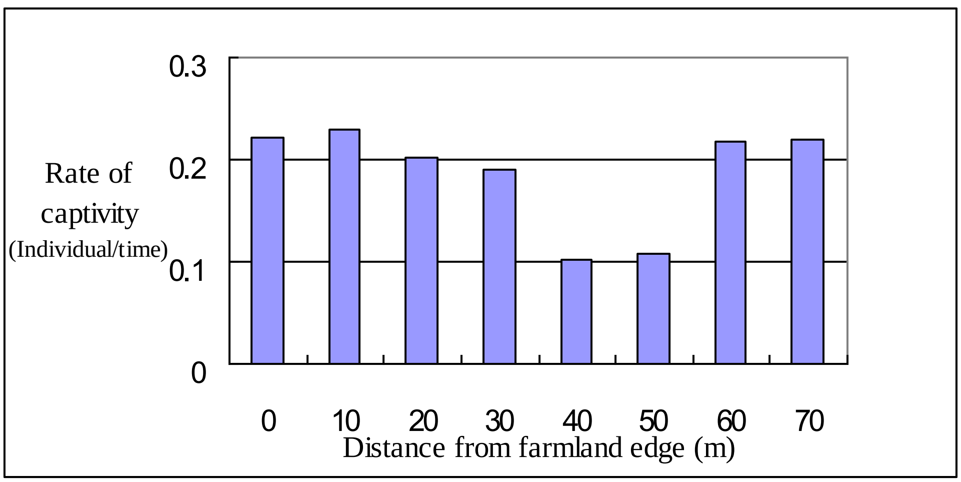

Figure 5. Average probability of capture of Brown country rat along farmland edge

d(m)	*r*	*P*
0~5	0.244	0.075
0~15	0.369	0.013
0~25	0.414	0.006
0~35	0.478	0.002
0~45	0.295	0.042

Table 4. Results of correlation analysis of farmland edge effect depths on Brown country rat

Ecological Edge Effects of Road Construction on Invertebrates

Invertebrates are a primary species in a trophic system which is dependent on them for supplementary nutrients. Although an elementary species, they are important and abundant members in an ecosystem. Due to their low tolerance of interferences, the population size and species of invertebrates are ideal indicators in evaluating the impacts of disturbances on an ecosystem. It remains unknown how air pollution, vibration, noise, contamination, and waste water from road construction affects the distribution and existence of individual invertebrate species. Nevertheless, roads create new open spaces that may lure phototaxis insects which, then appear as edge species. The number of individual invertebrates were collected in our research is 919. The average distribution of capture is shown in Figure 6. Capture rates were higher along the edge of the road and the farmland boundary. Most invertebrates are phototaxis species and are drawn to the edge for light and resources. Employing correlation analysis d=15m, next to the construction site, has the highest correlation coefficient, r=0.389, and lowest p-value, p=0.005 (Table 5). The effects of the distance of light and the edge of road construction on attracting phototaxis invertebrates can be defined as 15m. The concentration of various invertebrates along the edge shows that when invertebrates are lured to the edge, their predators also forage along the edge which leads to higher ecological abundance and diversity within the edge habitat.

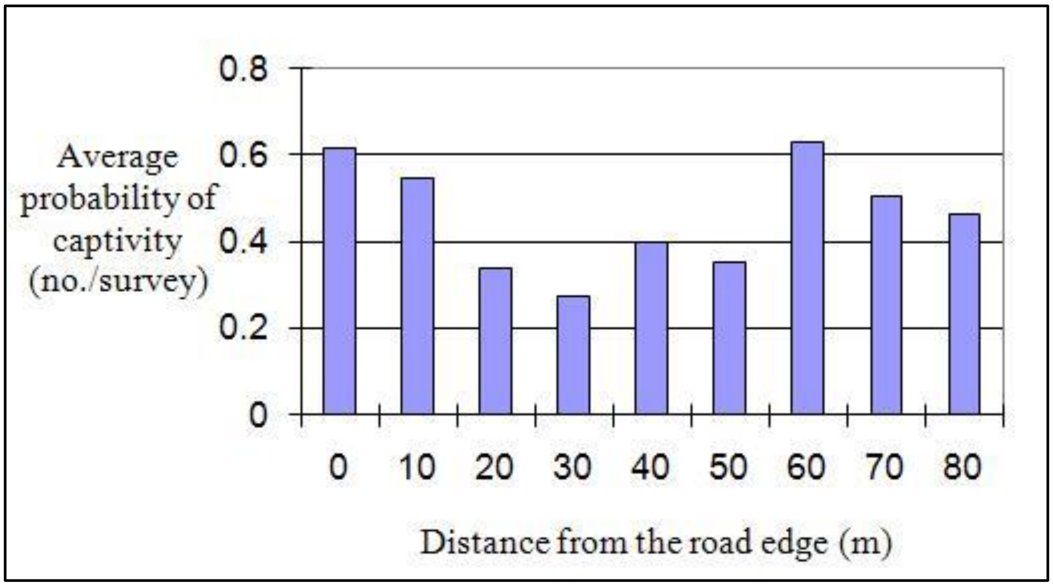

Figure 6. Average probability of captivity of invertebrates

d(m)	*r*	*P*
0~5	0.333	0.016
0~15	0.389	0.005
0~25	0.275	0.039
0~35	0.124	0.218

Table 5. Results of correlation analysis of depth of road edge effect on invertebrates

Similarly, we can analyze the effects of the farmland edge on the distribution of invertebrates by setting the irregular woodland/farmland boundary as an edge. The results of invertebrates captured are shown in Figure 7. The results of correlation analysis were obtained and are shown in Table 6. With the highest correlation coefficient r=0.294 and the lowest p-value p=0.041, the depth of the ecological edge along the woodland adjacent to farmland is d=35m and is statistically sound. This is due to the woodland invertebrates' attraction to the microclimate and light or resources in the area near the farmland edge. Here, the gradient of ecological variation is much lower than road/woodland edges. Therefore, captivity of invertebrates is higher along the woodland/farmland edge. Another explanation for this result is that invertebrates prefer the farmland habitat over the woodland. This phenomenon merits further study to clarify invertebrates' habitat preferences.

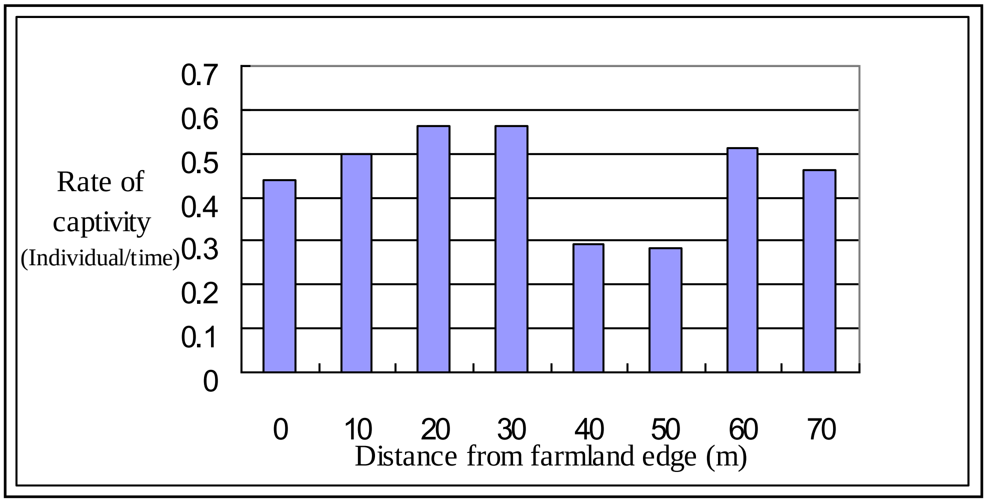

Figure 7. Average probability of captivity of invertebrates from farmland edge

d(m)	*r*	*P*
0~5	0.003	0.493
0~15	0.007	0.483
0~25	0.141	0.206
0~35	0.294	0.041
0~45	0.146	0.197

Table 6. Results of correlation analysis of depth of farmland edge effect on invertebrates

The Ecological Edge Effects of Road Construction on Other Species

(1) House Shrew

It is unusual to capture House shrews in the wild. They are commonly found in residential and developed areas instead of farmland (Lin, 1982). 51 House Shrews were captured in this study and they were widely distributed. The House Shrew is a generalist and the edge or interior of the woodland is their habitat.

(2) Ornate Ricefrog

In this research, animals captured by pitfalls - other than invertebrates - were mostly Ornate ricefrogs (*Microhyla omata*), Spectacled toads (*Bufo melanosticus*), and spiders. It is statistically insignificant to evaluate the corresponding scope of edge effect due to the minimal number of captures. However, by observing the locations of captivity, the individual species' responses to road construction can be identified.
Other than route G, the majority of Ornate Rice Frogs species caught were located at the interior of the woodland. Since they favor humid and dark environments, Ornate Rice Frogs avoid edges with a dry and bright microclimate. New road construction will expel this species from the newly formed edge and force them to retreat to the remaining inner habitat. High density road networks will reduce the interior area of their natural habitat and, therefore, be detrimental to their population persistence.

(3) Spiders

There are 22 families and 151 morph species of spiders in Kinmen (Kinmen National Park, 2007). Spiders are important invertebrate predators in the terrestrial ecosystem (Woinarski et al., 2002) and exhibit different habitat preferences (Tso et al., 2005). Numerous spiders were collected by pitfalls and they are uniformly distributed. This investigation only collected ground spiders which are more mobile than the bush and canopy species. However, forest understory and bush areas have the most abundant and diverse spider populations (Chen and Tso, 2004). This explains why spiders were collected both along the edge (mainly bushes) and in the interiors of the woodland (forest understory). Therefore, road construction has a minor ecological impact on understory spiders.

(4) Spectacled Toad

Although abundant in Kinmen, the number of spectacled toads captured was relatively low and randomly dispersed. Based upon their ecological features, we conclude that the spectacled toad is a generalist which migrates or forages over developed and natural areas. Road construction may have minor ecological impacts on this species.

Road Network Ecological Impact Analysis

Assuming that the road network in a region is a square grid, as shown in Figure 8 (Lin, 2006), the road density can be obtained as

$$\rho = \frac{2L}{L^2} = \frac{2}{L}, \qquad (1)$$

where, L denotes the length of road in either direction within the unit area (Figure 9). The ratio of edge area to total area of the region (γ, including roads themselves) can then be obtained by calculating the ratio within the unit area as

$$\gamma = \frac{(R+2d)\cdot 2L - (R+2d)^2}{L^2} = (R+2d)\cdot\rho - (R+2d)^2\cdot\left(\frac{\rho}{2}\right)^2, \qquad (2)$$

where, R denotes road width and d is the depth of edge. Equation (2) represents the relationship between road density and edge area ratio, γ, in the regional landscape. The relationship between road width, the ratio of edge area and road density can then be obtained (refer to Figure 9) as: R=15m and d=15m, 25m, 35m respectively. From the results of this research, the edge depth for Brown country rats and invertebrates is about 15m. Once the road has been widened, the edge area ratio in the region will increase and the population of edge species will augment. Therefore, in a fragile island ecosystem like Kinmen, the balance of the regional ecosystem is in jeopardy. Some interior species, such as rice frogs, avoid roads and road edges and retreat to fragmented and diminishing inner habitats with limited resources and a small habitat area. This will cause the reduction of their population and, more seriously, high road density could cause local extinction for sensitive interior species.

If we take road width R=20m of a normal secondary road and refer the distance of edge effects on various species in Table 1, we can assess the ecological impact of road density on a species at the regional scale.

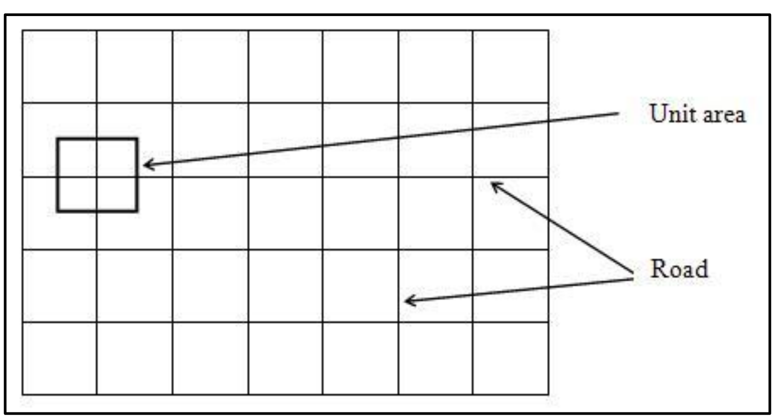

Figure 8. Square layout of road network

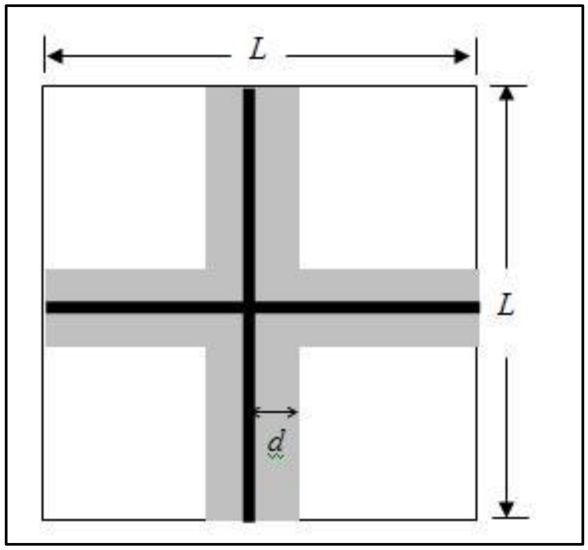

Figure 9. Unit area of road network

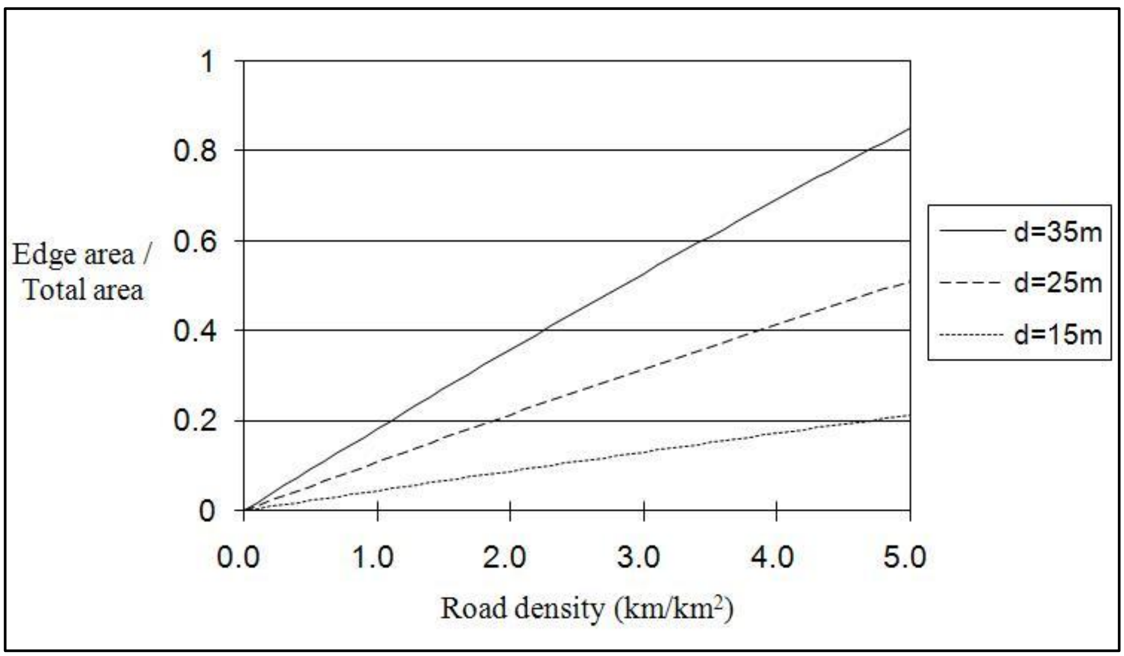

Figure 10. Edge ration in different road widths and road densities

Discussion

A special ecological edge habitat is created on either side of the road as construction commences. The disturbances of construction and the changes of microclimate instantly affect terrestrial animals' behaviors by attracting or expelling them. Non-native plants then gradually invade the natural area, starting from the edge, further altering the distribution of animals by the change of vegetation. Finally, a stable strip-like micro-ecosystem along the edges is established as road construction is completed. For edge species (rodents and invertebrates in this research), edges provide favorable habitats and lead to higher interior population density. For interior species (rice frog), the adverse edge environment forces them to retreat into the inner portion of the woodland. As regional development progresses, most interior species are prone to become threatened or locally endangered, and are in need of conservation. As discussed earlier, the edge depth varies depending on the species. A broad edge area can increase the number of edge species, which are mainly disturbance tolerant and over populated, and may damage the balance of the regional ecosystem.

The ecological effect roads have on fragmented ecosystems is an important issue in regional ecological conservation. For road planning, the effects on various species, especially keystone or endangered species, must be studied thoroughly. For the integrity of an ecosystem, species lower on the food chain, such as most invertebrates, must be investigated as they are associated with most of the higher level animals. This research has demonstrated a feasible surveying practice for evaluating the scope of the ecological edge effect due to road construction and provides a model to approximate the potential impact of road networks on a regional ecosystem. As seen in this study, even Brown country rats, which favor edge environments, avoid the road/woodland edge to some degree due to the constant and intense construction disturbances. Thus, this edge habitat of this species becomes smaller. Although road construction may reduce the area of an edge habitat, creation of new edges by a new road provide additional habitats for edge species and, thus, increases their population and changes the natural evolution of the ecosystem.

Road edges attract some invertebrates due to the alteration of the microclimate and availability of sun light. In this research, many different species of invertebrates were collected and it is not possible to examine the edge depth for each individual species. The survey data shows that most invertebrates congregate within 15m of the road/woodland edge area and 35m of the woodland/farmland edge and, therefore, can be characterized as edge species. It is believed that some invertebrates are interior species and may stay away from edges; therefore, road construction increases their vulnerability. The ecological implications of this finding are still unknown and merit further investigation.
Four species (house shrew, ricefrog, toad, and spiders) displayed various responses to the road edge environment. The Rice Frog is an interior species and exhibits avoidance to the edge and is the most sensitive to road construction. House Shrews, Toads and Spiders are generalists and may not be significantly affected by road construction or the influence of road networks.

As we do not comprehend animals' perception to road construction, we must change the methods used in development and construction in order to conserve the species that need protection. Quality of habitat (resource and environment) and configuration of habitat (structure and arrangement) are two major factors affecting population and spatial distribution of insects (Grundel and Pavlovic, 2007). This argument is also true for most terrestrial species. Roads change the ecological quality and configuration of the habitat edge. They alter the population and distribution of terrestrial and avian species and corresponding mitigation measures should be implemented at each phase of road engineering. At the road planning stage, connectivity of habitats or natural areas must be the leading priority. Alternative road alignment to avoid natural habitat should be seriously considered. Building animal passages is an important mitigation measure. Regional critical road density derived in this research is a useful indicator to evaluate road planning and allow focal species enough area to thrive. Road construction immensely impacts regional ecosystems. Only congregational development, ecologically friendly design and construction can achieve conservation and transportation convenience at the same time and, thus, meet the needs of both human beings and nature.

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INCORPORATING ROAD-MORTALITY HOTSPOT MODELING AND CONNECTIVITY ANALYSES INTO ROAD MITIGATION PLANNING IN ONTARIO, CANADA

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Abstract

In Ontario and world-wide, wildlife are increasingly involved in collisions with motor-vehicles, providing a real threat to human and wildlife safety on roads. This is particularly evident in Ontario due to its increasing human density, and traffic volumes along with its high biodiversity. The Committee on the Status of Endangered Wildlife in Canada has listed seven of Ontario's eight turtle species as endangered or of special concern and roads have been identified as a major threat for five of these species.

Ontario is planning to extend a number of 400 series expressways across Ontario over the next 20 years, some of which are currently underway. With increasing threats of a severely fragmented landscape, provincial and municipal transportation agencies are currently integrating transportation mitigation solutions e.g. wildlife overpasses and underpasses, within the environmental assessment study (EAS) process. To assist in providing cutting-edge road ecology science in this decision-making process a group of non-government, government, scientists, educators, and transportation planners collectively called the Ontario Road Ecology Group (OREG) formed at the Toronto Zoo in 2007.

This paper discusses two initiatives adopted by the OREG. We first discuss the development of a GIS habitat mapping model for wetland-forest animals in southern Ontario. Model development entailed weighting a land-use layer, and summing the land-use within 200 m buffers surrounding each 15 x 15 m pixel in the landscape. A Habitat Suitability Index (HSI) was then attached to each road pixel. Opportunistic validation using Chi-squared statistics showed that HSI's on roads with a score greater than 30,000 had higher numbers of road mortality than expected by chance. Alternatively, HSI scores less than 10,000 had significantly fewer road mortality. Ongoing work entails a systematic rigorous validation collecting road mortality data along random and hot and cold spot locations in predefined circuits to regress dead and alive on road animal abundance with HSI scores.

The second initiative entails combining the validated road hotspot model with natural heritage systems to incorporate landscape connectivity into the final model. Natural heritage modeling is an on-going process adopted by the Ministry of Natural Resources and Conservation Authorities to map and connect natural core habitat areas across southern Ontario and within watersheds. We show examples of the preliminary application of the hotspot model to already developed natural heritages systems e.g. the Greenbelt in the Project 400 study area. This type of integration in addition to species at risk habitat mapping can assist in prioritizing areas where mitigation measures such as crossing structures will be most effective to maintain connectivity for species at risk, e.g. turtles in addition to reducing wildlife road mortality. Once complete, these analyses can be used as leverage to bring together key stakeholders to determine a strategy to ensure province-wide landscape-level planning is adopted into policy by transportation agencies in Ontario.

Introduction

Ontario has the highest number of roads, vehicles, and species of animals in Canada. As a result wildlife is increasingly involved in collisions with motor-vehicles, providing a real threat for wildlife and human safety on roads. Based on 2004 statistics, roughly 6% of all motor-vehicle collisions involve wildlife (14,000/year) and this has increased by 83% over a 10 year period. Ontario statistics from 2004, show motor-vehicle collisions with moose and deer resulted in 7 fatalities, and 542 injuries for motorists (Ontario Ministry of Transportation, NE Division, personal communication).

For some species continued trends of increased road mortality has contributed to significant declines in population numbers in Ontario. For example, seven of eight turtle species are listed by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) as threatened, endangered or special concern and road mortality has been identified as one of the most direct, significant threats to five of these turtle species.

In 2007 a group of scientists, academics, consultants, and government planners assembled at an Ecopassages forum at the Toronto Zoo to begin to tackle some of the negative impacts associated with roads and wildlife in Ontario. As a result a group of individuals banded together and formed the 'Ontario Road Ecology Group'-OREG. Its goal is to raise awareness about the threat of roads to biodiversity in Ontario, and to research and apply solutions to these threats.

In response to the Ministry of Transportation's (MTO) plans to extend a number of 400 series highways as well as other provincial highways over the next 20 years, OREG initiated Project 400. This project entails working with the provincial transportation government to evaluate and provide solutions to minimize potential environmental and wildlife impacts such as wildlife-vehicle collisions (WVCs) along roads, specifically 400-level expressways. Possible solutions include the use of mitigation measures such as reptile tunnels (Aresco 2005; Dodd et al. 2004), overpasses and underpasses, culverts and other structures that have been successful in alleviating road mortality (Forman et.al. 2003).

This paper describes two components of Project 400:

1) The development, validation and application of a GIS-based, road-mortality hotspot model. This model prioritizes where there will be mortality sinks for wildlife on current and proposed roads.
2) The development and integration of connectivity and species at risk (SAR) presence data into road planning procedures. This model predicts where there roads will behave as barriers for movement of wildlife, most specifically SAR.

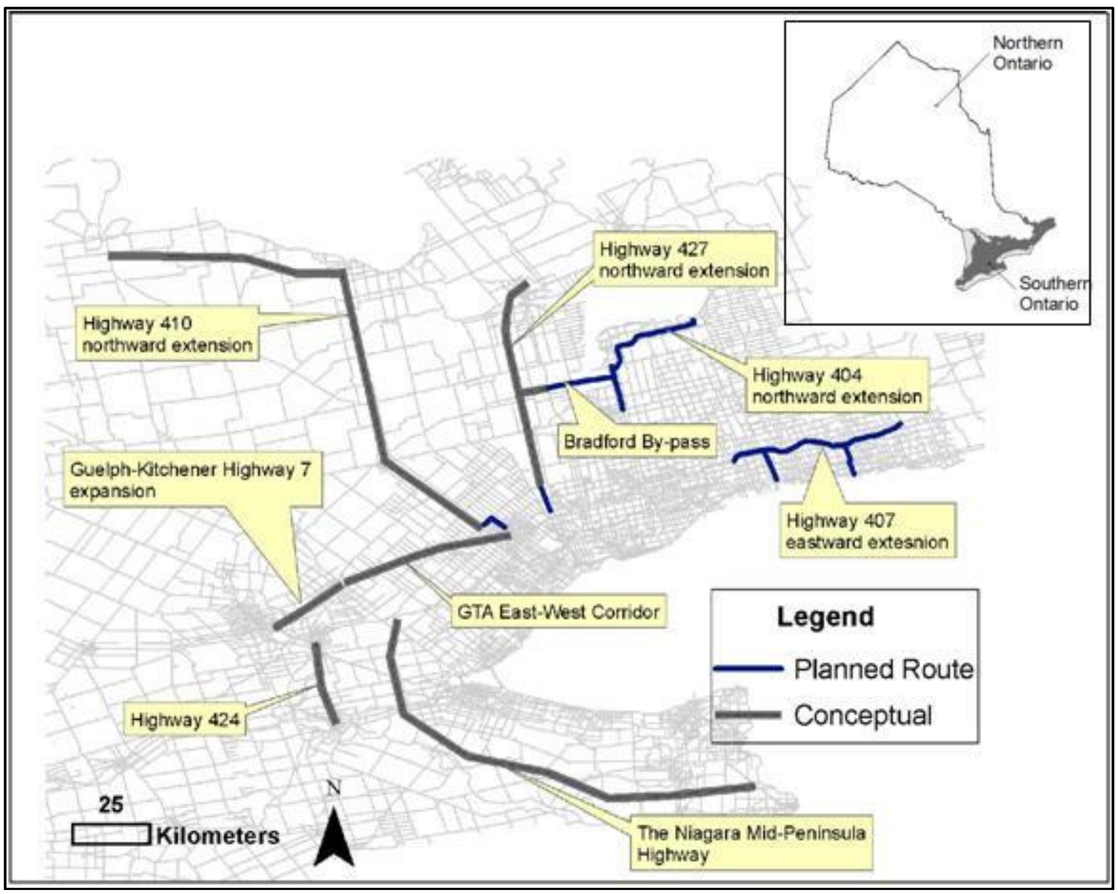

Figure 1. Study area for Project 400 showing the planned and conceptual routes in south-central Ontario. Note: The best available Information was used to complete this map as of September 2008.

Study Area

Ontario is divided into northern Ontario, the landmass of, and north of, the Canadian Shield, and southern Ontario the portion of the province south of the Canadian Shield (Figure 1). The study area for Project 400 is composed mainly of the central portion of Southern Ontario (Figure 1). There are several planned routes (blue lines) where a proposed route has been defined and the Environmental Assessment Study (EAS) is nearing completion. In addition there are conceptual routes (grey lines) where a proposed route has not been defined and the EAS process is in its early stages if at all. These highways are being developed in response to the population and employment growth expected in the major urban centres across the Greater Golden Horseshoe (GGH) (Ministry of Public Infrastructure Renewal 2006).

Methods

Road-mortality Hotspot Model

Development

After completing a review of the literature and available expert opinion we selected forest-wetland habitat to be associated with the distribution of the majority of SAR and other animals in southern Ontario. For example published literature has shown that ungulate (mainly deer) road mortalities are positively correlated to the amount of forest cover or have occurred close to forest cover in six published studies (Bahsore et al. 1985, Finder et al. 1999, Hubbard et al. 2000, Malo et al. 2004, Seiler 2005, Gunson et al. 2009). In addition, herpetofauna road mortalities (amphibians and reptiles), have been correlated to a mosaic of wetland-forest habitat (deMaynadier and Hunter 1999, Joyal et al. 2001 Guerry and Hunter 2002, Gibbs and Shriver 2005, Hermann et al. 2005, Langen et al. 2008) and at locations where roads bisect wetlands (Langen et al. 2008).

We then used the available regional geospatial layers for model development. The Southern Ontario Land Resource Information System (SOLRIS), and the Ministry of Natural Resources (MNR) road network were used for habitat identification and roads respectively. To produce a habitat map a score was applied to every habitat type within the SOLRIS layer. Wetland (swamps, fens, bogs, marshes, and open water) received the highest score (100), forest habitat (forest, mixed forest, deciduous forest, and plantations) received a score of 50, and all other features (agriculture, and built-up) received a score of zero.

We then summed the score of the newly classed pixels within a 200 m radius buffer surrounding every 15 x 15 m pixel within the study extent of the SOLRIS layer. This created an output layer herein called habitat suitability, where each 15 x 15 m pixel had a habitat suitability index (HSI) (range 0-55,000) associated with it. We then converted the vector-type MNR roads layer to a raster data-type with 15 x 15 m pixels and registered it with the habitat suitability layer so the two layers spatially overlapped. This allowed the summation of the two layers so an HSI could be attached to each road pixel in the landscape. We used ArcMap 9.2 for all spatial analyses using a Geographic Information System (ESRI, Redlands California).

Opportunistic Validation

We obtained a road mortality database for all wetland-forest amphibians and reptiles for southern Ontario collected by two organizations, the Bishop Mills Natural History Centre, and the Natural Heritage Information Centre from 1970 to 2005. We selected eastern Ontario-UTM Zone 18T as our study area because this region had the vast majority of road mortalities and was a spatial extent that could be easily manipulated to perform spatial analysis in a GIS. We filtered the database for species of herpetofauna that are typically found hibernating and breeding in wetland-forest complexes as per the literature and internet search (Gibbs 1998, Glista et al. 2007, Langen et al. 2008). These included the American toad (*Bufo americanus)*, Gray tree frog (*Hyla versicolor*), Wood frog (*Rana sylvatica*), Spring peeper (*Pseudacris crucifer*), Spotted salamander (*Ambystoma maculatum*), Painted turtle (*Chrysemys picta*), Snapping turtle (*Chelydra serpentine*), Blandings turtle (*Emydoidea blandingii*), Map turtle (*Graptemys geographica*), Musk turtle (*Sternotherus* odoratus), and the Spotted turtle (*Clemmys guttata*). To address spatial autocorrelation we reduced multiple mortality events within 500 m of each other, occurring on the same day, for the same species to only one event. From these data we only included events that were within 500 m of a road. The final collated data set had 447 road mortality data points.

We overlaid the observed road mortalities on the final output layer and attached the closest HSI score to each one. We grouped the HSI scores into groups of 5,000 starting with 0-5,000, etc. up to 50,000, and counted the number of observed turtle mortalities that were located within each class interval (Table 1). We did not include the final interval, 50,000 to 55,000 since there were no observed mortalities that were located on road segments with this score class. We calculated the expected count distribution for wetland-forest road mortalities at each score interval based on the proportional road length assigned to each score class (Table 1). We then used Chi-square statistics to compare the count of the observed mortalities to what was expected for each score class. We used Bailey's confidence intervals to determine if the difference between the observed and expected values were significant ($p<0.05$) (Cherry 1996) (Table 1). For interpretation we calculated the observed to expected ratio to obtain a percentage of observed kills to what was expected.

Systematic Validation

We selected a 232 km circuit along County Roads (and short stretches of connecting municipal roads) around Leeds & Grenville United Counties in eastern Ontario, from the Rideau River south to the St Lawrence River, straddling the Frontenac AxisAxis/limestone boundary (Fig. 2). In the circuit there were 18 hotspots (score > 30,000) and 23 coldspot stations (score < 10,000) (Fig. 2, see Results section).

We obtained geographical coordinates for all DOR Vertebrates, and nonvolant AOR vertebrates, seen in driving the circuit, stopping for all that may be SAR or related species (Snakes or Turtles). At each station we stopped at the station stretch, and each of two surveyors walked one way, gathering or counting carcasses and AOR animals until our GPS unit read 100 m distant from the station, returning on the other side of the road. We picked up all cm-scale roadkills seen on the pavement or gravel shoulders, and recorded nonvolant species seen alive on the pavement and shoulders. We also recorded Turtle nest excavations and predation, and various incidental road-related phenomena (including Anuran calling, and invasive plants & Gastropods.

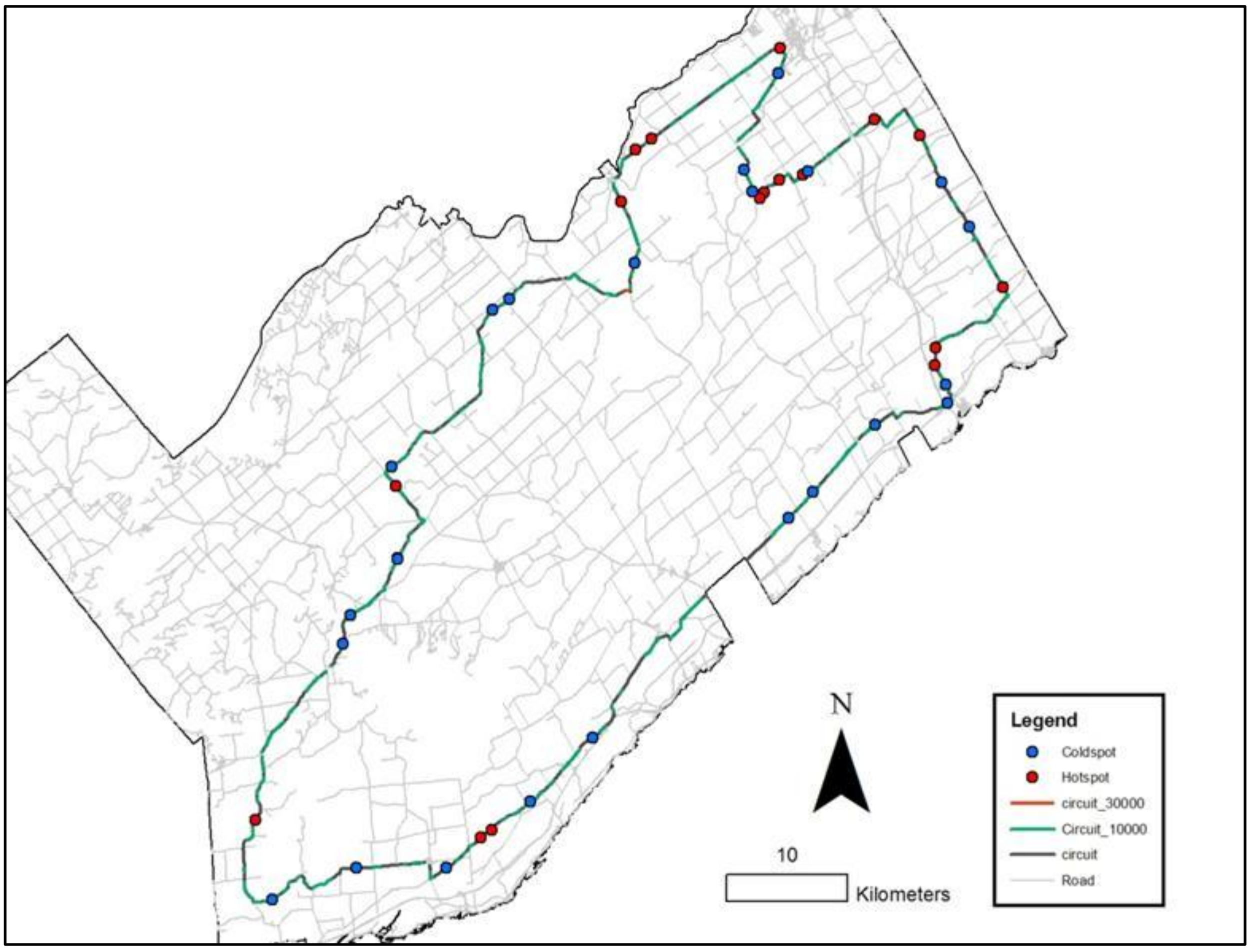

Figure 2. Surveyed circuit in Leeds & Grenville United Counties in eastern Ontario showing hot- and coldspot stations used to systematically validate the predefined hotspot model.

Road-connectivity Model

In the 1990's the Ministry of Natural Resources incorporated a natural heritage system (NHS) strategy into its policy (Ministry of Natural Resources 1999), and other agencies such as Ontario's Conservation Authorities are adopting a natural heritage approach to defining and connecting significant natural wildlands in their watersheds (e.g. Toronto Region Conservation Authority 2007). We integrated available NHS with our habitat models to incorporate connectivity in model output. First, we filtered the final output from the habitat suitability model for scored pixels greater than 30,000 which were previously defined hotspots for road mortality. We then overlaid this with the NHS models in the study area for

Project 400, e.g. the greenbelt NHS. The Greenbelt zone is a previously designated 'green zone' made up of key natural, agricultural, and rural areas that wrap around the golden horseshoe from Niagara to areas east of the Greater Toronto Area (The Greenbelt Plan, Ministry of Municipal Affairs and Housing, 2005). The natural heritage system contains connected natural areas within the green zone. The Ministry of Transportation 407 planning team invited OREG to assist in prioritizing where wildlife mitigation would be most effective along the highway corridor. We used the results from the validated hotspot model and the Greenbelt NHS to apply the model to the Highway 407 east extension.

Results

Road-Mortality Hotspot Model

Opportunistic Validation

Table 1 below shows that sections of road that receive a score between 0 and 10,000 will have significantly less road mortality with wetland-forest animals than expected, herein deemed a coldspot. Sections of road that receive a score between 30,000 and 50,000 will have significantly more road mortality than expected, herein deemed a hotspot.

Score Class	Observed	Expected	Observed/Expected	Type
5,000	54	158	34	Coldspot
10,000	56	85	66	Coldspot
15,000	73	62	117	n/a
20,000	42	48	88	n/a
25,000	63	38	166	n/a
30,000	36	26	138	n/a
35,000	47	15	313	Hotspot
40,000	36	8	450	Hotspot
45,000	22	3	733	Hotspot
50,000	18	4	450	Hotspot
Total	**447**	**447**		

Table 1. Summary of Chi-square and Bailey's confidence interval analyses using road-kill data from 1970 to 2005 for wetland-forest animals in eastern Ontario. Coldspots refer to sections of roads with significantly less road-kill than expected, and hotspots refer to road sections with significantly more road-kill than expected.

Systematic Validation

We completed one circuit on June 18th and June 19th, 2009 as a pilot test run to determine the time, cost, and methodological requirements for a rigorous and systematic study design. Wetland-forest herpetofaunal species found dead and alive on the road at the surveyed transects were: Snapping turtle, Painted turtle, Gray treefrog, American toad, Blanding's turtle, and the Wood frog. Other herpetofaunal species were the Water snake (*Nerodia sipedon*), Milk snake (*Lampropeltis triangulum*), Green frog (*Rana clamitans*), Leopard frog (*Rana pipiens*), and the Bull frog (*Rana catesbeiana*). Road-killed queen Bumble Bees (Bombus) were the most conspicuous invertebrates.

The circuit required 2 people ~ 9 hours to complete and has an estimated cost of $2,000 per circuit which includes mileage costs, and labour (set-up, surveying, and data entry). Ideally the circuit should be completed from early spring through summer for a number of years to obtain data on all species throughout their specific seasonal life-cycle requirements, e.g., breeding, egg-laying, and juvenile dispersal. The following questions and methodological considerations were formulated as a result of the pilot survey:

- Results can determine the best cut-off score to apply to a coldspot and a hotspot
- Results can determine if the land-use layer SOLRIS is appropriate to determine wetland-forest complexes as hotspots
- Seasonal replicates are required to produce species-specific models that will incorporate different seasonal movements for each species or species group
- Results (number of AOR and DOR animals) can be regressed against each scored class to determine appropriate scores for hotspots and coldspots
- The surveys will provide valuable insights on the death rate of animals on eastern Ontario county roads

Road-connectivity Model

Figure 3 shows twelve areas (yellow dots) where high quality habitat (black and white areas, score > 30,000) detected by the hotspot model, bisect the 407 east highway extension. These are plausible areas for attempted mitigation since they are contained in the Greenbelt natural heritage system. This means that these are probable wildlife movement corridors as well as probable sites of initially high wildlife road mortality, before dispersal attempts cease or the populations become extinct.

The 407 transportation planning team finalized the detail design phase of the EAS and there will be 55 wildlife crossings associated with watercourses, the majority of which will accommodate ungulates, and 6 wildlife underpasses not related to watercourses. Five out of the 6 wildlife underpasses are for small animals only. OREG's modeling efforts were used to support and corroborate the Study Team's pervious connectivity and linkage analysis and eco-passage system recommendations.

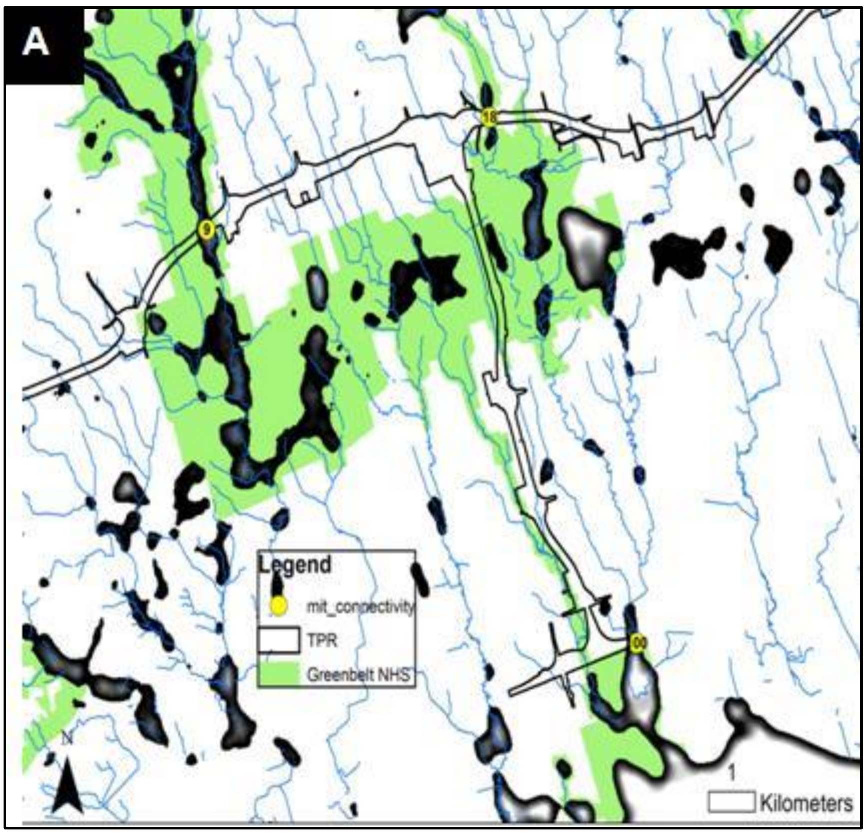

Figure 3A. The 407 east extension with the west link.

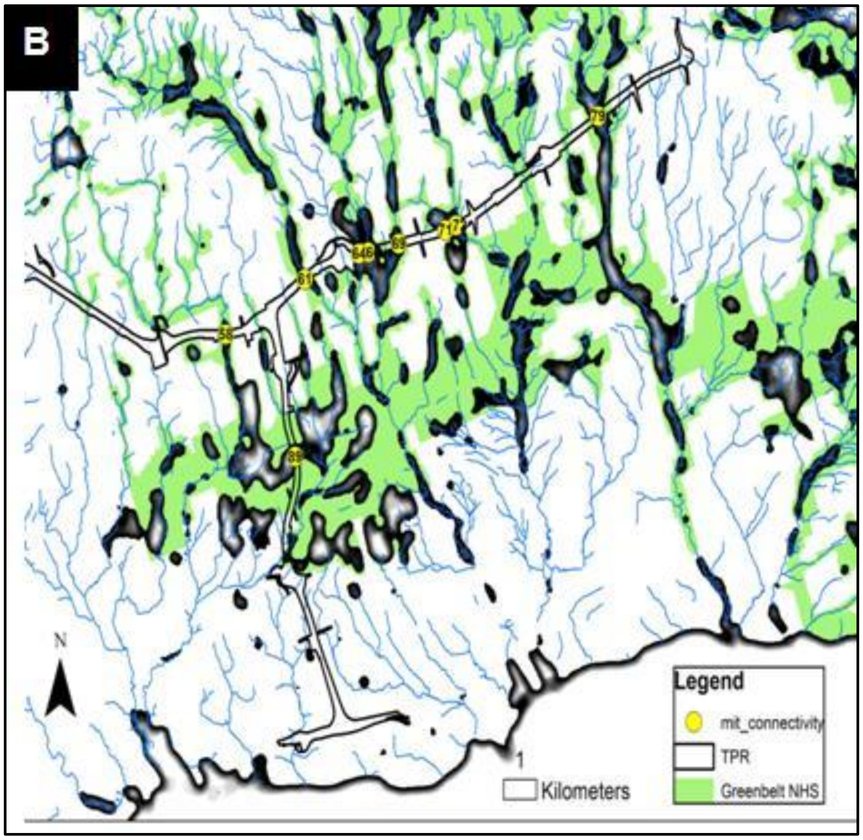

Figure 3B. The 407 east extension with the east link combined with the hotspot model and the greenbelt natural heritage system.

Yellow dots in both Figure 3A and 3B show where the hotspot model predicts high road mortality all contained within the natural heritage system.

Conclusion and Future Work

On-going validation and refinement of the road-mortality hotspot model can be achieved by engaging local citizens, conservation authorities and naturalist groups to report and collect locations of wildlife-vehicle collisions within their communities. This type of data collection requires a coordinated effort to sample road mortality across each watershed in southern Ontario. Local citizens can repeatedly monitor sections of roads falling under a larger project such as–'Adopt-A-Crossing' (Schueler and Karstad 2009). Collectively, the GIS modeling and data collation can work towards evaluating the model and providing a landscape-level blueprint for prioritizing mitigation efforts for wildlife in southern Ontario. This will ensure a validated hotspot model at a regional scale required to maintain population persistence for species at risk that are increasingly subjected to road-related threats, namely road mortality and landscape fragmentation.

The road mortality model will be applied to the Project 400 study area along with applicable natural heritage system models. When available, the model will be manipulated to incorporate the most up to date, high resolution, and validated habitat layers, e.g. the ecological land classification layers in specific watersheds. In addition, species at risk presence data will be used to develop species-specific models that incorporate other habitat characteristics such as stream crossings, traffic volumes and topography. SAR presence data can also assist in prioritizing areas for mitigation. However caution will be exercised since the data has been opportunistically collected and SAR can easily exist in areas not yet sampled.

These types of applications- hotspot modeling, and connectivity analyses will be applied to all 400-level roads by OREG and other roads in southern Ontario. At this point these applications are preliminary and a strategy needs to be defined to ensure long-term support to further test the models and to ensure their application into the planning stages of large-scale transportation projects at both the municipal and provincial level.

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Biographical Sketch

Kari Gunson holds a BSc. in Zoology and Ecology from the University of Calgary, MSc. in Conservation Biology from the University of Cape Town, and another MSc. in Geospatial Technologies from the State University of New York. She has eleven years experience in road ecology focusing mainly on the interactions of roads and wildlife, and has co-authored eight peer-reviewed articles in this area of research. She worked six years as a research associate on the Banff Crossings Project in Banff National Park and she is a co-founder of the Ontario Road Ecology Group initiated in the Toronto Zoo.

Dave Ireland is the Curator of Conservation Programs at Toronto Zoo and, among other duties, Chairs the Ontario Road Ecology Group. Dave works closely with local, regional and international organizations to collaboratively develop programs to conserve biodiversity. Dave has extensive experience in herpetology in Ontario where he received an MSc in herpetology from Trent University and published 2 peer-reviewed papers in this field.

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USE OF HABITAT CREDIT TRADING AS A MITIGATION TOOL FOR TRANSPORTATION PROJECTS: A FEDERAL HIGHWAY ADMINISTRATION PILOT PROJECT IN ARKANSAS

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Abstract

Two programs within the U.S. Fish and Wildlife Service's Habitat Credit Trading Program currently exist to allow for "banking" of habitat credits: traditional Conservation Banking and the recently introduced Recovery Crediting System (RCS). Both of these mechanisms embody the intent of Executive Order 13352 on Facilitation of Cooperative Conservation and the environmental stewardship and streamlining direction of SAFETEA-LU.

The RCS was introduced by the U. S. Fish and Wildlife Service in November 2007 as an additional conservation tool to aid Federal agencies in meeting their ESA obligations to conserve listed species. Similar to a conservation bank, a RCS allows Federal agencies to bank credits in advance of anticipated impacts to threatened and endangered species, their habitat, and its functions. Unlike a conservation bank, recovery crediting encourages Federal agencies to partner with private and non-Federal landowners to accrue credits through mutually beneficial conservation agreements, which may be in perpetuity (easement or fee title purchase) for permanent impacts, or that may address temporary construction impacts through non-perpetual easements. The first application of the RCS occurred in Texas where the U.S. Army/Ft. Hood Military Reservation banked credits for conservation actions conducted on private lands to offset impacts to endangered golden-cheeked warbler habitat. Recognizing the need to avoid piecemeal approaches to endangered species conservation, the Federal Highway Administration (FHWA) is considering a pilot project to establish a market-based system, Habitat Credit Trading, to address Section 7 of the Endangered Species Act (ESA) requirements for transportation projects on a local scale.

Arkansas State Highway 18 connects the city of Jonesboro and other townships in northeast Arkansas to Interstate 55. A proposed FHWA funded project will upgrade the facility from two to four lanes. Highway 18 (bridge and approaches) forms the southern boundary of Big Lake National Wildlife Refuge near Manila, Arkansas and the project will impact < 10 acres of the 11,038 acre refuge. The federally endangered fat pocketbook mussel (*Potamilus capax*) occurs in streams adjacent to private lands within the project area downstream of U.S. Army Corps of Engineer water control structures that drain Big Lake National Wildlife Refuge.

In this paper we analyze the applications of the RCS and evaluate the efficiency of this conservation tool in relation to the proposed and future transportation projects. We examine the RCS as one of the tools available to Federal agencies, which allows them to meet their ESA obligations through a more innovative and customized approach.

Introduction

Section 7 of the Endangered Species Act of 1973 (87 stat. 884, as amended; 16 U.S.C. 1531 et seq; ESA.) requires Federal agencies to use their existing authorities to conserve threatened and endangered (listed) species through a process of consultation with the U.S. Fish and Wildlife Service (Service). The use of market-based compensation programs provides opportunities for Federal agencies to meet this ESA Section 7 requirement by offsetting their impacts to listed species and their habitats. One such market-based system, Habitat Credit Trading (HCT), facilitates the exchange of credits between interested parties, which represent habitats that have been restored, enhanced, preserved, or otherwise conserved for the purpose of offsetting losses of similar functioning habitat elsewhere. Two HCT programs currently exist that allow for this exchange or "banking" of credits: traditional Conservation Banking and the recently introduced Recovery Crediting System.

Habitat Credit Trading is not only beneficial to Federal agencies, but it is also a useful tool for private landowners. The long-term survival of most listed species depends not only on preventing further losses, but also on the ability to increase populations by restoring degraded habitats, which often occur on private lands (Wilcove and Lee 2004). Habitat Credit Trading can facilitate the conservation of high quality habitat on private lands by providing private landowners with an economically viable land management alternative (Scheerer and O'Neil, *in progress*), whereby habitat for listed species on private lands is treated as a benefit rather than a liability (Service 2003). As such, HCT can be mutually beneficial to all participants. Both conservation banking and RCS provide an opportunity for the Service to conserve high quality habitat on private lands while providing project applicants greater flexibility in meeting their regulatory requirements under the ESA.

The Recovery Crediting System (RCS) is a specific habitat credit trading program introduced by the Service in 2008 as an optional tool for Federal agencies to promote and enhance the recovery of listed species on non-Federal lands. The RCS allows Federal agencies to implement recovery actions on non-Federal lands for specific listed species to generate credits that may be used to offset the effects of their actions (USFWS 2008). Similar to a conservation bank, recovery crediting permits Federal agencies to bank credits in advance of anticipated adverse effects to listed species, their habitat, and its functions. However, unlike a conservation bank, a RCS must provide a net benefit to the recovery of the target species and is only available to Federal agencies at this time.

Conservation Banking Overview

Conservation banking is a habitat credit trading tool designed to conserve listed species and the habitats upon which they depend, while providing a means for Federal agencies and private entities to offset adverse impacts to listed species and fulfill their regulatory obligation under the ESA. Conservation banking design borrowed heavily from the mitigation banking concept. Mitigation banking involves the preservation, restoration, creation, or enhancement of wetlands and/or other aquatic resources to provide compensatory mitigation under Section 404 of the Clean Water Act in advance of authorized impacts (USACOE et al. 1995). However, unlike mitigation banks, conservation banks are designed to improve habitat for one species, or enhance a key environmental correlate that supports several species; mitigation banks are developed to replace a habitat type (e.g. wetlands or streams) that has value for multiple species with no net loss of that habitat (Scheerer and O'Neil, *in progress*). Conservation banking focuses on the protection of existing habitat with long-term conservation value to listed species in order to mitigate for the loss of isolated habitat with little long-term conservation value.

A conservation bank is a parcel of land containing natural resource values that are conserved and managed in perpetuity, through a conservation easement held by an entity responsible for enforcing the terms of the easement, for specified listed species and used to offset impacts occurring elsewhere to the same resource values on non-bank lands (USFWS 2003). Conservation banks may be established on a Tribal, State, local, or private lands. The value of the natural resources within a bank's lands is translated into credits, and may vary by habitat type or management activities. Some of the biological criteria used when determining credit values may include habitat quality and quantity, species covered, conservation benefits, property location and configuration, and available or prospective resource values (USFWS 2003). Also, credit values typically include costs associated with the long-term operation, management, and monitoring of the conservation bank.

Credits may be bought, sold, or traded for the purpose of offsetting adverse impacts of Federal, State, local, or private activities. However, conservation credits may only be exchanged for debits resulting from projects that affect a species specifically covered by the bank. In some instances, a conservation bank may contain habitat that is suitable for multiple listed species. When this occurs, it is important to establish how the credits will be divided; as a general rule, overlapping multiple species credits is acceptable for a single project, but not multiple projects (USFWS 2003). Credits from a conservation bank may be used to compensate for impacts of activities regulated under Section 7 or Section 10 of the ESA, as well as environmental impacts authorized under other programs (e.g., NEPA and State or local regulatory programs). For this application, the same credit may be used to compensate for an activity that requires authorization under more than one program; however, the same credit cannot be used to compensate for more than one activity (USFWS 2003).

Recovery Crediting System Overview

The goal of a RCS is to enhance the ability of Federal agencies to promote the recovery of listed species on non-Federal lands and offset adverse effects to listed species from proposed actions. The RCS is an optional method for Federal agencies to meet their Section 7(a)(1) responsibilities. Potential benefits of a RCS include:

- Better and more cost effective integration of recovery with agency activities;
- Streamlined ESA Section 7 consultation;
- Increased predictability for Federal action agencies and private landowners (Harrelson 2008)

Unlike a conservation bank, the RCS requires the combined effects of both adverse and beneficial actions to achieve a net benefit to the recovery of the species. ''Net benefit to recovery'' is defined as the enhancement of a species' current status by addressing the threats identified at the time of listing or in a current status review (USFWS 2008). Unlike a conservation bank, recovery crediting encourages Federal agencies to partner with private and non-Federal landowners to accrue credits through mutually beneficial conservation agreements, which may be in perpetuity (easement or fee title purchase) for permanent impacts, or that may address temporary construction impacts through non-perpetual easements. Recovery crediting also allows for the accrual of temporary credits to address temporary impacts from activities subject to ESA Section 7 consultation. Yet, due to the 'net benefit to recovery' standard for crediting, temporary credits must provide a measurable contribution to the recovery of the target species (USFWS 2008). This can be applied to recovery actions such as needed research, management, or outreach actions. Non-permanent credits/contracts often provide incentive for private landowners to participate, as opposed to more permanent credits of conservation banking. However, the accrual of temporary or permanent credits is dependent on multiple factors and will vary among RCS's; some listed species may not be appropriate for a credit system.

Credit Generation

The RCS was developed to provide Federal agencies with an additional recovery tool using existing authorities. A RCS is created during the ESA Section 7 consultation process with the Service, whereby the credits and debits are defined and assigned a value reflective of the species' recovery needs. Therefore, only Federal action agencies may accrue, hold, and debit recovery credits (Harrelson 2008). A recovery credit is a quantifiable unit of measure established by a RCS that quantifies the contribution that an agency's action makes toward the recovery of a listed species (Harrelson 2008). The recovery credits are presented as part of the action agency's project description and represented by a legally binding commitment (e.g. a contract with a private landowner). Non-Federal partners may participate in RCS activities, as appropriate (i.e., acting on behalf of a Federal action agency), but the Federal action agency is ultimately responsible for accounting of recovery credits.

The crediting phase of the RCS involves the identification of threats to listed species and their habitat, and actions needed to address those threats. Generally, the recovery plan for the species, or other Service approved documents provides necessary information for such a threat analysis. Other documents which may provide acceptable frameworks include military Integrated Natural Resources Management Plans, State Wildlife Action Plans, 5-year status reviews, and biological opinions. The crediting analysis also establishes the means by which a credit in a RCS will be measured and tracked (USFWS 2008).

Temporary Credits

Recovery credits must be accrued and identified as a "bank" prior to being used (debited) and may provide for permanent or temporary conservation to listed species. However, the positive effects of the recovery credits may be temporary only if the negative effects to be offset are also temporary (USFWS 2008). As an example, many listed species only require periodic habitat management activities as part of their recovery. Therefore, recovery credits may provide short-term benefits if the activity provides a net benefit to the recovery of the species.

Credits may be temporary in nature, provided the action meets the recovery needs of the species. Temporary credits could be used to offset temporary adverse effects in appropriate situations that still allow a net benefit to recovery. For example, many transportation and linear utility projects require temporary workspace for construction, which is later returned to pre-construction conditions. An agency could accrue credits for the restoration and temporary protection of degraded habitat to mitigate for habitat that has temporary adverse effect, with the duration of credit based on benefits achieved at the restored site and eventual restoration of the affected site (USFWS 2008).

Credit Accrual and Release

This phase establishes the standards according to which credits will be used. This phase may be conducted separately or concurrently with the credit accrual planning and development. An advantage of considering crediting and debiting at the same time is that a better match may be achieved between the credits accrued and the debiting needs. In addition, the debit process could consider the possibility of Federal agencies other than the Federal agency that established the RCS being able to use credits.

Consideration of debits includes ensuring that agencies maintain a net benefit to recovery gained by credit accrual. In general, credits that accomplish tasks in a species' recovery plan would normally meet a net benefit to recovery standard. However, because credits would be used for mitigation, it is important to ensure the debit process does not limit, counter, or preclude necessary recovery objectives and is developed in reliance on a recovery plan or analogous document. Examples of using a debiting process to ensure a benefit to recovery include using biologically appropriate mitigation ratios in habitat-based crediting (e.g., more than one credit for each debit necessary to fully offset adverse effects), maintaining a credit balance that ensures an incremental increase in the species' recovery status, restricting use of debits to areas not deemed essential in recovery plans or a Service approved conservation plan, and limiting the types of activities available for debiting (USFWS 2008).

Current RCS Projects

The first and only current application of the RCS began in 2005 with a pilot project on the U. S. Army/Fort Hood Military Reservation near Killeen, Texas. Fort Hood is one of the largest and most active military training installations in the United States. Due to the nature of military training, adverse impacts to the endangered golden-cheeked warbler were unavoidable on the installation (Harrelson 2008). To offset these impacts, a RCS was developed to allow Fort Hood to accrue recovery credits by undertaking recovery actions for the golden-cheeked warbler on private lands. These off-base recovery credits would be applied in the future to offset unforeseen or unavoidable losses of golden-cheeked warbler habitat from future activities on the installation (USFWS 2009).

The RCS administered at Fort Hood contains 10- to 25-year contract agreements made with neighboring landowners to provide short term habitat protection and management for the golden-cheeked warbler on private lands. These agreements were banked as recovery credits for use by Fort Hood in exchange for debits. The use of these temporary recovery credits would mitigate for the adverse effects of future military activities on golden-cheeked warbler habitat and provide a short term benefit to the species. The RCS applied at Fort Hood provides an opportunity for the U.S. Army to conserve the endangered golden-cheeked warbler on private lands, offset adverse effects to the golden-cheeked warbler on Federal lands, and provide a better understanding of the golden-cheeked warbler's status on private lands.

Opportunities and Challenges of RCS

Recovery Credit System is a relatively new program with little implementation history, therefore the biological and programmatic strengths and weaknesses are somewhat dependent upon the perspective and experience of the reviewer. However, the RCS is based largely on the wetland mitigation and conservation banking models with a rich implementation history and clear guidelines. Therefore, many attributes of those programs are reasonably transferable to the RCS. Though rooted in existing HCT programs, recovery crediting employs unique programmatic attributes that make it distinct from other previously existing HCT programs. These alternative attributes are necessary to meet the goal of the program, which is to formalize an optional HCT protocol for Federal agencies to implement recovery actions, as intended by Section 7(a)(1) of ESA.

Although the RCS is intended to function as an alternative option for Federal action agencies, there is significant flexibility in the system for application to unique situations. First, recovery crediting allows Federal action agencies to trade credits amongst each other if biologically appropriate. This may reduce duplicative efforts in areas experiencing high development pressures, streamline the project consultation process, and produce larger scale recovery projects. Second, because credits can only be generated on non-Federal lands, the RCS seeks to address management of listed species on private land while providing a mechanism to provide incentive payments directly to landowners. Third, the creation of temporary credits to compensate for temporary impacts addresses landowner concerns of permanent protections and is expected to increase landowner participation in recovery efforts. Fourth, credits can be accrued for more than habitat preservation/restoration activities such as research, propagation, and other activities, similar to In-Lieu-Fee programs.

Finally, the RCS increases the certainty relative to credit availability as RCS credits are only available to Federal entities. In typical HCT programs, private and public sector entities generally compete for the same credits and demand may surpass supply as credits must be generated prior to impact activities. In areas of high development pressure, this may produce short and long term uncertainty regarding credit availability. Recovery crediting may alleviate some of this demand by creating additional credit generating options for Federal agencies. In areas of low development pressure, the RCS may be an avenue to generate credits when the overall credit demand is not sufficient to warrant a privately held conservation bank.

A unique attribute of RCS which will require careful consideration is associated with the introduction and suggested use of temporary credits as described in the guidance document. The intent of this option is to allow Federal agencies to compensate for impacts which are limited in both scope and duration, but once the impact is returned to some identified level of form or function, the credits are then returned to RCS and applied to another impact location, again, limited in scope and duration. Though the guidance does not provide explicit language defining “temporary impacts” examples might include channel maintenance or cleanout activities, equipment landings, or intense invasive species eradication efforts. One benefit of this attribute is that it allows for short-term, rather than permanent, easements which are likely to be more attractive to private landowners and more cost effective for agencies. Although the development of temporary credits is a novel approach, implementation may pose both biological and programmatic challenges.

From a biological standpoint, temporary impacts may alter the successional trajectory and/or structural components of an impact site, potentially causing the impact area to become inhospitable for the target species. In effect this may cause a net loss of habitat, potentially violating the “net benefit to recovery” goal. From a programmatic standpoint, a goal of RCS is to assist in the delisting or downlisting of listed species, however, it is not clear how temporary credits would be admissible in this regard. The use of temporary credits from both biological and programmatic standpoint pose difficult, though not insurmountable, questions and will require careful consideration and implementation in order to withstand extensive public scrutiny.

Pilot Project

Introduction

The Federal Highway Administration (FHWA) and the Arkansas State Highway and Transportation Department (AHTD) are required to provide mitigation for unavoidable impacts to wetlands and waters of the United States due to highway construction and maintenance activities via the Section 404 (of the Clean Water Act) permitting process. Additionally, FHWA and AHTD provide mitigative features during the Section 7 (Endangered Species Act) consultation (informal and/or formal) process as ways to minimize harm to endangered species that may be involved with transportation projects.

Since the early 1990s, the FHWA-Arkansas Division (FHWA-AR) and the AHTD have taken the approach that a few large, contiguous tracts of mitigation property are better suited to provide functional benefits than are many small, isolated mitigation sites. Following that philosophy, 5 formal wetland mitigation bank sites ranging in size from 160 – 845 acres have been established, and an additional 12 multi-project mitigation areas (pre-dating formal wetland banking) are owned and managed by the AHTD. A total of 3000+ acres in Arkansas have been purchased, restored or preserved, and managed by the FHWA-AR and AHTD for mitigation of project-related wetland impacts.

Evaluation of tracts that would provide wetland, stream, and/or (endangered) species conservation benefits is a normal part of project planning and development. Tracts that would provide outstanding (and cost-effective) mitigation benefits for wildlife habitat restoration and connectivity, wetland function, stream stability, and endangered species recovery are targeted for acquisition and development as bank sites.

The FHWA and the AHTD are developing a proposed project to widen Arkansas Highway 18 from a 2-lane to 4-lane facility from the St. Francis River eastward to near Roseland in Mississippi County. The proposed project crosses Big Lake National Wildlife Refuge (NWR) and streams that provide habitat for the endangered fat pocketbook mussel (*Potamilus capax*). Project planning and subsequent assessment required by the National Environmental Policy Act (NEPA) revealed a tract with potential multi-faceted benefits including improved stream water quality, aquatic habitat diversity, endangered mussel habitat stability, and improved land and water management capabilities for Big Lake NWR. Once the conservation and ecological importance of the tracts was established, the question becomes how to establish the site to accrue the greatest environmental benefit and how to maximize cost-benefit for the transportation funds utilized.

Site and Species Description

The St. Francis River is located in the Mississippi Alluvial Plain Eco-region of eastern Arkansas and southeastern Missouri. Land-use in this area consists predominantly of intensive row-crop agriculture with rice, cotton, and soybeans being the primary commodities. Historically, the eco-region consisted of an extensive bottomland hardwood ecosystem which has since been converted to agriculture through an extensive ditch and levee system (Sartain 1998) managed by local Drainage Districts and the U. S. Army Corps of Engineers (USACOE). Though the St. Francis is a highly altered and managed system, the watershed harbors the largest population of the endangered freshwater mussel *Potamilus capax* (Green 1832), commonly known as the fat pocketbook.

The fat pocketbook has been listed as endangered under the Endangered Species Act (ESA) and, according to the recovery plan, has been significantly impacted across its historic range by habitat modification, siltation, and pollution (USFWS 1989). Within the St. Francis River Basin, 30 USACOE projects have occurred over the past 30 years, with several more in the planning stages, each reasonably expected or known to directly impact fat pocketbook habitat or populations. Additionally, AHTD has multiple existing and planned transportation corridors each with associated stream crossings reasonably expected to affect *P. capax* habitat or individuals. All of these maintenance and construction activities require advanced conservation action which typically consists of relocating individuals from potential negative impacts, a lengthy and resource intensive practice (Miller and Payne 2006), often with mixed conservation success (Cope and Waller 1995, Dunn and Seitman 1997, Dunn et al. 2000). However, in order to down list this species, and avoid recurring relocation activities, the current recovery plan calls for protection of the St. Francis *P. capax* population. This objective has not been fully implemented as only one protected area specific to mussel aggregations exists on the main channel of the river. The proposed project seeks to contribute to down listing by protecting a substantial amount of stream corridor known to currently harbor *P. capax* individuals while enhancing areas not currently occupied and/or restoring previously altered habitat.

The area being proposed is ideal for several reasons germane to *P. capax* protection within the St. Francis Basin. First, the selected location has as its northern border Big Lake NWR, managed by USFWS, which provides long term protection from development pressures and may buffer against sediment and pollutant loads. Second, known *P. capax* populations occur upstream of, within, and downstream of the proposed project area allowing for source/sink population dynamics to occur. Third, this project could potentially make significant strides in the establishment of a riparian corridor between two large, federally managed conservation areas. Fourth, the river segment in which the site is located is sufficiently free flowing and allows for the migratory nature of the freshwater drum, the parasitic host fish required to complete the reproductive cycle of *P. capax*. Conservation action taken at the proposed location supports recovery of *P. capax* by addressing protection measures needed within the St. Francis Basin and allows for the creation of an education program at Big Lake NWR as stipulated in the *P. capax* Recovery Plan (USFWS 1989).

Highway Improvement Project Description

Arkansas State Highway 18 is an important transportation corridor which connects Jonesboro, Lake City, Monette, Manila, and Blytheville, AR, in the Mississippi Alluvial Plain ecoregion of northeast Arkansas. This corridor also provides convenient access to I-55 and such destinations as Memphis, TN and St. Louis, MO. This highway facility is being widened from 2 to 4 lanes to improve transportation access for the Jonesboro industrial complex as well as the growing population of northeastern Arkansas. The construction phase of the improvement project currently requiring mitigation is between Manila, AR and Dell, AR. The footprint of this improvement project is expected to directly impact Big Lake NWR through a taking and indirectly impact existing populations of the endangered freshwater mussel *P. capax* (Christian 2006). More specifically, the impacts of this improvement project include three stream crossings over Ditch 81, Sand Slough, and Stateline Ditch. The crossing over Stateline Ditch is expected to directly impact existing habitat and individuals of *P. capax*. The crossing over Sand Slough is expected to impact a Big Lake NWR impoundment and possibly downstream fish and mussel communities, which also include *P. capax* individuals.

The AHTD is required to not only mitigate for adverse impacts to stream crossings and mussel habitat, but it is also required to meet appropriate, compatible use standards established for Big Lake NWR. These standards typically require no net loss of habitat values, function, or quality. Therefore, any Big Lake NWR lands impacted either permanently or temporally by this project will need to be replaced by lands of equal or greater value, at the discretion of US FWS. As the proposed improvement is expected to require approximately 2.7 hectares (6.6 acres) of Big Lake NWR for highway use and effectively eliminate a segment of an existing interpretive trail, the AHTD will be required to not only compensate for the acreage lost but also the recreational use values lost due to the project. The improvement may alter user entrance and exit traffic, also requiring consideration in the mitigation design phase.

Conservation Action Options

The use of a conservation bank is not possible within the scope of this project. First, there are no currently existing private conservation banks due to a low demand for credits. Second, existing regulations do not allow the establishment of conservation banks by a federal agency. The RCS provides an avenue for FHWA to fulfill Section 7 ESA obligations by establishing a Habitat Credit Trading system.

In response to the conservation needs of the FHWA/AHTD, the US FWS, and Big Lake NWR, two conservation action scenarios have been identified which are located in close proximity to the Highway 18 improvement project and are appropriate for an on-site, in-kind classification. The scenarios presented in the following descriptions consist of various levels of complexity and involvement and are designed to meet the suite of potential opportunities, challenges, and future goals of both the FHWA/AHTD and US FWS. Ultimately, the restoration activities associated with any of these options would be undertaken by the AHTD with management responsibility most likely reverting to Big Lake NWR upon completion. Only the acreage used as replacement property for the FHWA/AHTD "take" will become Big Lake NWR property.

The conservation action associated with Scenario 1 would be located south of the existing Highway 18 corridor on 110 hectares (272 acres) with Ditch 81 acting as the western boundary while Sand Slough and Stateline Ditch would serve as the eastern boundaries (see Figure 1). This scenario would involve the restoration of 33.6 hectares (83 acres) of upland habitat and 66.4 hectares (164 acres) of wetland habitat. This effort would include the re-establishment of hydrologic connectivity with Ditch 81, Sand Slough, and Stateline Ditch; although water control structures are already in place and functional on this property. This restoration would directly influence approximately 4,500 m (2.8 miles) of in-stream habitat associated with Ditch 81, Sand Slough, and Stateline Ditch. Additionally, *P. capax* was found along the channel margins of Sand Slough and Stateline Ditch but was not discovered in Ditch 81. This is likely caused by differing substrate and flow conditions attributable to the flow control structure on Ditch 81 and sediment depositional conditions associated with Stateline Ditch during high flow periods.

The flow control structure, which assists with water level control on the Big Lake NWR, is a feature driving in-stream habitat conditions in Ditch 81. The velocity produced downstream of this feature is unnaturally high which has led to erosion and channel incision problems within the reach. This also produces a potential threat to restoration activities associated with Scenario 1. However, significant stream credits could be generated by the installation of velocity dissipation devices which would reduce erosion forces, promote sediment deposition and potentially create viable habitat for *P. capax* and other aquatic species. Additionally, available migratory waterfowl habitat would be increased by more than 64.8 hectares (160 acres) and bank fishing opportunities associated with Ditch 81, Sand Slough, and Stateline Ditch would be dramatically increased. Opportunities also exist for wildlife viewing platforms coupled with interpretive trails.

Mitigation Scenario 2 could include the previous scenario, or it could serve as a standalone effort for future mitigation needs in the region. The total size of Scenario 2 is 1670 hectares (4,126 acres) and would influence 23,146 m (14.4 miles) of stream and restore 981.8 hectares (2,426 acres) of upland habitat and 640.6 hectares (1,583 acres) of wetland habitat (see Figure 1). This proposed scenario would have the current Highway 18 corridor as a northern boundary, and the AR Highway 77 corridor (north of Lennie, Mississippi County, AR) serving as a southern boundary. The east and west boundaries would consist of the existing levee system which runs parallel to Right Hand Chute of Little River.

In addition to the in-stream restoration described under Scenario 1, this scenario would potentially restore prominent hydrologic connectivity between the secondary and primary channels within the targeted area. By removing existing channel plugs and grading selected areas to appropriate elevations, this effort could restore approximately 10.1 kilometers (6.3 miles) of Right Hand Chute of Little River. This will likely serve to dramatically improve fish habitat within the reach and make a significant contribution toward connecting the Saint Francis Sunken Lands and Big Lake NWR both aquatically and terrestrially. *Potamilus capax* is likely present in this reach as the species is present in the upstream areas of this proposed bank area and state agencies report occurrences between the Highway 77 proposed boundary and Rivervale, AR. The restoration of over 1620 hectares (4,000+ acres) of bottomland hardwood habitat along with the creation of open water habitats for migrating waterfowl would have significant impact on the regional restoration efforts along with dramatically increasing public use opportunities associated with the refuge. Implementation of Scenario 2 would likely require collaboration among two or more Federal partners, as the scope of this scenario would exceed the mitigation requirements of the FHWA/AHTD for the foreseeable future.

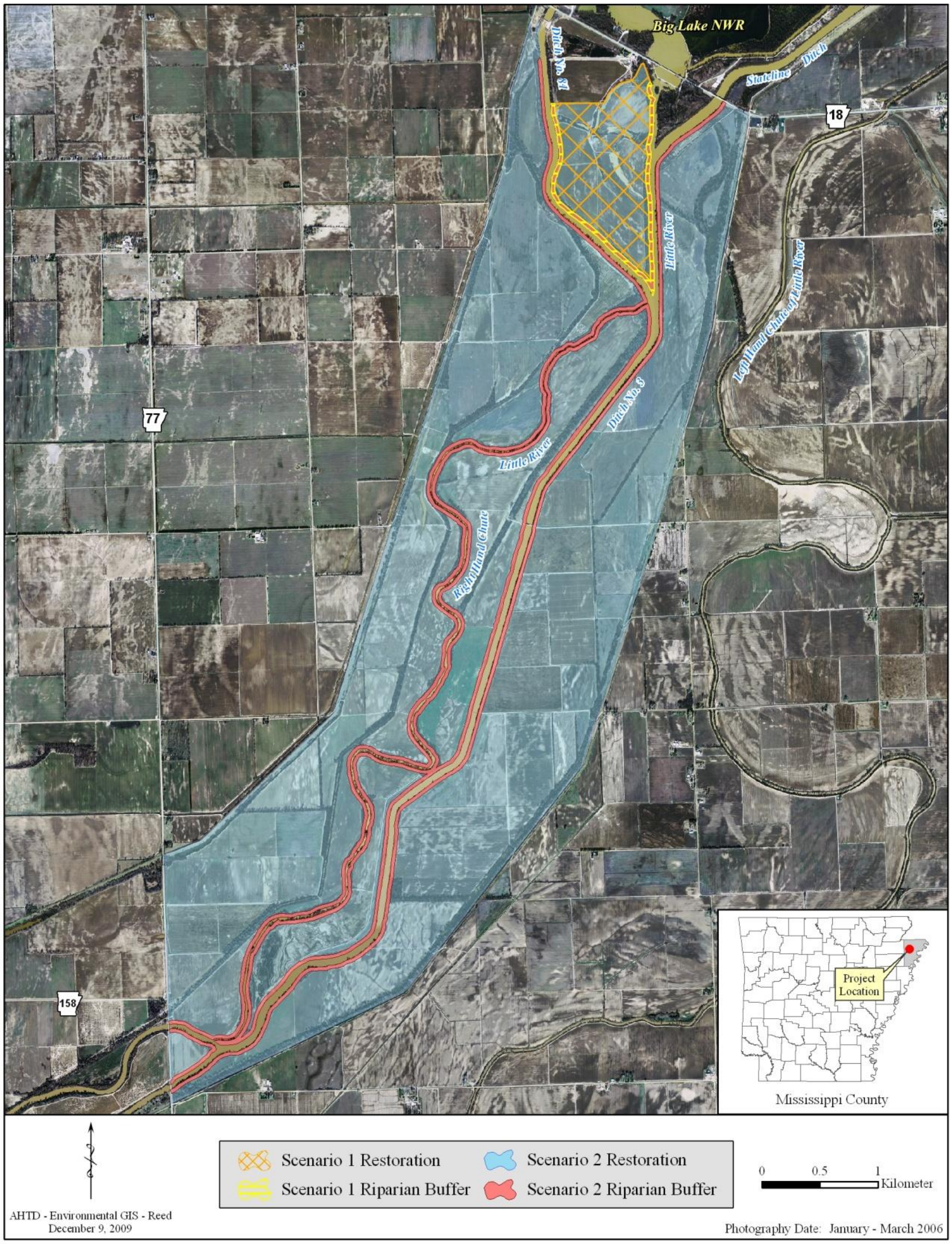

Figure 1. The aerial extent of the proposed Recovery Credit System for the Highway 18 widening project. Scenario 1 (cross-hatched) is the smaller of the two scenarios while Scenario 2 (blue and red shading) is significantly larger and includes the area of Scenario 1.

Credit Generation Framework

A considerable challenge in conservation and mitigation banking has been the assessment of credits and determination of a compensation ratio that reflects the existing and/or potential functional condition in a bank (Stein et al. 2000). Both habitat area and habitat functionality must be taken into account. Habitat utility by target species within a conservation bank or RCS should also be an important factor in determining credit values (Scheerer and O'Neil, *in progress*). Consideration of habitat utility by a listed species in determining credit calculations would provide sufficient incentive for bank operators to target landscapes that support these species.

Multi-use habitat credit banks, such as the pilot project proposed in this article, add an additional layer of complexity when determining credits since these credits must be generated separately to prevent "double-dipping". Double-dipping would imply the generation of two different credit types (e.g. stream credits and conservation credits) from the same parcel of land. We propose to avoid this by allowing credit generation to be enhanced by presence and/or density of the target listed species (fat pocketbook mussel) through a mathematical multiplier in the credit generation formula. This process would ensure that credit generation is directly related to the status of the fat pocketbook within the protected habitat and would negate the need for generation of "species" conservation credits.

Two RCS scenarios presented for this project are evaluated relative to the baseline credits and costs generated by a hypothetical conventional public mitigation bank. The credit generation framework proposed for this pilot project is additive in nature with baseline credit generation determined by standard procedures for establishing a conventional public mitigation bank in the state of Arkansas (Table 1). Initially, wetland and stream baseline credit generation estimates were calculated via the Charleston District Method and the Little Rock Stream Mitigation method, respectively. The baseline credits are then used to calculate two RCS credit generating options. The RCS sponsors, FHWA/AHTD in this case, will have two management options to choose from. The first is simply a target species occurrence enhancement which applies a credit enhancement to RCS sites which have target species occurring on the parcel. In the current example habitats which indirectly influence target species habitat, wetland areas in this case, receive a 15% enhancement and habitats directly influencing target species habitats, streams, receive a 25% enhancement.

The second RCS option is to directly manage the densities of the target species, with additional credits being released following a sufficient monitoring period. Indirect and direct habitats are eligible for the credit enhancements but at differing rates. Indirect (wetland) habitats supporting low densities of the target species will receive a 5% credit enhancement, medium densities will receive a 7.5% enhancement and indirect habitats supporting high densities receive a 10% enhancement. Habitats directly supporting target species populations (streams) would also be eligible for enhancements with low densities receiving a 10% enhancement, medium densities receiving a 15% enhancement, and high density habitats receive a 20% credit enhancement. The total number of credits available is determined by summing the baseline credits, the occurrence enhancement and the density enhancements for both wetland and stream habitats; for purposes of the following examples we assume low, medium, and high densities occur equally throughout the proposed project location. Two potential project scenarios of differing acreages were evaluated in relation to cost effectiveness and benefit to the fat pocketbook.

Scenario 1

The proposed multi-use habitat credit bank would consist of approximately 50 acres of stream riparian habitat and 222 acres of wetland (with some upland inclusions). Using current stream mitigation methodology to determine baseline credit availability, restoration of a 100 ft. riparian corridor along protected streams would net 102,336 total credits at a cost of $1,406,808 and $15,000 in monitoring costs ($13.89/credit). Wetland restoration would net 821.4 credits at a cost of $896,276 and $15,000 in monitoring costs ($1,109.42/credit). Monitoring of the site would be most intensive during the first seven years of the project and would gradually decrease in intensity.

Projected enhancement of credits with a mathematical multiplier resulting from fat pocketbook occurrence could increase credit generation and offset monitoring and maintenance costs. We propose that riparian habitat that directly supports fat pocketbook populations at some pre-determined abundance increases credit generation by 25% and wetland habitat (indirect support) credits by 15%. This would reduce stream credit costs to $12.05/credit and wetland credit costs to $964.71/credit which incorporates wetland monitoring costs of $15,000 and stream/riparian monitoring would increase to $135,000 due to the occurrence threshold. This occurrence enhancement would increase total wetland credits to 944.61 and stream credits to 127,920.

A second multiplier resulting from post-project monitoring data could also be used to further enhance credit generation. This multiplier would be implemented post-project based on target species densities. This additional multiplier would generate at total of 1, 015.46 wetland credits with a cost, including monitoring, of $897.41/credit and a total of 147,108 stream credits at a cost, including monitoring, of $11.50/credit.

	Public Mitigation Bank		RCS with Species Occurrence Multiplier		RCS with Species Density Multiplier	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Hectares (Acres)						
Wetland	89.85 (222.00)	1520.00 (3,756.00)	89.85 (222.00)	1520.00 (3,756.00)	89.85 (222.00)	1520.00 (3,756.00)
Stream	20.23 (50.00)	149.73 (370.00)	20.23 (50.00)	149.73 (370.00)	20.23 (50.00)	149.73 (370.00)
Total	110.07 (272.00)	1669.73 (4,126.00)	110.07 (272.00)	1669.73 (4,126.00)	110.07 (272.00)	1669.73 (4,126.00)
Base Level Credits						
Wetland	821.40	13,264.50	821.40	13,264.50	821.40	13,264.50
Stream	102,336.00	734,013.00	102,336.00	734,013.00	102,336.00	734,013.00
Occurrence Credits						
Indirect	-	-	123.21	1,989.68	123.21	1,989.68
Direct	-	-	25,584.00	183,503.25	25,584.00	183,503.25
Density Credits						
Wetland (Indirect)						
Low	-	-	-	-	47.23	762.71
Medium	-	-	-	-	70.85	1,144.06
High	-	-	-	-	94.46	1,525.42
Stream (Direct)						
Low	-	-	-	-	12,792.00	91,751.63
Medium	-	-	-	-	19,188.00	137,627.44
High	-	-	-	-	25,584.00	183,503.25
Credits Generated						
Wetland	821.40	13,264.50	944.61	15,254.18	1,015.46	16,398.24
Stream	102,336.00	734,013.00	127,920.00	917,516.25	147,108.00	1,055,143.69
Wetland Total Cost						
Acquisition and Construction Cost	$911,276.00	$15,032,336.00	$911,276.00	$15,032,336.00	$911,276.00	$15,032,336.00
Monitoring (15yrs)	$15,000.00	$225,000.00	$15,000.00	$225,000.00	$15,000.00	$225,000.00
Cost/credit	$1,109.42	$1,150.24	$964.71	$1,000.21	$897.41	$930.43
Credits/acre	3.70	3.53	4.26	4.06	4.57	4.37
Stream Total Cost						
Acquisition and Construction Cost	$1,406,808.00	$10,410,320.00	$1,406,808.00	$10,410,320.00	$1,406,808.00	$10,410,320.00
Monitoring (15yrs)	$15,000.00	$225,000.00	$135,000.00	$575,000.00	$285,000.00	$1,375,000.00
Cost/credit	$13.89	$14.49	$12.05	$11.97	$11.50	$11.17
Credits/acre	2046.72	1983.82	2558.40	2479.77	2942.16	2851.74

Table 1. A comparison between a Public Mitigation Bank and the proposed Recovery Credit Systems. Values listed below compare acreage, credits generated, and costs associated with all options.

Scenario 2

The second scenario for the proposed project would consist of 370 acres of stream habitat and 3,756 acres of wetlands. Restoration of a 100 ft. riparian corridor along protected streams would net 734, 013 stream/riparian credits at a cost of $10,410,320 and $225,000 in monitoring costs yielding a cost of $14.49/credit. Wetland restoration would net 13,264 credits at a cost of $15,032,336 and $225,000 in monitoring costs yielding a cost of $1,150.24/credit.

A similar mathematical multiplier for target species occurrence, such as that described in Scenario 1, could be applied to the larger acreages in Scenario 2. This would generate a total of approximately 917,516 stream credits and 15,254 wetland credits. These enhancements would decrease stream credit costs to $11.97/credit and wetland credit costs to $1,000.21/credit as compared to a conventional mitigation bank.

The density multiplier credit enhancements would generate a total of approximately 1,055,144 stream credits at a cost of $11.17/credit and 16,398 wetland credits with a cost of $930.43/credit. These estimates include monitoring costs of $225,000 for wetland habitats and $1,375,000 for stream habitat and target species monitoring for 15 years of the RCS; these costs are considered to be over-inflated.

In order to provide for a net recovery benefit, a mathematical multiplier is also used to address impacts to fat pocketbook. This multiplier can be based on presence/abundance or occurrence densities at the impact site as outlined above for the credit multiplier. However, the multiplier used for credit debiting is higher than the multiplier used for credit generation in order to provide a net benefit to the target species and to discourage development within fat pocketbook habitat.

Credit Debiting Framework

Similar to the credit generating framework, the credit debiting framework uses the Charleston District Method and the Little Rock Stream Method. The determination of baseline compensatory credits for the project location are conventionally derived and then enhanced based on target species occurrence and density multipliers (Table 2). If a project location harbors a population of the target species, affects to indirect habitats (wetlands) are multiplied by 25% and impacts to direct habitats (streams) are multiplied by 35%. If a RCS is managed for target species densities, then the number of credits required for compensation is also enhanced. Indirect (wetland) and direct (stream) habitats supporting low densities of the target species at the project location are increased by 30%, medium densities by 35%, and high densities are increased by 40%; the following example assumes all density levels are equally distributed throughout the site.

	Highway 18 Impact Assessment		
	Public Mitigation Bank	**RCS with Species Occurrence Multiplier**	**RCS with Species Density Multiplier**
Baseline Compensation (Credits)			
Wetland	76.30	76.30	76.30
Stream	6,993.00	6,993.00	6,993.00
Occurrence Multiplier			
Wetland (Indirect)	-	19.08	19.08
Stream (Direct)	-	2,447.55	2,447.55
Density Multiplier			
Wetland (Indirect)			
Low	-	-	5.72
Medium	-	-	6.68
High	-	-	7.63
Stream (Direct)			
Low	-	-	2,097.90
Medium	-	-	2,447.55
High	-	-	2,797.20
Total Compensation Credits Needed			
Wetland	76.30	95.38	102.05
Stream	6,993.00	9,440.55	11,888.10
Cost of Credit Acquisition: Option 1			
Wetland	$84,648.75	$92,009.22	$91,581.81
Wetland Cost/Credit	$1,109.42	$1,205.89	$1,200.29
Stream	$97,132.77	$113,758.63	$136,713.15
Stream Cost/Credit	$13.89	$12.05	$11.50
Total	$181,781.52	$205,767.84	$228,294.96
Cost of Credit Acquisition: Option 2			
Wetland	$87,763.31	$95,395.03	$94,951.54
Wetland Cost/Credit	$1,150.24	$1,000.21	$930.43
Stream	$101,328.57	$113,003.38	$132,790.08
Stream Cost/Credit	$14.49	$11.97	$11.17
Total	$189,091.88	$208,398.41	$227,741.62

Table 2. Estimated credit requirements and costs associated with a debiting scenario as the described in the credit debiting framework.

The Highway 18 improvement project, discussed above, is estimated to require 76 wetland credits and 6,993 stream credits. If credits were acquired from a public mitigation bank, stream and wetland acquisition costs would total $181,781 from the smaller bank described above, and $189,092 from the larger bank. If credits were acquired from a RCS with Species Occurrence Multiplier, 95 wetland credits would be required at a cost of $92,009 from the smaller RCS and $95,395 from the larger RCS. Total required stream credits would be 9,440 at a cost of $113,758 at the smaller RCS and $$113,003 at the larger RCS. If the credits are acquired from a RCS with Species Density Multiplier, 103 wetland credits would be required at a cost of $91,582 from the smaller RCS and $94,952 from the larger RCS. Required stream credits would total 11,888 at a cost of $136,713 from the smaller RCS and $132,790 from the larger RCS. Under this credit debiting framework total credit acquisition costs from the smaller RCS are estimated to be $228,295 while costs from the larger bank are estimated to be $227,742.

Although this is an oversimplification of a complex process, it provides insight into a potential mechanism by which federal agencies can meet or exceed Section 7 ESA requirements while also satisfying Section 404 obligations. They are able to realize the benefits of meeting their specific mitigation needs through an integrated approach that incorporates landscape scale conservation of listed species.

Performance Monitoring Framework

Performance monitoring of the proposed RCS project will focus on the restored stream, wetland, and riparian areas as well as the mussel population. In order to establish baseline conditions at the project site for all monitored variables, 2 years of pre-restoration surveys will be conducted. Initial post-restoration monitoring efforts will occur annually for 5 years following restoration. Following the initial monitoring, it is likely that stream and mussel population monitoring will be necessary bi-annually for a second 5-year period. Following this 10-year period, monitoring will continue at 5-year intervals or as warranted by site conditions. Should corrective action be required to improve performance, annual monitoring of variables germane to the corrective action should be conducted for a period of 5 years.

Monitoring variables associated with wetland and riparian area restoration efforts will include living seedlings per acre, volunteer and herbaceous species occurrences, and the extent of hydrophytic vegetation. Monitoring wetland restoration and riparian buffer performance is estimated to cost $6,000 per event based on past bank monitoring experience.

Stream restoration monitoring should be conducted during both bank full and low to moderate flows using an Acoustic Doppler Current Profiler (ADCP) which can be used to evaluate information relative to channel dimensions and stability along with in-stream hydraulic information. The cost estimate of this monitoring component is $6000 per event (includes both bank full and low flow) with one-time ADCP equipment acquisition cost of approximately $17,000. Substrate sediment sampling should also occur within the in-stream restoration reaches, during low flow periods, to ensure appropriate benthic conditions for target species and to monitor for significant spatial and temporal shifts in sediment types and/or depositional rates. The channel elevation, hydraulic, and sediment survey and analysis will cost approximately $11, 000 per event if conducted internally.

Mussel densities and population estimates will be assessed within the reach, and *P. capax* individuals will be further processed for size measurements (a recruitment surrogate) and gravidity status. Condition factor (i.e. glycogen and lipid concentration) should also be analyzed pre- and post-restoration as a surrogate for habitat quality and individual condition, this analysis will terminate 5 years post-project but could be reinstituted if excessive mortality is observed or following corrective activities. The mussel population monitoring will cost approximately $11,000 per event.

Cost-Benefit Analysis

The proposed credit generation and credit debiting framework exhibit several important attributes of an efficient credit trading system which fulfill legal requirements as well as economic and biological interests. First, from a credit generation perspective, the framework is able to provide credit enhancements which sufficiently cover the added risk of managing and maintaining a viable population of listed species. Second, the relationship between cost per credit and credits generated becomes increasingly favorable as the RCS site size increases. Third, the proposed debiting framework provides an efficient ratio which is likely to cause development entities to evaluate project alternatives prior to impacting threatened and endangered species and their habitats.

Compared with the Public Mitigation Bank, Scenario 1 results in a cost per wetland credit savings of 13% for RCS with Species Occurrence Multiplier and 19% savings for the RCS with Species Density Multiplier. This same scenario results in a cost per stream credit savings of 13% for the RCS with Species Occurrence Multiplier and 17% for the RCS with Species Density Multiplier.

Compared with the Public Mitigation Bank, Scenario 2 results in a cost per wetland credit savings of 13% for RCS with Species Occurrence Multiplier and 17% savings for the RCS with Species Density Multiplier. This same scenario results in a cost per stream credit savings of 17% for the RCS with Species Occurrence Multiplier and 23% for the RCS with Species Density Multiplier.

Summary

This proposed pilot project indicates that this RCS could provide a flexible, cost effective, biologically relevant alternative for FHWA to fulfill their obligations under Section 7 of the ESA and Section 404 of the CWA. This proposed framework also indicates that an RCS is capable of achieving the same standard as Conservation Banking and In-Lieu Fee options, while maintaining cost effectiveness. Use of a RCS may provide additional conservation benefits and a substantial per credit savings when threatened and endangered species are included in the site selection of a conventional banking system. In addition, use of a RCS will help streamline FHWA ESA Consultation process and provide a clear understanding of expectations and responsibilities. Potential partnerships between Federal agencies undertaking infrastructure projects and private landowners to implement conservation actions could also prove to be a valuable asset in endangered species recovery nationwide.

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Regional Advance Mitigation Planning: A Pilot Study Integrating Multi-Agency Mitigation Needs and Actions within a Comprehensive Ecological Framework

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Abstract

Compensatory mitigation required of infrastructure agencies to fulfill regulatory requirements is often implemented in the latter stages of project construction. It also tends to be focused on project specific impacts that are localized around the area of impact. This single project approach to addressing unavoidable impacts to natural resources is non-systematic and piecemeal. The late timing of mitigation can lead to both greater expense for and reduced ecological integrity of lands dedicated to impact offsets. In order to increase resource enhancement opportunities, funding source efficiency, and ecological function and sustainability, the concept of a Regional Advance Mitigation Planning (RAMP) effort was launched in California. Two infrastructure action agencies (California Departments of Transportation and Water Resources) worked with The Nature Conservancy, UC Davis, EDAW/AECOM, and the Resources Legacy Fund Foundation to bring together state and federal regulatory agencies to initiate a RAMP framework and identify likely mitigation requirements for a set of infrastructure projects within our pilot study area. Project "footprints" were estimated and their overlap with regulated ecological features was calculated. Using typical compensatory mitigation ratios, total regional mitigation needs were projected. Further, a framework was developed for identifying sites that could meet these ecological requirements with the lowest costs and the greatest contribution to regional and statewide conservation priorities, such as larger ecological reserves and greater landscape connectivity. This project is unique in its methodology. It combines mitigation requirements from transportation and water delivery, and flood management projects within the study region and identifies suitable mitigation sites that align with regional conservation objectives. When the environmental obligations from multiple agencies are integrated, planners can leverage program resources towards more significant habitat conservation at ecologically relevant scales across regions. This approach has multiple benefits to the resources of the State with greater fiscal efficiencies. The model developed here, if successful, is intended to be used throughout the state of California in the future.

Introduction

Habitat conversion by humans is an ongoing, large-scale process that is responsible for the population decline of many species and degradation of ecological communities (Wilson 1992; Foley et al. 2005)). Much of this conversion is driven by the development of infrastructure to meet human needs, such as housing, transportation, and resource extraction (Hardner and Rice 2002). The cumulative extent and effects of these activities is expected to increase in the foreseeable future as a result of human population growth and expanding economic investment (World Bank 2007). If biodiversity and ecosystem services are to be maintained, policy mechanisms are necessary to address these impacts.

One increasingly adopted measure in this regard is compensatory mitigation, or biodiversity offset (Kiesecker et al. 2009a; Kiesecker et al. 2009b). While it is widely acknowledged that ecological impacts should first be avoided, minimized, or restored at the location of the impact (CEQ 2000), many times there are unavoidable biodiversity losses that cannot be addressed in this manner if a particular infrastructure project is to be implemented. In this case, preservation or restoration of equivalent (or "like for like") ecological components, preferably spatially proximate, can be required. An example is the "no net loss" policy for wetland mitigation that was enacted at the national level for the United States in 1990 (Bendor 2009).

One set of organizations that routinely use compensatory mitigation actions to help offset negative effects to ecosystems is public infrastructure agencies. These agencies use public funds to construct and maintain roads, water delivery systems, flood control structures, and other infrastructure components. In so doing, there are often impacts to existing ecosystems (Forman 2000) which require some form of compensatory mitigation. These impacts can range from small, temporary disturbances associated with certain road repair projects to habitat loss on the scale of thousands of hectares for large water delivery projects or major highway construction. Because there are often many assorted infrastructure projects within a given region on an annual basis, there is the potential for a substantial cumulative effect on species and habitats found within that region, and hence the possible need for substantial mitigation activity. There have been some recent attempts to integrate these activities within a regional, comprehensive framework (e.g. SAFETEA-LU; U.S. Congress 2005).

Compensatory mitigation generally occurs on a piecemeal, project-by-project basis (Thorne et al. 2009a) which has several drawbacks. One outcome is that as a result of the reduced mitigation requirements of any one project, parcels used to fulfill mitigation needs are necessarily smaller in area and thus potentially less valuable from an ecological perspective. This is especially true for those parcels that are isolated from other ecologically relevant natural or conservation lands (habitat fragmentation). Thus, these parcels do not necessarily contribute to regional conservation goals, or a collectively-defined “greenprint”. We define greenprint as the compilation of multiple regional land use analyses created by regional conservation organizations or governments that identify habitat conservation areas of any type specified for protection. Smaller parcels also generally cost more on a per acre basis than do larger parcels, thereby increasing the overall financial cost of the mitigation. Also driving up cost is the timing of the mitigation actions; these usually occur in the latter stages of the infrastructure project. This timing incurs greater costs both because of the generally upward trend in real estate prices, the time-value of money, and the potential delays associated with acquisition and regulatory agency approval of the compensatory measures undertaken (American Association of State and Highway Transportation Officials 2003).

A regional approach to compensatory mitigation planning can lead to an improved ecological outcome. If mitigation needs from multiple projects are pooled, larger, less fragmented parcels can be acquired, contributing both to ecological integrity and fiscal savings. Further, parcel acquisition can be focused on areas identified as conservation priorities, providing support from a broader array of stakeholders. Other time and cost savings can accrue from eliminating redundancy associated with regulatory processes if fewer but spatially larger parcels are acquired for project impact compensation.

Additional savings can be realized if the regional mitigation planning happens in the early stages of project delivery rather than the more usual latter stages. If regulatory approval is achieved through implementation of an effective planning process, parcels can be acquired before they increase in price and costly delays can be avoided in infrastructure construction. The long planning horizons associated with infrastructure agencies further uniquely position them to contribute to the implementation of a long term regional greenprint.

This study reports an ongoing process in California, USA, that brings together two public infrastructure agencies – the California Departments of Transportation (Caltrans) and Water Resources (DWR) – with the regulatory agencies that oversee their mitigation requirements – the United States Fish and Wildlife Service (USFWS), California Department of Fish and Game (DFG), United States Environmental Protection Agency (EPA), National Marine Fisheries Service (NMFS), and United States Army Corps of Engineers (ACE). In addition The Nature Conservancy (TNC), University of California, Davis (UCD), Resources Legacy Fund Foundation (RLFF), and EDAW/AECOM (a consulting firm) are participating in a technical advisory capacity. This collaboration will produce a framework for bundling mitigation requirements of multiple projects at a large regional scale (1000’s of square kilometers). The framework will include identified processes for upfront approval by the regulatory agencies, that will permit the mitigation planning process to occur earlier, or even in advance of, project implementation than is usually the case. The goal is to increase the positive ecological impact of offsite compensatory mitigation while reducing the overall cost of infrastructure project implementation.

In order to achieve this goal, a number of steps for integrating regional conservation plans with projected regional infrastructure impacts (Thorne 2009b) were undertaken as part of a pilot study designed to demonstrate and implement the overall framework in one region of California. First, planned infrastructure projects for Caltrans and DWR were identified within the region and their likely ecological impacts estimated. Second, typical mitigation requirements associated with the expected impacts were calculated. Next, a site-selection tool was used to identify parcels that could contribute to meeting the regional compensatory mitigation needs. Final steps include site specific analysis of several areas most likely to contribute significantly to meeting mitigation needs and comparison of the parcel selection analysis to an identified regional greenprint to merge mitigation actions with regional conservation goals. These final steps are scheduled to take place in the summer of 2009. This paper details the methods used in the above steps and draws some conclusions about the process of regional advance mitigation planning and its potential use in future conservation planning efforts.

Study Area

The area chosen for analysis is a subregion of the Central Valley, California, located north of the city of Sacramento (Figure 1). It was selected both because of the presence of a number of species and communities that require mitigation and because there are a variety of infrastructure projects planned there by both of the participating agencies (Caltrans and DWR).

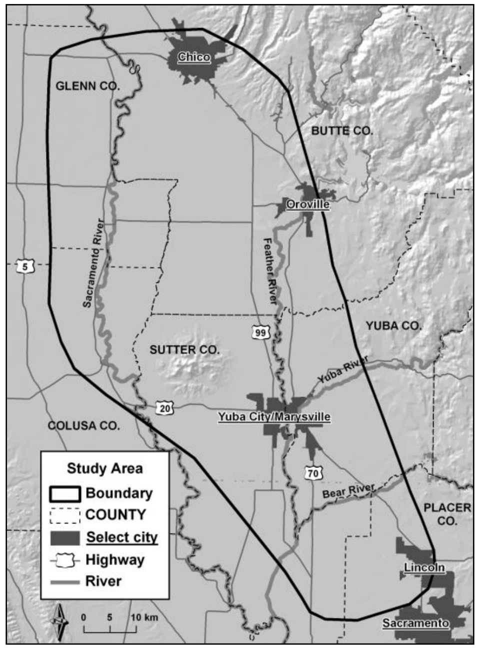

Figure 1. Regional advance mitigation planning area.

The Central Valley ecoregion is an area known for its historic biological richness and diversity (Ricketts et al. 1999). However, widespread conversion of natural ecosystems to largely agricultural (and increasingly urban) land cover has led to extensive fragmentation and ecological degradation. Further, important controlling ecological processes, notably fluvial processes such as flooding and meander dynamics, have been largely eliminated by historic flood levee construction. Currently the major native ecosystem patches in this region consist of riparian forest, valley oak woodland, blue oak woodland, freshwater emergent wetland, and grassland (some of which contain vernal pool complexes).

Methods

The overall regional advance mitigation planning (RAMP) process engages in a number of topics, including policy and financing components. This paper however focuses on the technical aspects of identifying native habitat landscape parcels and/or parcels that would benefit specific species through restoration for potential use in this planning framework.

The first step in assessing regional mitigation needs for this study area was identification of the planned infrastructure projects. A database of planned Caltrans projects was obtained and rendered into a geographical information system (GIS) for spatial analysis. DWR project boundaries were estimated and digitized within a GIS.

Project impact assessment required estimation of the areal extent of the infrastructure projects. While the DWR project boundaries were already approximated, we needed to convert the linear Caltrans project data into polygonal data. We used a table of typical project-specific estimates (Thorne et al. 2009b), assembled by Caltrans agency personnel, to buffer the centerline of the roads dataset (Figure 2).

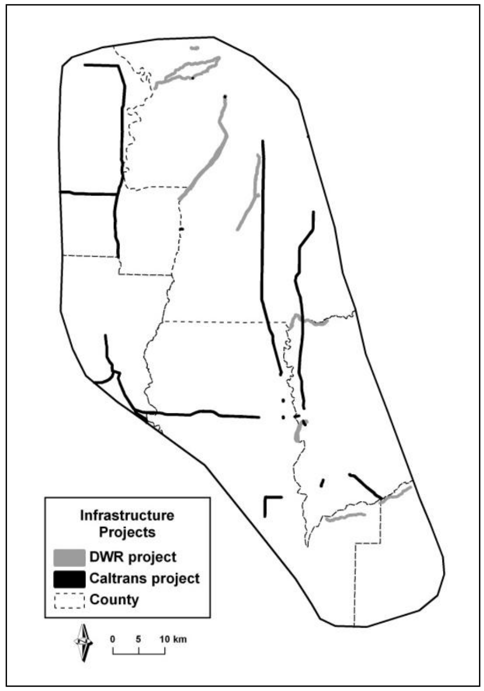

Figure 2. Caltrans and DWR project footprints.

We then overlaid these project footprints on a land cover dataset assembled from a number of sources (Nelson 1998; DWR 2005; Jones and Stokes 2005; SAIC 2007; Jones and Stokes 2008). From this overlay we obtained the summed estimated impact to general vegetation types by the infrastructure projects.

Project impacts to specific regulatory plant and animal species were estimated by identifying likely habitat for the selected species and overlaying the infrastructure footprints on this area. Habitat was defined as land cover types rated as "high" quality in the California Wildlife Habitat Relationships system (DFG 2005) and was within a 3 km radius of known occurrences of the species (DFG 2009). The project impacts were then assessed by summing the amount of habitat for each species that intersected the project footprints.

Mitigation requirements are often calculated by applying a ratio of affected area to area needed for either preservation or restoration (or both) "No net loss" policy, for example, generally is interpreted as requiring a 1.1:1 ratio (i.e. slightly more area required as compensatory mitigation than area impacted) for restoration activity. Preservation ratios however can vary widely. We consulted with regulatory agency personnel active in the study area to estimate the ratios usually required for preservation of existing lands as ecological offsets for impacts for each of the regulatory species. Total mitigation needs were calculated by applying the identified ratios to the total estimated project impacts.

Regulatory agencies generally require that compensatory mitigation activity take place in the vicinity of the impacts. Because the extent of this pilot project was larger than is typically permitted, it was necessary to spatially stratify the vegetation types and species-specific habitats. For most of these ecological components, watershed boundaries of the five large study area rivers (Sacramento, American, Yuba, Feather, and Bear Rivers) were used as the stratification units (Figure 3). Impacts to giant garter snake habitat were stratified by the low elevation basins delineated by the rivers (Natomas, Sutter, Colusa, and Butte Basins). Finally, vernal pool impacts were delineated into 11 "core areas" (defined by the USFWS). Thus project impacts to a regulatory species or vegetation type in one stratification unit must be mitigated for within that same unit. For modeling purposes, each stratified area for each ecological component is treated as a different species.

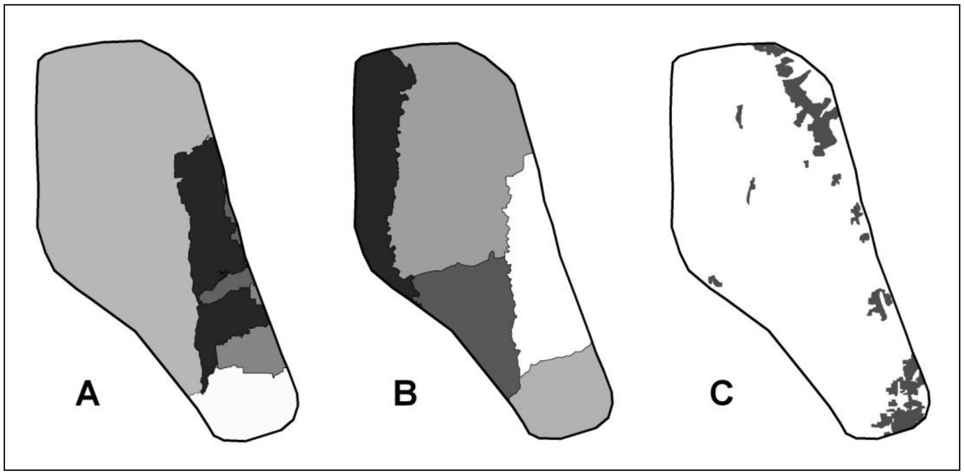

Figure 3. Spatial stratification of project impacts and required mitigation: A) major watersheds, B) basins (for giant garter snake), and C) vernal pool complexes.

Ownership parcel datasets for the six counties encompassed in the study area were combined into one dataset to be used as the units of analysis for this project. Each parcel was attributed for inclusion in an existing conservation area (both fee title and easement) using the GreenInfo Network (2008) protected areas dataset.

The parcel ownership dataset was also overlaid on the land cover and species' habitat datasets in order to calculate the area of each of these ecological components occurring within each parcel.

Additionally, for the giant garter snake and burrowing owl, the effective mitigation area (EMA) was calculated. For these species, compensatory mitigation can be accomplished either through preservation of existing habitat or restoration of previously converted habitat. Equivalent area units were required to allow the reserve selection algorithm to select the most efficient means to achieve mitigation goals for these species. The mitigation ratios were used to convert different land cover types to EMAs. Thus,

$$P_{EMA} = \sum_{i \in S} \frac{h_i}{r_i} \tag{1}$$

where P_{EMA} is the total EMA for an ownership parcel for a specific species, h is the total area within the parcel of a specific existing habitat type used by the species or is a restorable land cover type, r is the mitigation ratio quotient for that species, and S is the full set of habitat or restorable land cover types for that species. Therefore, if a parcel is selected for inclusion in the mitigation needs "solution", it can include both existing habitat and restoration potential.

Marxan reserve selection software (Ball and Possingham 2009) was used to evaluate each ownership parcel for potential use as a site for compensatory mitigation activity. Marxan uses spatial and attribute data for planning units comprising the analysis area (in this case ownership parcels) to find sets of planning units that meet the overall conservation goals (defined by the user) while minimizing the costs. For this analysis, goals were defined as the mitigation area needed to offset infrastructure project impacts to various regulatory species and ecological communities. We developed two sets of goals. The first goals were defined by the estimated project impacts and their associated mitigation ratios. The second goals were used to represent a longer range set of potential mitigation needs. The time horizon for these needs was set as five times longer than the time frame of the current planned projects. For these goals, we multiplied the DWR impacts by five to estimate this agency's potential impacts. For Caltrans projects, we assumed that new, currently unplanned projects could happen essentially anywhere within the study area. Thus instead of using the current projects as a baseline, we multiplied the total area of impact by five, but calculated impact to each regulatory species or land cover type as proportional to its overall area within the study region.

"Cost" refers to both economic cost of parcel acquisition and ecological cost. Here, cost was calculated from five input variables: road density (at a 3 km radius; U.S. Census Bureau 2007), urban area density (3 km radius; FMMP 2006), parcel area modified by a cost-per-area function (i.e. larger parcels generally have a lower cost-per-area value than smaller parcels; Thorne et al. 2009b), crop value (for agricultural parcels; ASFMRA 2007), and urban growth model outputs (Information Center for the Environment 2009, unpublished data; parcels likely to be developed will generally have a higher cost associated with them). These variables were combined where the factors were weighted by their perceived importance in affecting mitigations decisions. There are little data from which to derive a quantitative model for mitigation site selection, so we used expert judgment in setting the weights. The equation to set the total per parcel cost values is:

$$C_p = \sum F_w \qquad (2)$$

Where the total cost *C* for each parcel *p* is the sum of all normalized cost factors *F* multiplied by a weight of *w*. The values of w were as follows: road density and projected development: 1, crop value and urban density: 2, and size of parcel: 10.

One further aspect of cost associated with each parcel is the effect of inclusion of the parcel on total boundary length of the set of selected parcels. As the overall boundary length increases, so does the cost of the solution. The rate of increase can be adjusted when running the model (through the "boundary modifier" function). For this analysis, we used five different boundary modifiers and ran the model using each, as we had no way to determine the most effective value for this modifier.

We ran Marxan 100 times (at 10 million iterations per run) under 10 different scenarios (short- and long-term with five different boundary modifiers each). This led to a total of 1000 runs. Each parcel was attributed with the total number of runs for which it was identified as part of a mitigation or restoration potential solution.

The final portion of the analysis focused on the integration of the mitigation activity with a regional ecological framework, or greenprint. We identified the greenprint by assembling the conservation priorities datasets obtained from agencies and non-governmental conservation organizations within the study area (organizations consulted were: DFG, TNC, Butte County, Placer County, Yuba County, and Sutter County). These were layered together and summed, so that for every raster cell (30 m x 30 m) in the study area, the total number of conservation efforts identifying that location as a priority was calculated. This is meant to be a simple way to represent conservation priorities for this study, but given differences in scale, conservation objectives and planning methods, areas selected by more conservation plans should not be interpreted as higher priority for conservation.

Next, both the Marxan results and greenprint results were normalized to a maximum value of 1.0. These values were then multiplied (resulting in values that also ranged from 0 to 1) and the ownership parcels were given a value equal to the mean value of the raster cells within their boundaries. This eliminated those parcels that either were outside of any identified conservation priority area or that did not contribute towards meeting mitigation needs. The highest values were thus given to parcels that were repeatedly identified in the Marxan analysis and addressed multiple conservation priorities.

Results

A total of 21 Caltrans and 8 DWR future planned projects were identified in the study area. While the DWR projects were largely associated with channel vegetation and sediment clearing for maintenance of flood water capacity, the Caltrans projects varied in their type, ranging from surface rehabilitation to construction of additional lanes for traffic volume expansion. These projects combined to create an overall footprint of 1,742.2 ha, of which 500.8 ha were the result of Caltrans and 1,241.4 ha the result of DWR projects.

We calculated that this footprint would impact a variety of vegetation types and species that typically require compensatory mitigation actions (Table 1). The greatest impacts were anticipated to occur to riparian forest, with a total of 618.8 ha estimated to potentially be affected. Most of this impact (610.9 ha) was attributed to DWR channel maintenance projects. The species expected to be most affected by the suite of projects was giant garter snake, with 188.6 ha of habitat expected to be impacted by the infrastructure projects.

Target	Ratio - preservation	Ratio - restoration	Mitigation type	Short-term impact (ha)	Long-term impact (ha)
Freshwater wetland	3:1	1.1:1	both	54.6	397.0
Valley oak		2:1		61.3	333.9
Riparian forest	5:1	1.1:1	both	619.0	2,600.0
Blue oak		2:1		2.0	47.3
Giant garter snake	3:1	1.1:1	either/EMA	187.8	276.0
Swainson's hawk	1.1:1			102.1	197.3
Valley elderberry longhorn beetle		10:1		157.8	213.4
Burrowing owl	1.1:1	1.1:1	either/EMA	14.4	37.8
Bank swallow	2:1			156.8	65.0
Sandhill crane	2:1			0.0	9.3
Tricolored blackbird	2:1			72.2	34.6
Western yellow-billed cuckoo	2:1			25.4	30.3
Vernal pool - tadpole shrimp	19:1	1.1:1	both	0.5	30.0
Vernal pool - no tadpole	5.7:1	1.1:1	both	0.3	34.5

Table 1. Ecological components requiring mitigation activity in the study region, their typical mitigation ratio by type, and the calculated impact (under near- and long-term scenarios) due to agency infrastructure projects.

Mitigation ratios identified by regulatory agencies ranged from 1.1:1 for restoration actions to a maximum of 19:1 for preservation activity for vernal pools containing highly restricted, endangered, vernal pool tadpole shrimp. However, most preservation ratios were found in the 2:1 to 5:1 range (Table 1). When the mitigation ratios were applied to these impacts, a total of 6,539.8 ha of ecological offsets resulted; however, a good deal of overlap could occur in fulfilling these requirements. These offsets included both preservation and restoration activities. Significant mitigation actions identified included riparian forest preservation, riparian forest restoration, and valley elderberry longhorn beetle habitat restoration.

The Marxan analyses were run under two different temporal scenarios (near- and long-term) and five boundary modifiers, which led to two separate results, one for each scenario. For each, the results from the five runs were summed for individual ownership parcels, leading to a scale from 0 (the parcel was never selected as part of a solution) to 500 (every solution included the parcel) (Figure 4). Existing conservation areas were automatically included in solutions and thus received scores of 500. Parcels containing no ecological components designated for mitigation were excluded from analysis and received a score of 0.

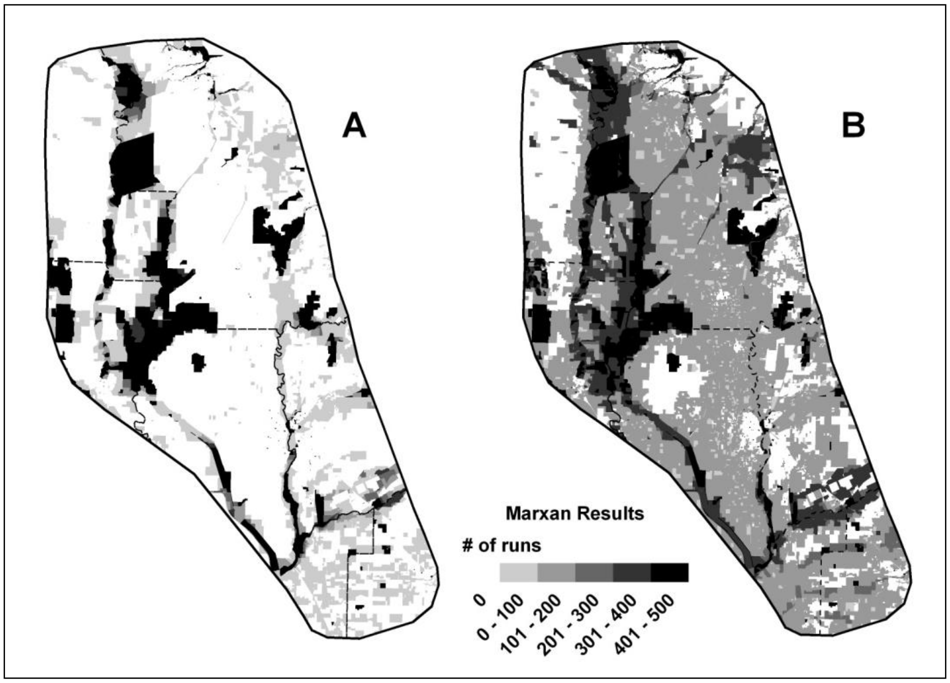

Figure 4. Marxan results for "cost effective" solutions to compensatory mitigation actions for: A) short-term scenarios, and B) long-term scenarios.

Areas identified frequently for mitigation activity under the near-term scenario included wetland complexes in the central portion of the study area (that helped link a number of existing conservation areas) as well as riparian parcels along the Sacramento River (in the western portion of the study area). When the analysis was conducted under a long-term scenario however, the focus of potential mitigation activity expanded to include more riparian areas in the west, vernal pool complexes in the northeast, the Sutter Bypass flood protection infrastructure in the southwest, and the Bear River riparian area in the southeast. These new areas were included in the long-term analysis as a result of the method used for calculating future Caltrans projects (that focused on the entire study area rather than simply current project locations). Thus these areas were included even though there was little identified mitigation needs in these areas in the short-term analysis.

The overlaid greenprint datasets were summed, leading to a conservation priority surface with scores ranging from 0 to 4 (Figure 5). The highest priority scores were found in the vernal pool complexes in Butte County and riparian forests in Butte and Glenn Counties. When the Marxan results for mitigation needs were integrated with the greenprint, there was little change in focal areas under the near-term scenario (Figure 6). Under the long-term scenario, however, the area of greatest value shifted to the Butte County vernal pool complexes. Other high value areas were the Bear River as well as Butte Creek (east of the Sacramento River in the western portion of the study area).

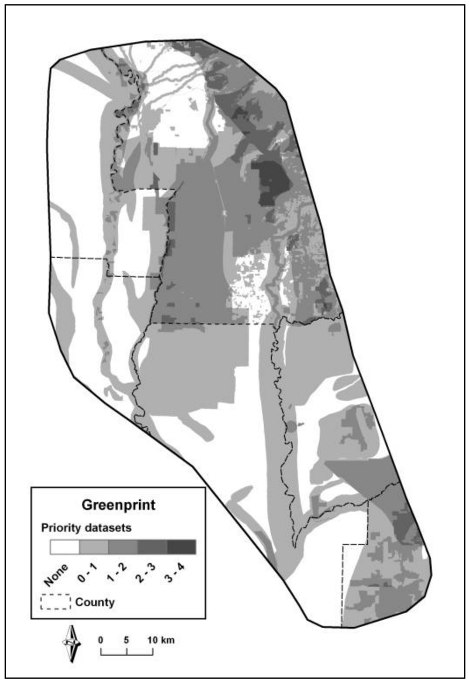

Figure 5. Study area “greenprint”,
identified by overlaying priority area datasets from several organizations.

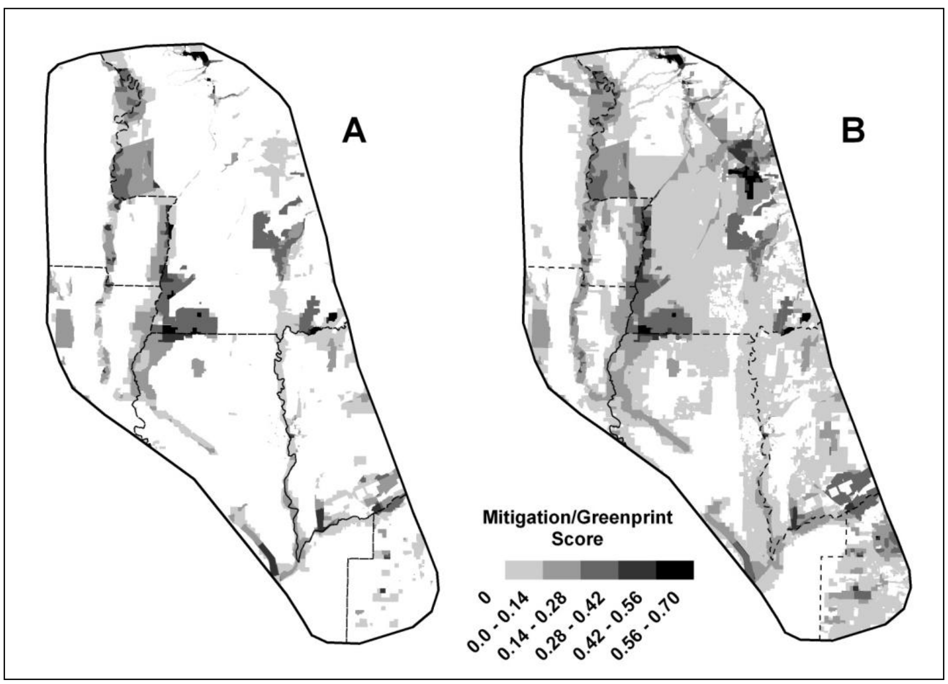

Figure 6. Overlap of mitigation needs analysis and regional greenprint.
The darker shades indicate those areas that both meet mitigation goals across several scenarios but also contribute to meeting regional conservation priorities. Results shown here are for A) short-term scenario and B) long-term scenario.

Discussion

We consider there to be a number of important planning elements addressed by this project. One element that has received attention recently is the potential benefits (ecological and economic) accrued when mitigation needs for several infrastructure projects are bundled into regional mitigation goals (Thorne et al. 2009b, Florida Department of Transportation 2001, Kiesecker et al. 2009b). This project serves as another example of this new direction in systematic planning of ecological offsets for infrastructure projects.

One important addition to the current literature on mitigation planning is the integration of mitigation needs of more than one infrastructure agency, with their different types of projects and mitigation needs. In this case, road maintenance and enhancement projects are coupled with flood channel capacity projects with their ecological effects and mitigation needs bundled within a specific region. This integration potentially allows for more systematic planning for regional ecological benefit. Additionally, this approach can also potentially lead to cost savings for the infrastructure agencies to an even larger extent than simple project integration within the agencies separately.

Another important element in our approach is the integration of the mitigation needs analysis with a regional conservation greenprint. The normalization of values and multiplication of the two datasets allowed us to identify parcels that would contribute to both agency mitigation needs and the overall ecological needs of the region. This will allow for the focusing of future mitigation actions towards those areas already identified as high priority by such efforts as regional Habitat Conservation Plans. When the greenprint analysis is coupled with the regional bundling of mitigation obligations, there will be the opportunity for infrastructure agencies to contribute substantial resources towards the implementation of regional conservation networks while concurrently meeting their legal mitigation obligations.

For this approach to be effective, it was necessary to accurately represent the actual mitigation obligations that the regulatory agencies would be likely to require of the infrastructure agencies. Informal discussion with regulatory agency personnel revealed that most obligations would consist of both habitat preservation and restoration. Thus our model needed to integrate these different types of activities. We were able to do this by treating these needs as separate ecological components. In addition, the use of the “effective mitigation area” concept allowed for an equivalency to be established when either type of activity would suffice to meet regulatory needs (e.g. giant garter snake mitigation). We feel that our approach was able to effectively represent the complexities of regulatory requirements in terms of mitigation ratios and types.

The inclusion of near- and long-term scenarios allowed for a more nuanced view of how mitigation needs might change over the course of time in the study region. Not only did overall area needed to meet obligations grow from near- to long-term, but the type of needs changed as well. While near-term needs focused on riparian forest preservation and restoration, for example, long-term needs shifted to include more vernal pool mitigation activity. The methods used here to calculate the long-term Caltrans mitigation needs allowed for the possibility of road projects throughout the region, rather than assuming that they would occur in the same types of areas. This approach then assumes that road project locations are somewhat stochastic in nature and that the current set of planned projects does not necessarily accurately represent the overall nature of projects in this region. The results of this project then can inform the planning process at several temporal scales and reflect different sorts of planning needs.

We encountered several issues while preparing the data for analysis that could serve as cautionary tales for others attempting similar efforts. The first major difficulty faced was the identification of applicable projects in the study region. The DWR projects were not assembled into a centralized database; identification and boundary delineation were accomplished through an ad hoc process by agency personnel. While the Caltrans projects were contained in a centralized database, there was little data on status of the projects. Discussion with regional agency personnel revealed that some of the projects and their associated mitigation actions had already been completed. Thus the final set of infrastructure projects included in our analysis were generally identified through a combination of existing datasets, communication with agency personnel, and GIS digitizing from aerial imagery, rather than being found in centralized databases.

A potential source of error in the analysis lies in the infrastructure project footprint calculation. The distances used to buffer the road centerlines for the Caltrans projects were taken from a table developed for projects across the state of California as a whole and was intended to be used as a state average for the project type. Thus the buffer distance used for the projects in the study region might not accurately reflect the actual affected area. DWR projects were delineated through analysis of aerial imagery rather than on-site, and thus may also display inaccuracies. Error in footprint delineation can lead to errors in the calculation of mitigation needs. On-site delineation of project boundaries would help alleviate this potential problem.

Further error could occur through the process of land cover classification based on the existing datasets to which we had access. These varied in accuracy (both spatial and thematic) across the study region. More effective mitigation needs analysis would be accomplished if there existed a comprehensive fine-scale land cover dataset for the whole study region.

One unexpected difficulty lay in the derivation of typical mitigation ratios required by regulatory agencies for various sorts of impacts. Contrary to expectations at the outset of this analysis, the ratios are arrived at on a case-by-case basis rather than through systematic application of predefined requirements. The ratios used here were based on interviews conducted with regulatory agency personnel and reflect their best interpretation of typical requirements. The actual ratios may vary as applied to specific projects. Much of the source of uncertainty in the derivation of mitigation ratios is due to the effects of spatial scale in the modeling process. Mitigation needs are generally calculated as the sum of effects on individuals of regulatory species. GIS modeling takes place on a landscape-scale, however. For instance, valley elderberry longhorn beetle (VELB) mitigation needs are derived through impacts to elderberry bushes used by VELB and involve calculating the number of stems impacted and new bushes that need to be planted. We translated this to a 10:1 ratio at the landscape-scale, but this is a rather crude generalization of the implementation patterns of compensatory mitigation for this species.

A bias may also occur in identification of the greenprint used for integration with the mitigation needs analysis. The datasets used were those to which we had access and thus did not necessarily represent all of the major ecological features that would comprise an ideal greenprint. For example, there were priority areas identified in ongoing HCP efforts for two counties in the study region (Butte and Placer) that were included in the greenprint. Two other counties (Yuba and Sutter) have an ongoing HCP process but to date have not identified priority areas. The final two counties (Colusa and Glenn) are not engaged in HCP planning currently. Thus priority weighting will shift towards the two counties with identified priority areas in the final greenprint. It is easy to assume that a place with more planning processes selecting it is a higher conservation priority than one with fewer plans prioritizing it, but this would be mistaken interpretation. There is no element of risk of loss in this prioritization, so a higher-rated area may have been selected by multiple plans, but may be relatively well protected already. Additionally there are other private conservation organizations that may have priority areas identified but were not able to be contacted or were missed in the project scoping process. An ideal greenprint would be comprehensive in nature and conducted with consistent goals and spatial data.

Despite these potential issues, we feel that this analysis represents an important next step in integrated mitigation needs planning. There are some additional steps that could lead to an even more robust analysis. One would be to include wildlife and landscape connectivity explicitly in the greenprint identification. While there are ecological features that serve as proxies for some aspects of connectivity (e.g. riparian forest preservation), there is a lack of comprehensive analysis of this important conservation feature. This should be included in the next phase of this project.

A further point of inquiry would be a comparison of the effect of bundling the multiple agency requirements (as was done here) with treating the agencies separately. This would help elucidate what specific benefits (if any) accrue when combining the mitigation needs of the agencies. This would effectively test one of the assumptions made at the outset of this analysis (i.e. the effectiveness of mitigation bundling).

A similar analysis would test the assumption that regional bundling of project needs actually leads to cost savings and ecological benefit. A useful analysis would examine the effects of selecting parcels using the overall project footprints versus the project-by-project status quo. If benefit is found (as we would expect it to be), this analysis could serve as a useful tool in creating interest in other agencies for participating in this sort of comprehensive mitigation planning.

One potential partner that could be approached with the results of this sort of analysis would be local and county transportation agencies which are responsible for the majority of the road projects within our study area (and other regions as well), but were not included in this state-agency based assessment. If there are demonstrated benefits in regional advance mitigation, there is a potentially greater likelihood that mitigation activity from many more road projects could be incorporated into this process, leading to even greater integration of mitigation action with regional conservation needs.

This analysis demonstrates one means through which ongoing mitigation needs of multiple infrastructure agencies can potentially be incorporated within the overall conservation network within a given region. This has the potential to lead to a more ecologically effective use of public funds and to help achieve regional conservation goals. There will also likely be a concurrent fiscal savings. If an effective process is implemented, there is further potential for collaboration with other organizations with mitigation requirements. While these actions alone will not lead to fully realized regional ecological networks, they can contribute substantial resources over the long-term towards meeting regional ecological conservation goals.

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Biographical Sketch

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Dr. James Thorne is a Research Scientist at the Information Center for the Environment at the University of California, Davis. His work focuses on resource planning, plant distribution modeling, and the effects of climate change on vegetation communities.

Ted Frink is an Environmental Program Manager at the California Department of Water Resources (DWR).

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STATUS OF MITIGATION BANKING FOR TRANSPORTATION IN THE UPPER MIDWEST

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Abstract

The St. Paul District of the Corps of Engineers and the state wetland regulatory agencies in Minnesota and Wisconsin have undertaken a series of studies to evaluate the successes achieved by the transportation-related wetland mitigation banking programs, the state of the sites entered into the program to date, and opportunities for improving program quality and efficiency into the future. The objective of this paper is to synthesize the findings of:
1) The Corps' comprehensive long-term monitoring program initiated for all Wisconsin bank sites; 2) A comprehensive long-term monitoring program initiated by the Minnesota Board of Water and Soil Resources and the Corps; and 3) a Wisconsin Department of Natural Resources evaluation of the compensation site review process and site quality for a sample of compensation site projects, including bank sites.

The two comprehensive monitoring programs were initiated in 2007 and are expected to generate complete monitoring reports for the approximately 300 existing mitigation bank sites by the end of 2012. The Wisconsin DNR study file reviews and site visits were completed in 2007 with the findings revised in 2008 - results include an analysis of current status of 19 bank sites as well as the process followed by applicant and reviewing agencies to develop and approve the sites. All three efforts have developed recommendations for future bank projects that are in the process of implementation by the transportation and regulatory agencies.

The assessments of the bank site review process found: inconsistent levels of engagement in the project review process by state and federal regulators; inconsistent or unclear state-level guidance that lead to regional variations in both the site review process and final compensation site product;

Findings of the on-site monitoring reviews include: occasional variation from projected wetland acreages, considerable variation in site vegetative quality, occasional variation from projected hydrologic regimes (often too wet); an overabundance of permanent and semi-permanent inundation commonly associated with hybrid cattail, sites with wildlife challenges to structural integrity of engineered structures, unfunded long-term management needs, adaptive management, structural integrity questions), sites with ambiguous real estate protection, sites where long-term management (undertaken by a third party) was inconsistent with the bank site goals, sites where necessary adaptive management was not anticipated in the long-term management plan, sites with increased risk of easement violation due to lack of clearly-marked property boundaries.

Introduction

Transportation agencies in the upper Midwest have long been proactive in providing compensatory mitigation for impacts to wetlands. Minnesota, Wisconsin and Michigan all have active transportation banking programs.

As the art and science of wetland restoration have evolved, so have the approaches taken to provide compensatory mitigation at both programmatic and field levels. The process has evolved due to the diligence of both the regulated community and regulators. That evolution has taken place at both administrative (programmatic) level and at the field level where the wetland technical experts from the various agencies coordinate.

Discussion

Program-Level Approaches to Mitigation Banking

At the program level, the Minnesota Department of Transportation (MnDOT) has long been engaged in development of mitigation bank sites to compensate for project impacts in advance. Initially wetland mitigation was to satisfy federal permit requirements, but in the early 1990s, Minnesota implemented a state wetland regulatory program.

Initially MnDOT took the traditional approach of developing mitigation banks where opportunities arose with either dedicated banking funds or funds dedicated to a specific project where an opportunity for consolidation of mitigation for multiple projects arose on a site originally envisioned as a single-project mitigation site.

While the state was able to cope with the challenges of developing compensatory mitigation to acquire state and federal permits, those same challenges were posed to much smaller county and local transportation agencies as well.

Minnesota chose to establish a funding mechanism that enabled a state agency experienced in restoring wetlands to seek out wetland mitigation opportunities on a statewide basis to begin addressing the needs of local transportation entities. The Minnesota Board of Water Resources (BWSR) has developed and continues to develop a variety of mitigation banks sites around the state to generate wetland mitigation credits for use by local transportation agencies for basic infrastructure maintenance.

More recently, in advance of the new federal rule preference for banking, MnDOT has entered into a cooperative agreement with BWSR that has resulted in joint funding of a bank program now dedicated to developing mitigation banks throughout Minnesota t meet state and local transportation agency needs.

Wisconsin Department of Transportation (WDOT) has a long history in wetland mitigation banking, with more than 30 bank sites developed with funds that the state specifically dedicated to bank development. Another 30+ sites that function as banks were developed as sites where mitigation needs could be consolidated at a single site. The state also was early into developing interagency agreements on how banking should be done both inside the WDOT and amongst regulatory agencies. They have taken an additional step in the agency collaboration process by funding a number of Wisconsin Department of Natural Resources (WDNR) liaison positions to help review transportation projects and provide valuable technical assistance to WDOT staff in development of banks sites and bank policy.

Field-Level Banking Issues

The 2008 federal mitigation rule codified a number of key issues that have emerged as we learn more about how to go about the business of compensatory mitigation, including wetland restoration, wetland creation and wetland preservation.

On-site monitoring by regulatory agencies, completed some years after completion of sponsor-required monitoring identified a number of concerns that merit consideration as banking evolves. Many of the concerns identified by monitoring staff were not non-compliance issues in the sense that the site failed to meet mandated regulatory performance standards. Many old sites do not meet standards we commonly impose today – not surprising since not-so-many years ago there were few if any performance standards imposed by regulators on bank site developers. Resolution of some of those concerns will have to be brought about by improvements in the design and project review of future projects.

There were occasional variations from projected wetland acreages discovered, although the wetlands that actually developed on a site were not always smaller than anticipated, and only a few sites had wetland acreage that varied by more than one acre from the anticipated wetland size. Concerns with wetland acreage need to be addressed in performance standards, credit releases, and by more careful review by regulators before credit releases.

Another concern identified during monitoring was considerable variation in site vegetative quality, and occasional variation from projected hydrologic regimes –sites were often too wet.

In looking at monitoring room both states, there was a consistent overabundance of permanent and semi-permanent inundation – a problem that was also commonly associated with establishment of invasive hybrid cattail

At least one older site has been identified where muskrats are so aggressive in burrowing into berms that there is some question about the long-term stability of the berms. The site appears to be functioning as regulatory agencies anticipated thus far, so the primary issue here is one of long-term maintenance. Long-term management of the site has been taken over by a university-related foundation that does not have adequate funding to do major engineering work on the site if that proves necessary. To address the issue, the first step being taken is an assessment of the structural stability and also implications of failure of specific structures – the failure of some structures might be of little consequence because there would likely be little wetland loss, just change of wetland type. Other structural degradation may merit an engineered solution that could require additional funding from the original project sponsor.

At least one bank site that was transferred to public ownership by a conservation agency had substantial food plot acreage that was not allowed by the approved bank plan – that problem was ultimately resolved, but did require substantial time to sort out.

A number of sites were found to lack clearly marked site boundaries, increasing the risk an easement boundary violation. Not all banks were initially required to have posted boundaries, but boundary posting is now a commonly anticipated requirement. To increase boundary posting, the state of Minnesota currently offers free boundary posting signs, regardless of whether the signs were required by bank approval conditions.

Monitoring – Beyond Sponsor's Obligations

Monitoring is typically talked about in terms of obligations incurred by the bank sponsor. However, experience in the upper Midwest dictates that monitoring by regulators can also be very important. The Corps and state agencies have recognized that it is important to monitor banks sites over the long term. The Minnesota Board of Water and Soil Resources (BWSR), the agency that administers the state wetland regulation program in Minnesota has periodically monitored all banks established in the state. Recently the agency has developed a systematic, long-term monitoring program that includes permanent monitoring staff. Dedication of permanent staff to monitoring allows the agency to develop a greater institutional knowledge of wetland restoration and site succession. Minnesota agency staff have recently presented preliminary results from two years of monitoring by the Corps and state (Strojny and Swenson 2009).

Real Estate Protection

The new federal rule requires real estate protection for all mitigation bank sites. Experience in the upper Midwest bears out this requirement: older sites often have ambiguous or weak real estate protections – sometimes none; chosen land stewards occasionally do not follow the terms of easements (not common, but it has happened; deed restrictions and covenants are generally weaker than permanent conservation easements and in many states are not 'permanent' and may be removed after 30 years.

Most banks initially established restrictive covenants at the request of the Corps. Later guidance and experience with conservation easements for incentive programs lead to a preference for permanent conservation easements for bank sites – a preference incorporated into state rules in Minnesota. However, not all easements are created equal and regulators learned that older easements in Minnesota were not written to exclude some management that can be detrimental to a site, *e.g.*, grazing. The state expanded the list of prohibited activities to include activities like grazing, logging and burning along with the establishment of food plots. The current easement in Minnesota has worked well to-date; the problems being encountered now are all attributable to older real estate provisions that were less specifically protective. In fact we may have reached a point in Minnesota where there may be merit in allowing some activities currently prohibited as adaptive management practices to manage troublesome plant species.

In Wisconsin, real estate protection has often taken the form of finding a long-term manager for bank properties once a bank has passed through the regulatory approval process. However, Kline *et al* (2008) found that there were problems with the transition from DOT ownership to long-term manager ownership that needed to be addressed in upcoming projects where DNR or similar agencies were the projected long-term managers. When asked in 2005, Wisconsin developed a program-level mechanism to establish real estate protection for bank sites not destined for future management by the WDNR – that protection is a standardized set of protective covenants tied to the property deed.

Corps experience also dictates that the roles of long-term managers need to be more carefully explored during the bank plan review process and more carefully delineated before a plan is finalized. The goals of the bank site need to be made clear to a long-term manager and spelled out in a management plan – if the potential manager is not comfortable with the management plan requirements, then most likely another long-term steward should be identified.

In the private banking program in Wisconsin, there is recognition of the value of permanent conservation easements and the state is authorized to hold those easements when private-sector banks are established. However, there has not yet been a comparable shift in the real estate protection approach for transportation projects in Wisconsin. A transition towards easements driven by regulatory requirements is likely for transportation banks, but the necessary discussion of the details between the state and federal agencies has yet to be completed.

Adaptive Management

Adaptive management has occurred in the field, out of necessity. However, there has been little proactive adaptive management to date. In both Minnesota and Wisconsin, the need for management of woody species has arisen – but the long-term management plans and real estate protections typically placed on sites commonly prohibit woody species removal. Adapting management plans reactively has often been challenging, and will remain so under the new federal rules that require a rigorous public and agency review process for the kinds of changes typically proposed to adapt to unanticipated site challenges.

Anticipating at least some future management adaptations at the initial plan development stage has always made sense on paper. Experience in Minnesota and Wisconsin is now bearing that judgment out. Most projects have required little adaptive management thus far, but the few that do have to revise management plans require an inordinate amount of staff time to work through and can involve unanticipated expenses as well. Those expenses are not always small. Both regulators and bank sponsors would be wise to anticipate problems and devote at least a little text and thought to adaptive management plans as they consider long-term management of bank sites. Simple provisions in real estate instruments and long-term management plans can set the stage for adaptive management down the road. However, implementation remains a problem because implementation typically requires funding.

Invasive and non-native species present an adaptive management challenge throughout the region. In some cases, there are ready solutions that offer at least partial resolution of the problem, as with control of purple loosestrife by beetles. Most other problems are more intractable, but there are always options to consider before deciding the only feasible option is to ignore the problem. For example: At the suggestion of The Nature Conservancy, Minnesota is considering a study of the effectiveness of certain grazing management regimes at reducing cover of the non-native reed canarygrass (*Phalaris arundinacea)*.   Fire is a tool that can be affordable in some situations, but has not yet proven to be a viable tool in the region with the exception of managing upland prairie buffers.

Summary

The solutions to the problems identified to-date require interagency coordination at both the field and main office levels and many will require the revision of existing policies and procedures. These problems will require the best efforts of both regulated and regulators to resolve, with few of the solutions reached easily or quickly, if at all. In many cases the obvious solution at the beginning of the assessment process will not be the optimal solution after more careful evaluation of a particular problem.

One pressing need in the region is the need for an umbrella bank instrument or state-level bank site development agreement that provides for a bank site long-term management process that provides some room for resolution of future bank program problems without frequent, extensive overhauls of the entire system. Both Minnesota and Wisconsin are in the process of establishing programmatic agreements that could include such provisions.

Another vexing problem that will need attention is the issue of long-term protection and management of mitigation sites – especially attention to keeping open the options beyond ‘no management.’ Requiring active management has a price, and often the price is higher than anticipated by even those experienced at stewardship. How much is enough? How much it too much? Although the answers may not come quickly or easily, we really need to ask the questions.

Biographical Sketches

Tom Mings is a senior ecologist with the regulatory branch of the St. Paul District, U.S. Army, Corps of Engineers. His primary job with the Corps is oversight of the district mitigation bank programs in Wisconsin and Minnesota. Prior to joining the Corps, he was a senior wetland specialist for the Minnesota Board of Water and Soil Resources, the wetland coordinator for the Missouri Department of Transportation, a wetland ecologist in the private sector, and a rangeland ecology research specialist with North Dakota State University. He received a master’s degree in rangeland ecology and management from Texas A&M and a B.S. in range management and wildlife management from Humboldt State University.

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Integrating Ecology and Transportation Planning at the Landscape Scale

CALIFORNIA ESSENTIAL HABITAT CONNECTIVITY PLANNING

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Abstract

SAFETEA-LU (Safe, Accountable, Flexible, Efficient, Transportation Equity Act – A Legacy for Users) section 6001(Metropolitan Transportation Planning) more specifically referred to as Title 23CFR 450.316 and 450.322 addresses consultation and cooperation requirements between State and regional Metropolitan Transportation Planning organizations (MPOs) and contains the requirement to discuss potential environmental mitigation activities in Regional Transportation Plans (RTP). To implement these sections of the Act, transportation planners and MPOs need appropriate data to effectively incorporate natural resource planning into transportation plans. The California Essential Habitat Connectivity Project developed a model to delineate natural landscape blocks and essential connectivity areas for habitat and wildlife throughout the state of California that will provide a vital data set at an appropriate scale to be useful for a variety of transportation and land use planning decisions and projects.

Many data sets exist at several different scales and are successfully analyzed at the project level to evaluate specific impacts to a particular resource. However, while some connectivity analyses have been completed for some regions in California, there has been no comprehensive wildlife connectivity analysis completed statewide. Successful modeling of wildlife corridors or connectivity has been conducted in more localized areas of the state, but different methods were used in different parts of the state. Some models were more transparent in their design than others; some were based on habitat integrity while others utilized focal species. Some included local area or species expert input while others did not. This Project was initiated to model natural landscape blocks and essential habitat connectivity areas in the state of California and to establish an approach that is repeatable and developed in coordination with major land managers and regulatory agencies.

While essential habitat connectivity information is needed in transportation planning per SAFETEA-LU, Caltrans is aware that integrated planning cannot be done with the sole focus of transportation planning needs in mind. Through a partnership between California Department of Transportation (Caltrans) and CA Department of Fish and Game (DFG), a scope for this project was developed and received funds through the State Planning and Research special projects program. The project was developed with the following steps outlined: 1) establish a multidisciplinary team (MDT) that includes land management agencies, infrastructure agencies and wildlife or regulatory agencies; 2) construct a statewide wildlife habitat connectivity map using a Geographic Information System (GIS) based modeling approach; 3) identify criteria and priorities for connectivity analyses; and 4) develop a strategic plan that will outline the framework necessary to complete connectivity analyses on a local or regional level. This project and its' final products is scheduled for completion in February 2010.

The role of the MDT was to help shape the end products of this project by identifying their needs and uses for the products. Some members of the MDT volunteered to assist the project team in making key technical decisions regarding the products. These volunteers were called the Technical Advisory Group (TAG), who provided input on model preferences and criteria selection to inform the model, evaluated the results of the GIS model, and assisted with the development of a prioritization framework. The strategic plan was developed with ongoing input from the TAG and

MDT. This team worked together to develop the products and provide consensus on the framework and approach that was used.

Introduction

Caltrans has been working to develop a program that evaluates wildlife movement and the interaction with highway facilities and operation. While we as practitioners tend to think primarily of implementation or project level improvements, we recognized that wildlife movement is an issue that needs to be evaluated scientifically and politically in order to be incorporated into institutional practices and efficiently implemented. Over the past few of years, the conservation community and public agencies have worked collaboratively on these elements of wildlife movement conservation in California.

While some connectivity analyses have been completed for some regions in California, no comprehensive wildlife connectivity analysis has been completed statewide. Successful modeling of wildlife corridors or connectivity has been conducted in more localized areas of the state, but different methods were used in different parts of the State. Some models were more transparent in their design than others; some were based on habitat integrity while others utilized focal species. Some included local area or species expert input while others did not. This Project was initiated to model natural landscape blocks and essential habitat connectivity areas in the state of California and to establish an approach that is repeatable and developed in coordination with major land managers and regulatory agencies.

Politically, California successfully passed Assembly Bill 2785 which requires DFG to identify essential wildlife corridors and habitat linkages spatially. SAFETEA-LU section 6001(Metropolitan Transportation Planning), more specifically referred to as Title 23CFR 450.316 and 450.322. CFR section 450.316 addresses consultation and cooperation requirements between State and regional Metropolitan Transportation Planning organizations (MPOs) and CFR section 450.322 contains the requirement to discuss potential environmental mitigation activities in the RTP. To efficiently implement these sections of the Act, transportation planners, MPOs, resource agencies and land use planners need appropriate data to effectively incorporate natural resource planning into transportation and land use plans.

Many data sets exist at several different scales and are successfully analyzed at the project level to evaluate project specific impacts to a particular resource. This Project was designed to develop a data set that will be usable during planning. The product will provide an appropriate scale to delineate the natural landscape blocks and essential connectivity areas for habitat and wildlife throughout the State of California.

In order to better institutionalize the results of the analyses of wildlife movement in the planning and project delivery process, Caltrans has taken several steps to provide guidance, training, best practices, data gathering and methods for integration with other agencies goals and missions.

Methods

Based on the understanding that legislation was heading in the direction of requiring wildlife connectivity mapping at the state level and recognition of the common need for this information, Caltrans and DFG began to collectively evaluate the issue.

Through this partnership the two Departments evaluated existing modeling methods, developed the scope for a statewide essential habitat connectivity project, and sought and received funding through the State Planning and Research special projects. The project was developed with the following steps outlined: 1) establish a multidisciplinary team that includes land management agencies, infrastructure agencies and wildlife or regulatory agencies; 2) construct a statewide wildlife habitat connectivity map using a GIS based modeling approach; 3) identify criteria and priorities for connectivity analyses; and 4) develop a strategic plan that will outline the framework necessary to complete connectivity analyses on a local or regional level.

Coordination with biologists, technical staff, planners and implementers influenced the way in which the products were developed and considered both land use and transportation modeling practices. The role of the multidisciplinary agency team was to help shape the end products of this project by identifying their needs and uses for the products. Some members of the MDT volunteered to assist the project team in making key technical decisions regarding the products. These volunteers were called the Technical Advisory Group (TAG), who provided input on model preferences and criteria selection to inform the model and work plan, and evaluated the results of the GIS analyses. In addition, the prioritization framework evolved into a biological values matrix based on TAG input, which provides more flexibility to the various implementers. The strategic plan was developed with ongoing input from the TAG and MDT. This team worked together to develop the products and provide consensus on the framework and approach that was used.

The statewide wildlife habitat connectivity map identified areas where maintaining or restoring functional ecological connectivity is essential to conserving the state's biological diversity. The intent was to create a baseline map of essential connectivity areas, based largely on GIS data layers that reflect ecological integrity or "naturalness" of land features, and therefore likely to reflect the needs of diverse species and ecological processes. Thus, this statewide map provided a relatively "top-down, broad-brush" depiction of essential connectivity areas, with the intent that finer resolution mapping and analysis will later be performed using finer resolution and "bottom-up" (e.g., species-based) modeling and analyses. The analysis area was defined as the entire state of California plus a buffer into adjacent Oregon, Nevada, Arizona, and Baja California to ensure that cross-border connections were also addressed.

The work plan developed by the project team based on TAG input identified the following approach. To delineate natural landscape blocks the model primarily relied on a "naturalness" score calculated by equally weighting three parameters – Percent Agriculture (rangelands not included), Percent Road Density, and Mean Housing Density. Each parameter was ranked from 1 (lowest naturalness) to 10 (highest naturalness). Adding these three scores gave "naturalness" scores across the state from 13 to 30, with 30 being the most natural areas (i.e., the areas least affected by development, roads, and agriculture).

The naturalness score was then reduced by one point for areas suspected to be strongly altered in ecological structure and function. Any cell with Gap Analysis Program (GAP) status = 1 was not demoted. We then increased the naturalness score (for areas not already receiving the top score of 30) by 1 point for known areas of high biological value (HBV), such as biodiversity hotspots, important wetlands, Essential or Critical Habitat for listed species, Areas of Critical Environmental Concern (ACEC), and oak woodlands.

From the results, we selected thresholds for the size of contiguous areas that constituted natural landscape blocks. Areas outside these blocks were treated as matrix lands through which connectivity needs were assessed.

After natural landscape blocks were defined, we used expert opinion to determine which blocks should be connected using such factors as landscape context (e.g., are the blocks adjacent?), ecological context (e.g., do the blocks share species that require movement?), existence of barriers (are there absolute barriers between blocks that cannot be mitigated?), and ecological processes (would connecting these blocks accommodate migrations or ecological shifts due to climate change or disturbance factors?).

We used a least-cost corridor model to define essential connectivity areas for each pair of natural landscape blocks that were determined to require connectivity. We used the centroid of each natural landscape block as terminuses for each analysis. The resistance surface or cost raster for the least-cost corridor was based on ecological integrity. We added natural streams that provide potential aquatic or riparian connections between the natural landscape blocks if a linkage polygon did not encompass those streams already. Streams were buffered on each side out to 250 m or to any substantial barriers to movement, such as urban edge.

Once this model framework was completed we compared the results to other conservation and pertinent maps. We overlaid the results of the analyses to delineate natural landscape blocks and essential connectivity areas with other conservation plans and assessed differences. We also discussed compatibility with other statewide plans (e.g., regional transportation plans, State Wildlife Action Plan) and online databases.

We then described the mapped linkages according to their *biological value*. The values assigned were emphatically *not* intended to set agendas for any regulatory, management, or conservation entity. Rather, the assigned values of each linkage were intended to serve the following limited purposes:

- To allow each agency to use the description of statewide biological value as one of several inputs into their own prioritization scheme. The agency will continue to set its own priorities based on its particular mission.
- To allow DFG, Caltrans, or another state or regional entity to voluntarily allocate planning resources for development of fine-scale linkage conservation plans, inform the State Wildlife Action Plan, or aide in developing a new Natural Communities Conservation Plan (NCCP) or Habitat Conservation Plan.
- To allow agencies and conservation planners to focus conservation or mitigation in particular areas of high biological importance.
- To provide public information that can highlight essential connectivity areas in California.

The following criterion were used:

- size of each natural landscape block associated with the essential connectivity area

- ecological integrity of the essential connectivity areas;
- fraction or area of the natural landscape blocks and essential connectivity areas in protected status; and,
- a metric derived from graph theory called the "integral index of connectivity" that integrates landscape value (e.g., ecological integrity) and graph connectedness into a single measure (Pascual-Hortal and Suarta 2008).

Rather than assign relative weights to each metric, we provided a matrix of scores for each metric by essential connectivity area. The matrix identifies which ecoregion(s) and which county(s) the essential connectivity area falls within.

The Strategic Plan discusses the following:

- Methods and results of the preceding analyses, including their limitations;
- Steps required to complete regional level analyses;
- Steps required to complete fine scale analyses
- Strategies for integrating essential connectivity areas into other planning and implementation strategies (e.g., General Plans, transportation plans, NCCP plans);
- Comparison of this approach with that of other plans;
- Description of necessary coordination and collaboration efforts;
- Description of threats and opportunities for implementation, including strategies for rating threats (e.g., development, climate change, fires, pests) and opportunities (e.g., state and regional transportation plans); and,
- Description of how to integrate results into transportation and land use models.

Results

The State of California is renowned for its incredibly diverse geography and ecology, from the deserts to the coast and from the Great Central Valley to the mountains. This wide variety of land types support an amazing array of native plants and animals, including many species found nowhere else in the world. Federal, state, regional, and local public agencies and many private non-profit conservation groups and land conservancies have worked for decades to protect critical landscapes throughout the State in order to preserve natural values and the plant and animal species that depend on them.

Unfortunately, human development has threatened these species by converting much of our natural landscape to agriculture, cities, and freeways which fragment native habitats and limit movements by species and essential ecological processes among the remaining habitat areas. Research has shown that strategically conserving and restoring essential connections between these remaining habitat areas is a successful and cost-effective counter-measure to these adverse effects of habitat loss and fragmentation. California's wild legacy can be sustained in the face of development and improving transportation networks, provided that our remaining natural areas are functionally connected into a large network of open space. This process identified connections that are most essential to maintaining healthy populations of native plants and animals.

This Project clearly furthered the goal of maintaining a connected California, while simultaneously making transportation planning projects more cost efficient and reducing dangerous interactions between vehicles and wildlife. Through the successful completion of this project, transportation and land use planners will be able to take into account essential habitat connectivity and wildlife movement corridors early in their planning processes. This will allow planners integrate connectivity conservation considerations early when such decisions are both less costly and more effective. For example, the maps, data sets, and other information generated by this Project could be used to adjust proposed road alignments or to design wildlife crossing structures during planning and design of a transportation project, rather than addressing project impacts to habitat connectivity later, as expensive remedial actions. Products of this project will make transportation and land use planning both more efficient and less costly, while also improving the health of our natural resources. It is anticipated that the integration into other agency decision processes and conservation goals or evaluation of proposed plans will produce a common vision for maintaining connectivity throughout the state.

Conclusion

Coordination with the conservation and scientific community has proven to be essential to integrating wildlife connectivity data into planning practices and plans. SC Wildlands has had tremendous success working with scientists, wildlife agencies, land use managers and planners, decision makers, tribes and private entities to facilitate coordination and provide data to inform land use and conservation plans. Cross discipline collaboration during the planning, design, and implementation phases of wildlife connectivity studies has been beneficial in California due to the complexity of biodiversity, land uses, infrastructure needs and jurisdictional boundaries. Partnering to develop an understanding of essential wildlife movement corridors allowed for the consideration of natural resources in planning at the state, regional and local levels. The availability of data and guidance or analysis tools can successfully influence decision making at both the planning and project level. The institutionalization of approaches to analyze wildlife movement at different scales is beneficial for integration into planning processes, securing funding for acquisition and mitigation measures. Understanding the needs of different end users of wildlife corridor information is critical to the development of your approach for modeling habitat connectivity and wildlife movement. Partnering and collaboration have made for more robust products that will not only be supported by a wide range of federal, state, local agencies, but also assist a wider variety of users.

The results of this statewide effort will be will be further integrated into Caltrans and Department of Fish and Game planning, project analysis, and restoration or project design elements. Caltrans recently developed a Wildlife Crossing Guidance Manual which incorporated existing literature and case studies associated with wildlife movement and transportation facilities, as well as a construct for how the Department should evaluate wildlife connectivity in planning and project evaluation. This guidance manual, literature, and case studies are available on the internet http://www.dot.ca.gov/hq/env/bio/wildlife_crossings/ and are intended to help build a database of wildlife crossing information to be shared with colleagues in different agencies and organizations. The statewide map and strategic plan will be incorporated into this on-line resource which will make it readily available to users. A wildlife carcass database and web based platform has also been established to allow staff to track information about animal vehicle collision locations to help identify areas of high density of wildlife collisions or safety concerns. With this location specific information regarding animal vehicle collision concentrations along with the statewide map of essential habitat connectivity, the Department and its partners can begin to address common concerns of safety and wildlife connectivity. Integration in facets of planning and project delivery as described will help institutionalize the use of this information and ways in which collective solutions can be identified.

As planning for conservation, infrastructure and land use needs becomes more integrated, comprehensive data sets need to be developed to be incorporated into dynamic planning practices. These data sets will need to be developed in a way that is scientifically defensible, transparent and repeatable. In light of fast pace development pressures and ecosystem function shifts, practitioners should plan to update these datasets on a cycle to take advantage of new data layers that become available.

Trying to develop a program to address wildlife movement within a Department of Transportation, requires partnering and collaboration with other agencies, land managers, and scientist to evaluate the best strategy for developing a dynamic data set and approach for modeling wildlife. Due to modeling technology and capabilities of spatial analysis, conservation planning can be integrated into other planning forums and models for consideration. Tools for implementation and data development are also helpful to engage other functions within DOT's to institutionalize the evaluation of wildlife movement and infrastructure interaction.

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Establishing the Legacy Nature Preserve through Collaborative Planning and Adaptive Management

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Abstract

To help accommodate regional growth and alleviate congestion, the Utah Department of Transportation (UDOT) developed the Legacy Parkway as a new 14-mile roadway and trail system in northern Utah near Great Salt Lake. The Great Salt Lake Ecosystem contains a complex mosaic of diverse wetland and upland habitats and is recognized as a site of hemispheric significance for millions of migratory birds. Resource agencies and environmental organizations expressed concerns about potential impacts to the ecosystem from the project and a publicized debate over whether to build the project became increasingly controversial. With input from agencies and stakeholders, UDOT proposed creating the Legacy Nature Preserve as mitigation for impacts to wetlands and wildlife resources.

UDOT established an interagency-stakeholder “Collaborative Design Team” to develop an adaptive management plan for the proposed 2,225-acre Legacy Nature Preserve. The adaptive management plan is structured around habitat goals that focus on suitable habitat conditions for a diversity of nesting and migratory shorebirds and other water-associated birds. These goals consider vegetation structure, species composition and hydrology. The plan provides different management options to manipulate vegetation and actively manage hydrology. Many wetlands and uplands in the Preserve had been degraded and channelization cutoff hydrology to an historic river delta. To restore wetlands, an adaptive approach to water management was developed to optimize wetland quality through mimicking natural cycles of flooding and drawdown in shallow playas and grassland ponds within the historical river floodplain. To optimize habitat quality for bird use, water timing and amount has been controlled to provide a late summer drawdown, which in turn draws salts to the soil surface and keeps playa substrates at the proper salinity for desired macroinvertebrate productivity. Through implementing vegetation management strategies and then adapting them based on monitoring results, large areas once dominated by invasive species have been converted to desirable habitats. Increase in avian abundance and productivity correlate to effective vegetation and water management.

Truly implementing adaptive management is unique to both wetland mitigation and habitat management in this region. Natural systems are inherently complex and dynamic. A well-planned adaptive approach to restoration and habitat management can grapple with altered environmental states and system dynamics. This approach can be widely used in restoring lost functions of wetland and floodplain areas in the Great Basin and other arid environments. Mimicking natural hydrologic cycling through adaptive management should be the basis of design of river and wetland restoration projects wherever they are planned. We are currently working with the EPA to apply our results to a regional wetland goals project.

Project Background

When the Governor of Utah announced plans for the Legacy Highway in 1996, conservation and environmental groups became immediately concerned about a portion of the proposed roadway alignment near the Great Salt Lake, just north of Salt Lake City in Davis County, Utah (See Figure 1). The Great Salt Lake Ecosystem (GSLE) is a veritable oasis in the arid Great Basin that supports a number of diverse plant and animal species in a unique mosaic of upland, wetland, mudflat, river delta, brackish and freshwater marshes, ephemeral ponds and other habitat types (UDNR 2000).

There are 250 species of birds which occur within the GSLE and it is estimated that about 5 million migratory birds annually utilize the lake and its shoreland habitats. The GSLE has been designated as a Hemispheric Reserve of the Western Hemispheric Shorebird Reserve Network. Despite extensive and ongoing alterations to hydrology and dramatic landscape changes resulting from agrarian and urban development since the mid-1800’s, the GSLE ecosystem has continued to support robust biota (UNDR 2000).

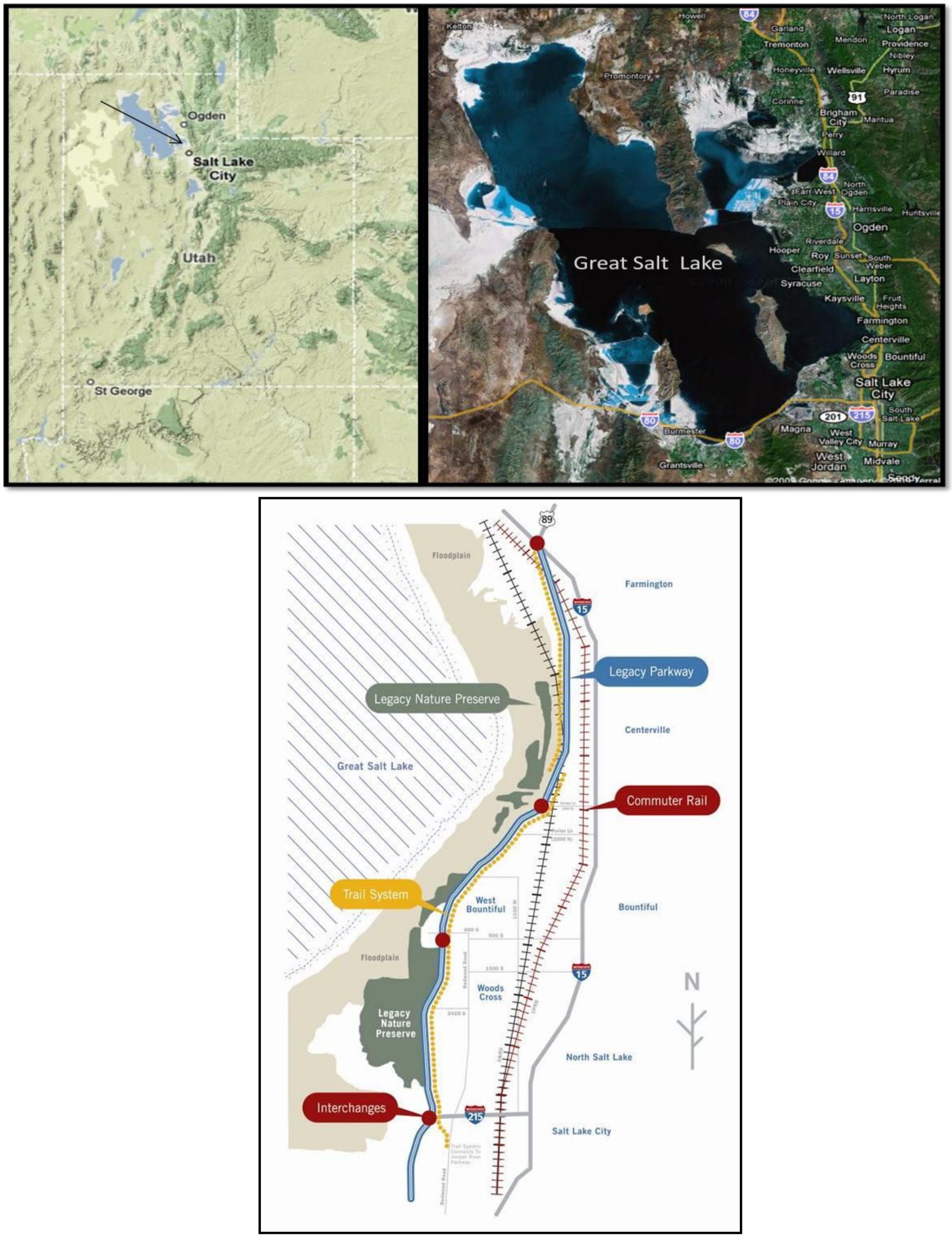

Figure 1. Project Site Location Maps (Courtesy of UDOT)

Over the last several decades, northern Utah has experienced a tremendous population boom. Along the northern Wasatch Front, urban development pressures are extending east to the foothills of the Wasatch Mountains and west to the shores of the Great Salt Lake, particularly in Davis County, an area historically known for agriculture and open lands. Open space in Davis County is being developed at the rate of about 700 acres per year, which would lead to most of the Legacy Parkway project study area being developed by 2020 (Sommerkorn 2004). Increased traffic Pressures in northern Salt Lake County and southwestern Davis County are a direct result of the population growth concentrated north of Salt Lake City. The Utah Department of Transportation (UDOT) identified the construction of a roadway west of Interstate 15 and east of the Great Salt Lake as a means to improve traffic congestion in this corridor. Environmental groups immediately protested this proposed roadway, which became known as the Legacy Parkway. Resource agencies also expressed concerns about potential impacts from the project to GSLE habitats. The concept of a establishing a preserve as mitigation for wetland and wildlife impacts was developed through input from resource agencies and other experts familiar with the GSLE. A total of 2,225 acres between the Great Salt Lake and the Legacy Parkway alignment were proposed as Legacy Nature Preserve (LNP).

Resource agencies and environmental groups were in support of establishing the LNP, but were still concerned about potential impacts from the new roadway and whether UDOT could successfully establish the LNP. Proponents hoped the LNP could provide an integral part of the existing wetland and associated upland habitat complexes along the eastern shore of the Great Salt Lake that provide foraging, nesting, and staging habitat for millions of migratory waterfowl and shorebirds. The LNP lands contained over 1,300 acres of uplands and about 800 acres of wetlands, including a large portion of the historic Jordan River delta. However, hydrology to the river delta floodplain had been largely cut-off, tile drains and deep ditches drained many LNP wetlands, a majority of the lands were severely overgrazed, and invasive species dominated much of the LNP landscape.

Collaborative Design Team

Construction of the Legacy Parkway was halted in 2001, when the U.S. Tenth Circuit Court placed an injunction on the project, pending the results of further studies as dictated by the court ruling. In January 2005, UDOT established a *Collaborative Design Team* (CDT) with the charge to develop an adaptive management plan for the LNP that would include management strategies to offset wetland and wildlife impacts from the Legacy Parkway, restore LNP habitats and provide recommendations on how the Legacy Parkway could be designed and constructed to minimize environmental impacts. The CDT included resource agencies, environmental groups including groups that had been party to the plaintiffs against the project and other stakeholders, providing diverse expertise and a regional perspective for habitat restoration and wildlife management. The following organizations participated on the CDT:

- Bear River Bird Refuge
- Farmington Bay Waterfowl Management Area
- Friends of Great Salt Lake
- Foundation for the Provo-Jordan River Parkway
- Great Salt Lakekeeper
- Sierra Club
- The Nature Conservancy
- U.S. Army Corps of Engineers
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- Utah Division of Wildlife Resources
- Utah Department of Transportation

From February 2005 through January 2007, the CDT generally met monthly to design and shape the adaptive management plan. The monthly meetings allowed resource specialists from various government entities and conservation groups to discuss the prominent issues for each and the most effective actions to address the issues. UDOT's consultant team prepared draft documents based on guidance from the CDT. Early in the planning process, the CDT crafted the following mission statement for the LNP:

> *"The Legacy Nature Preserve provides in perpetuity quality wildlife habitats for mitigating impacts to wetlands and wildlife associated with the Legacy Parkway."*

Guiding principles and were then developed:

1. Meet all mitigation requirements detailed in the Supplemental EIS Mitigation Plan and Section 404 permit.
2. Protect, preserve, and enhance aquatic and aquatic-dependent resources present in the LNP.
3. Protect, preserve, and enhance habitat for Utah State Species of Concern in the LNP.
4. Protect, preserve, and mitigate any cultural resources present in the LNP.
5. Restore functional habitat for wildlife that is consistent with ecological potential and management capabilities.
6. Monitor and manage invasive species to protect and preserve desirable native or naturalized species from deleterious effects.
7. Coordinate LNP adaptive management strategies with adjacent managed areas and land uses to protect into perpetuity, improve, and enhance overall habitat integrity of the Great Salt Lake ecosystem.
8. Be proactive in the greater community to prevent impacts from external threats that would compromise the integrity of the LNP.

9. Provide opportunities for public education and outreach compatible with Guiding Principles 1–10 that enhance the visibility and image of the LNP, develop and maintain a sense of public stewardship, and create a better appreciation and awareness of the Great Salt Lake ecosystem.
10. Prohibit active recreation in the LNP.

Next, the CDT divided into sub-committees in order to develop detailed management objectives and associated actions and strategies to be applied in concert with principles of adaptive management. Individuals with a specific interest in or knowledge of vegetation, wildlife, water, and/or education participated in monthly subcommittee meetings, in addition to the larger CDT meetings. In the first year, an adaptive management plan was completed as a guidance-level document to develop more detailed resource management plans. The adaptive management plan is structured around habitat goals that focus on suitable habitat conditions for a diversity of nesting and migratory shorebirds and other water-associated birds. These goals consider vegetation structure, species composition and hydrology. The plan provides different management options to manipulate vegetation and actively manage hydrology. The plan's adaptive framework is an iterative process that incorporates the following steps:

- Review project mitigation goals, requirements, and management objectives,
- Select and implement management strategies and actions intended to achieve objectives,
- Monitor effects of management actions,
- Evaluate monitoring results and measure progress towards objectives, and
- Based on insights gained from monitoring results, adjust objectives and strategies if needed and adapt management actions to continue the process.

In November 2005, UDOT and plaintiff parties reached an out-of-court agreement that allowed construction of a redesigned Legacy Parkway to proceed and incorporate establishment of the LNP as prescribed by the adaptive management plan. Mainly during 2006, The CDT developed three resource management plans: the Habitat Management Plan (HMP), the Comprehensive Water Management Plan (CWMP), and the Access and Education Management Plan (AEMP). These plans provide detailed guidance towards achieving mitigation goals to improve and maintain quality wildlife habitats.

Adaptive Management Implementation

Implementation of the adaptive management plan and associated resource management plans began in early 2007 and will continue through the adaptive management phase of the project, until mitigation permit requirements are satisfied. Labor to implement the plans has entailed a full-time site manager, numerous part-time support staff, engineering and construction contractors, an herbicide contractor, a goat herder and oversight management. Interested CDT members have continued to provide guidance on LNP management as an advisory group to the site manager.

To date, establishing the LNP in accordance with its mission, objectives and associated regulatory requirements has been largely successful, especially in consideration of the formerly degraded condition of LNP habitats. LNP staff monitor resources throughout the LNP. Water, vegetation, and birds are observed to evaluate the success of adaptive management strategies. Monitoring results and annual management action plans are evaluated and adapted with the intent to implement appropriate, dynamic, robust strategies that promote ecological vitality.

Many site management actions focus on controlling the timing and amount of water to provide a maximum benefit for wildlife. Timing of water-level drawdown is correlated closely with bird use and diversity. Through the study of habitat use patterns, it appears that certain rates of water elevation change provide optimal prey availability for specific species. Proper timing of inundation and drawdown phases, corresponding to migration periods, provides resources for migratory and nesting birds. Water levels appear to be appropriately timed to allow for the spring growth of hydrophytic vegetation and the mid-summer drying of evaporative basins—resulting in improved habitat quality for shorebirds in the spring. Analysis of the areal extent of water shows positive correlations between drawdown periods and bird abundance and diversity.

Vegetation treatments are part of an ecologically based Integrated Pest Management strategy. Targeted goat grazing, mechanical pulling, and properly timed chemical applications have increased the effectiveness of weed control efforts. Follow-up seeding efforts are being used to establish native grasses and forbs in noxious and invasive weed control areas. Vegetation monitoring was designed to 1) detect changes in plant species composition and percent cover resulting from mitigation measures and water dispersal, 2) collect data that would provide insight regarding causes of changes in the avian communities, and 3) determine the relative abundance and extent of noxious and invasive plants to aid in achieving the mandate of less than 20% cover of these plants in each habitat type. Data were collected using a stratified random sampling of these cover types. Grassland weed cover was reduced from 23.5% in 2007 to 11.5% in 2008 through application of herbicides and grazing cattle in the grasslands. Intensive management of noxious and invasive species in the initial phases of mitigation plan implementation continues to be successful in many locations on the Preserve. Results of goat grazing, chemical use, and shallow disking of infested areas show many beneficial effects including a reduction of invasive weed cover and an increase in native and desirable species. Timing of all vegetation treatments is specifically controlled to reduce any potential impacts to wildlife. In some large areas, once dominant weedy species have been completely eradicated and replaced with native species

Area searches, belt transects, and variable-distance point counts are conducted on the Preserve and provide valuable insight into breeding and migratory bird habitat-use patterns. Preserve staff has altered management actions based on the apparent response of birds to changing water levels and manipulation of vegetation structure. Observations of bird use in the Jordan River floodplain indicate that bird nesting density has increased from previous years and the increase in bird abundance is correlated with inundation and drawdown of water in specific areas.

Conclusions

As a result of environmental conflict, the Legacy Parkway project was delayed for several years and incurred substantial costs. Through an intensive collaborative stakeholder approach, a redesigned Parkway was allowed to move forward with a comprehensive plan to establish the LNP. Many wetlands and uplands in the Preserve had been degraded and channelization cutoff hydrology to an historic river delta. To restore LNP habitats, an adaptive approach to water management was developed to optimize wetland quality through mimicking natural cycles of flooding and drawdown in shallow playas and grassland ponds within the historical river floodplain. To optimize habitat quality for bird use, water timing and amount has been controlled to provide a late summer drawdown, which in turn draws salts to the soil surface and keeps playa substrates at the proper salinity for desired macroinvertebrate productivity. Through implementing vegetation management strategies and then adapting them based on monitoring results, large areas once dominated by invasive species have been converted to desirable habitats. Increase in avian abundance and productivity correlate to effective vegetation and water management.

Truly implementing adaptive management is unique to both wetland mitigation and habitat management in this region. Natural systems are inherently complex and dynamic. A well-planned adaptive approach to restoration and habitat management can grapple with altered environmental states and system dynamics.

This approach can be widely used in restoring lost functions of wetland and floodplain areas in the Great Basin and other arid environments. Currently, data from the NLP is being used to help develop models for the EPA's ongoing Great Salt Lake Wetland Goals Project.

Biographical Sketches

Michael Perkins works for HDR in Salt Lake City where he is the Utah Biology and Environmental Compliance Practice Group Lead. His experience includes research in behavioral ecology, terrestrial and aquatic habitat assessments, collaborative mitigation planning, habitat restoration, and adaptive management. His technical field experience includes performing jurisdictional wetland delineations, wetland functional assessments, threatened and endangered species (TES) and sensitive species surveys and monitoring, and environmental oversight compliance monitoring for mitigation and roadway projects. Mr. Perkins also has experience in coordinating and writing collaborative mitigation plans, Section 404 permitting, preparation of National Environmental Policy Act (NEPA) documentation and other technical reports, statistical data analysis and dynamic systems modeling. Mr. Perkins is the Environmental Oversight Manager for the Legacy Nature Preserve.

Eric McCulley, as a consultant with SWCA, manages the Legacy Nature Preserve on behalf of the Utah Department of Transportation. Mr. McCulley's professional and academic work focuses on water/soil interactions with biota, wetland ecology, restoration ecology, and environmental compliance. He has more than eight years of experience in natural resource research and consulting, including extensive fieldwork, in the Intermountain West, northern Rockies, and central Alaska. He has performed stream channel stability analyses and classification of stream types in Utah, Idaho, Wyoming, and Montana. In addition, Mr. McCulley has mapped numerous noxious weed infestations along the south shore of Great Salt Lake and in southern Montana. He has trained numerous workers in identification of noxious weeds and native plants and has developed seed mixes for revegetation of disturbed areas and areas where noxious weed control has removed vegetation.

Acknowledgements

Utah Department of Transportation Legacy Nature Preserve
Collaborative Design Team
HDR Engineering, Inc.
SWCA Environmental Consultants

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NEBRASKA DEPARTMENT OF ROADS PLAN FOR THE ROADSIDE ENVIRONMENT

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Abstract

Changing NDOR's established landscaping approach from primarily beautification into a more ecologically-based program was desired in order to provide more durable and sustainable roadsides. The *Plan for the Roadside Environment* was created to promote development of roadside landscaping and mitigation designs that use native plant materials and to provide a common base of information for administration and staff. Selecting plant species that are adapted to the varying climatic and physical conditions across the state improves the survivorship of the plantings.

The content of the Plan includes the Nebraska Landscape Regions Map, which provides a visual representation of the climate, soils, and ecosystem variability within the six identified regions. For each of the six individual landscape regions, the *Plan* contains maps that summarize a variety of ecosystem information, as well as corridor classifications for each highway in the region. Descriptions of each region's characteristics include components such as hydrology, climate, plant communities, and soils, along with sociological components such as history, land use and economic features. A list of plant species native to the area (grasses, wildflowers, woody shrubs and trees) that are known to do well in the region is included for each region. Additional components include five Roadway Corridor types for the state, which are defined and classified based upon their location, capacity, and traffic characteristics. Landscaping objectives were developed for each roadway corridor type to support the goals of safety, operation, maintenance, and improved environmental quality of the roadway corridors.

Implementation of the Plan will include roadside environment consultation and review at the earliest stages of a project's development. During alignment selection, project scheduling, and design reviews, the elements important to the project's landscape region will be discussed and incorporated for best design development. The *Plan* integrates ecosystem information with highway design, safety, operation and maintenance needs, and presents that information for a broad internal and external audience.

The Plan presents a process to establish roadsides that can 1) better overcome the disturbances of construction; 2) withstand the rigors of the Nebraska climate; and 3) perform the landscaping objectives that contribute to safe and sustainable roadsides while complementing the surrounding landscape.

Background

A little over 5 years ago, our landscape program (which was located within the Design Division at that time) was put on hold and projects were to be reviewed again at the end of the 2005 program year. The Roadside Development Unit in Roadway Design Division was restructured in the next year, and staff and responsibilities were redefined and incorporated into two new units within the Environmental Section of the Planning and Project Development Division. For over 30 years we had been using native grasses and wildflowers to stabilize the roadsides and thought we were very environmentally oriented. We had not acknowledged our "eastern" style use of woody plant materials over the years in this mid and short grass prairie state.

A variety of influences were having a profound effect on our existing roadside plantings and pointing toward a discouraging landscape in the future if something wasn't done soon.

- Ice storms across the state in the last 10 years had devastated mature trees.
- Several pine diseases continue moving across the state destroying the Scotch and Austrian pine, the backbone of our past evergreen plantings.
- A 6 to7 year drought was broken last spring, having weakened many more plantings.
- New construction continues to force removal of mature plantings and no replacements were being planted.
- A new threat to a major deciduous tree group is the Emerald Ash Borer.

As the end of the temporary suspension of the landscaping program neared, our Environmental Section Manager, Cindy Veys, recognized it was time to re-evaluate the landscape program and put forward a concept and vision for the future of the Nebraska roadsides. We needed an appropriate “Nebraska” style that fit our prairie heritage.

The Nebraska Department of Roads (NDOR) *PLAN FOR THE ROADSIDE ENVIRONMENT* was completed and approved in June of 2008 thanks to the efforts of the *NDOR Landscape Plan Committee* and various reviewing agencies.

Introduction

Landscaping of the roadside involves many issues such as grading, drainage, soil stabilization techniques, grass and wildflower seeding, selection of perennials and woody plant materials, and guidance on mowing. How and where these elements are installed, coupled with the use of environmental mitigation within the right-of-way whenever possible, can result in a number of secondary benefits to the roadway corridor. A better understanding at the beginning of a project regarding the role landscape treatments play in improving the perception and operation of the roadway corridor, enables better decisions to be made throughout the development of a project.

This plan for the roadside landscape provides a framework to direct current and future development of sustainable highway corridors in Nebraska. The *Plan for the Roadside Environment* recognizes the need for safety, ease of maintenance and environmental stewardship. It draws on over 40 years of experience working with Nebraska roadside projects and presents an aesthetic based on our prairie heritage, offering a unique Nebraska Style.

Accomplishing this plan will combine our experience with new technologies and the knowledge and diverse skills of landscape architects, environmental scientists, civil engineers and many others working together.

Enhancing existing partnerships and developing new ones with other agencies, communities, organizations and interested parties of all kinds will help fulfill this plan. Ongoing partnerships with the Nebraska Game and Parks Commission, Nebraska Forest Service, University of Nebraska at Lincoln-Center for Grassland Studies, Nebraska State Department of Agriculture-Weed Advisory Committee, NRCS-Nebraska Plant Materials Committee, various Natural Resource Districts across Nebraska and others will broaden the benefits to the public. Through these partners we will be able to share knowledge and combine resources for mutual benefit.

Structure of the Plan

The manual compiles environmental and sociological information about Nebraska, providing a foundation for better understanding Nebraska landscapes and the highway corridors within their environment. *The Nebraska Natural Legacy Project,* a comprehensive wildlife conservation strategy published in August 2005 by the Nebraska Game and Parks Commission, has developed a comprehensive dataset of knowledge of species and habitat and identified critical threats to plants and animals, while developing actions that will lead to conservation of the biological diversity of Nebraska. This document formed the foundation for the NDOR plan.

The purpose of this agency manual is to guide development of roadside landscapes for Nebraska highways so they can better overcome the disturbances of construction, withstand the rigors of Nebraska’s climate and fulfill the landscape objectives that contribute to safe and maintainable roadsides that complement the surrounding environment.

The information in the Plan is directed at understanding the integration of environmental concerns, landscape objectives, mitigation requirements and the ability to maintain the roadway corridors. As the plan was being developed, NDOR involved resource agencies for their expertise. During this interagency involvement, it was realized that this documented approach to roadside development would also be of benefit to these agencies. The agencies can better understand and be a part of NDOR’s vision for an integrated landscape that maximizes benefits to both the environment and the traveling public.

The elements used to create the roadside landscape should substantially be those that are already included in each project, but they may be accomplished in new ways. When these elements also accomplish the landscape objectives of that roadway corridor, they increase the benefits of that investment and improve both the quality and value of our investment in that roadway corridor. Core elements to be used to accomplish desired landscape objectives include the following:

- Increased use of native plants appropriate to each landscape region of the state.
- Using seeding of native grasses, legumes and forbs in new ways as design elements to accomplish landscape objectives as well as provide soil stabilization for the roadway corridor.
- Using required environmental mitigation in a manner that will accomplish landscape objectives within the highway corridor.
- Using permanent erosion control and stormwater control constructions as design features to accomplish landscape objectives within the highway corridor, as appropriate.
- Development of additional ways to use plantings to reduce maintenance efforts and improve stewardship.
- Enhance existing partnerships and develop new partnerships with natural resource agencies and others to broaden benefits and to share knowledge and combine resources for mutual benefit.

The roadside landscape must also recognize the movement of plants and animals. These highway corridors provide a way for plants and animals to move between habitats that have been fragmented by agriculture, expanding communities and various other activities of man and nature. Understanding this need and using thoughtful design and appropriate long-term management of these corridors will allow for safer movement of all species whether for seasonal migration or changes over longer periods of time.

Plan Components

Landscape Regions Map

In order to keep each roadway corridor in context with its surroundings, six landscape regions are defined for Nebraska. This NDOR *Landscape Regions Map* takes into consideration the differences in climate, geology, hydrology, geography and native plant communities across the state, as well as our experience working in these areas.

The statewide highway system contains several functional classifications for roadways. For the purposes of this plan, we have organized the highways into corridor types based on the context of their location, usage and complexity. The corridor types are:

- Metropolitan Corridor
- Community Center Corridor
- Community Edge Corridor
- Rural Interstate/Expressway Corridor
- Scenic Corridor

Based on the characteristics of these corridors, landscape objectives have been assigned to each corridor type. The purpose of the landscape objectives is to improve:

- How the motorist perceives the roadway corridor.
- NDOR's ability to maintain each corridor type.
- Appearance and environmental quality of each corridor.

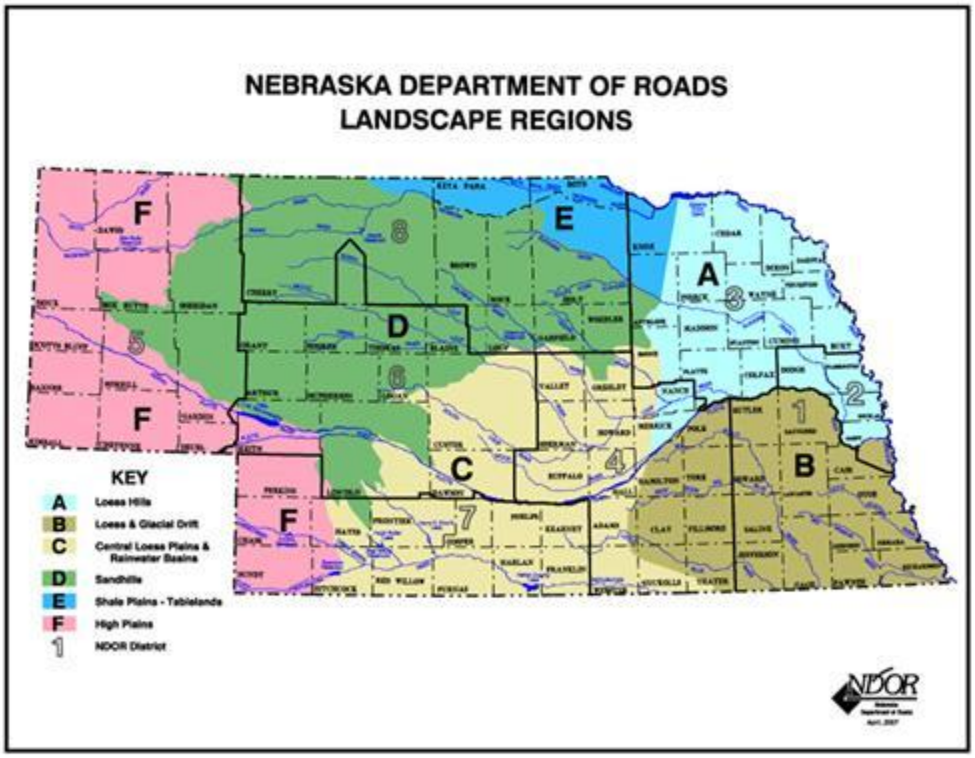

Figure1. The regional boundaries shown on this map are based on shared characteristics that describe the unique qualities of each region. Climate, soils, topography and vegetation all play a part as well as our experience planting across the state in the open conditions and highly disturbed soils of our highway right-of-way. Maps such as the USDA Plant Hardiness Zones, US EPA Eco-regions and the UNL Topographic Regions all provided an influence on this map. This map was developed to improve agency planning and design in context with the environmental resources of Nebraska.

Landscape Objectives

The designation of "landscape objectives" for each roadway corridor type defines specific ways that landscape architecture design techniques and plant material characteristics can be used to improve the safety, maintenance, visual interest and perception of the corridor.

There are seven landscape objectives described below that we determined should apply to all corridor classifications in addition to the other landscape objectives that are specific to a particular corridor type. The following objectives should be considered in the design of all roadway corridor classifications:

- <u>Stabilize the soil, prevent erosion, protect roadway structures</u> – This objective includes our erosion control measures and storm water pollution prevention methods; meeting the requirements of mitigating agencies, protecting our water resources and protecting the infrastructure of the roadway corridor.
- <u>Manage wildlife habitat and connect wildlife corridors</u>* - This is an issue of safety to both the motorist and the wildlife resources. It may include anything from avoiding disturbance to an area to regular maintenance procedures or specific mitigation procedures during construction. The Department should be aware of locations where wildlife movements cross through our transportation corridor on a regular or migratory basis and should accommodate this movement as much as possible.
- <u>Minimize maintenance, increase maintenance efficiency</u> – The use of appropriate plant materials and landscape techniques can reduce routine maintenance procedures such as the need to access steep slopes or hard to reach areas of the ROW. This can save time and effort.

- Integrate the roadway corridor into the surrounding regional landscape – This includes the use of regionally native plant materials on the ROW through the rural settings to keep the corridor in context with the adjacent property. Within communities, the green infrastructure established within the ROW should be considered in the same manner as other infrastructure elements and considered for replacement or upgraded when disturbed by construction.
- Display native vegetation and introduce the motorist to the regional landscape – Understand and express regional changes in the landscape within the ROW. This is both favorable to the tourist industry and increases all motorist awareness of their surroundings.
- Minimize effects on biotic communities – Limiting possible negative effects of construction and maintenance activities on the living features of the natural systems the roadway corridors traverse.
- Filter runoff pollutants – Protect surface and ground water through the use of a variety of landscape and civil engineering techniques and plant materials to treat runoff from the roadway within the ROW.

**May be limited in Urban and Community corridor types*

Additional objectives have been selected from the following list to be accomplished in individual corridor types where they are thought to provide the most benefit to the safe operation and maintenance of that corridor type.

- Storm water detention/ground water infiltration
- Screen headlight glare
- Control blowing snow – snow drift control
- Accent informational signage
- Screen distractions outside of the right-of-way
- Frame views (help reduce highway hypnosis)
- Provide point of interest/ identify community entry/ improve way-finding
- Provide an emergency hay bank for livestock
- Guide traffic – indicate change in direction
- Buffer vehicle noise from adjacent properties
- Screen undesirable views – to or from roadway corridor
- Separate pedestrian and/or bicycle traffic from vehicular traffic
- Preserve existing views
- Improve perception of roadway and traffic:
    - assist in estimating traffic speed/distance
    - traffic calming/reduce traffic speed
- Aesthetic enhancement

Statewide Landscape Corridor Classifications

Metropolitan Corridor

This corridor type is located within metropolitan areas and includes multilane divided roadways with full control of access and four or more traffic lanes designed to freeway standards and located within metropolitan areas. These corridors have closely spaced interchanges and ramps, occasional vehicular and/or pedestrian overpass/underpass structures, and possibly noise or retaining walls. Development adjacent to the right-of-way will range from dense buildings and streets to office and industrial development to residential back yards. This corridor is usually a primary commuter route with a high traffic volume. In contrast to the dense metropolitan area surrounding it, this corridor often provides a visual "open expanse." This corridor will connect to the Rural Interstate/Expressway Corridor.

Numerous signs, message boards, median barriers, guard rails, light poles and other elements compete for the driver's attention in addition to distractions outside of the right-of-way. Adjacent property owners and users often have concerns about views and noise along this corridor type. The overriding need here is to visually simplify and unify the corridor. Using color, pattern and texture on the repeated elements, such as the median barriers, sign structures and bridges can help unify the roadway corridor. Plant materials, earth forms, and screening devices can be used to simplify the views within the roadway and beyond and reduce distractions for the driver.

High traffic volume and heavy commuter traffic in this corridor type necessitate designs that include seasonal change to maintain the effectiveness of the plantings to the repeating users. Use of varieties of trees and shrubs that bloom in the spring or summer or have distinctive leaf color change in fall, will help keep these plantings fresh in the eyes of the daily commuter. For the same reasons, continuous good appearance with simple regular maintenance is necessary. There is also the need to create visual clues that help the driver at critical decision points and increase the motorist's awareness of their location. Opening up views to adjacent features or framing a view of a well-known building can do this. Developing a feature within the right-of-way can also serve this need.

The potential for heavy use of deicing chemicals and future regulation of water quality in this corridor type will require innovative design and careful plant selection for pollutant removal areas using techniques that are both effective and appropriate within these areas.

A good understanding of the long range zoning and land use plans is necessary, as well as close coordination with local governments and civic improvement groups.

Landscape Objectives

- Screen undesirable views – to or from the roadway corridor
- Screen distractions outside of the right-of-way
- Accent informational signage
- Improve perception of roadway and traffic
- Screen headlight glare
- Provide point of interest/ identify community entry/ improve way-finding
- Buffer noise
- Aesthetic enhancement

Community Center Corridor

This corridor consists of two lane or four lane roadways and some four lane divided roadways with no control of access. This corridor type runs through cities and villages of varying size. The corridor has very limited right-of-way which is often shared by many above and below grade utilities. Adjacent property is composed of a commercial/business core surrounded by established residential areas. The area is characterized by pedestrian traffic, numerous entrances to the roadway from driveways, streets and alleys, and vehicle parking movements. The community image is often derived from the visual character of this corridor. This corridor usually connects and blends into the Community Edge Corridor.
Pedestrian and parking activities, in conjunction with the utilities and multiple access points, necessitate reduced speed. Traffic calming is a primary need for this corridor type and results from various physical design features that influence the motorist's perception of the corridor. A four lane divided roadway, incorporating a raised median to protect pedestrians at a designated crosswalk, is one example of traffic calming. Introducing properly designed roundabouts or replacing large trees removed by construction can recreate a canopy and that feeling of enclosure which will both reduce speed and maintain or improve the community image. Using colors, textures and pedestrian scale lighting fixtures, in addition to typical street lighting, can also unify this corridor with the Community Edge Corridor.

Close coordination with local government is essential in this corridor type to meet local concerns and understand cost sharing and long-term maintenance responsibilities.

Landscape Objectives

- Improve perception of roadway and traffic
- Guide traffic – indicate change in direction
- Separate pedestrian and/or bike traffic from vehicular traffic
- Accent informational signage
- Aesthetic enhancement

Community Edge Corridor

This corridor type includes both two lane and multi-lane roadways. Four lane facilities may be divided in numerous ways. Access control is generally limited. The right-of-way is usually restricted and shared with utilities. Adjacent development ranges from big box developments, fast food chains, motels and vehicle dealerships to industrial uses and grain elevators. Volume of traffic and speed may vary with the community size. This corridor is a transition zone for the motorist to reduce or increase vehicle speed when entering or leaving a community. This corridor is the link between the Rural Highway Corridor and the Community Center Corridor and includes the community entrance.

The primary need within this corridor type is to identify the community entry, create qualities that help the motorist "automatically" reduce speed and heighten motorist awareness of vehicle turning movements and possibly pedestrian traffic. Developing unity through this corridor to the Community Center Corridor will improve both and help maintain the community image.

Close coordination with local government is also essential in this corridor type to help meet local concerns and desires and understand cost sharing and long-term maintenance responsibilities.

<u>Landscape Objectives</u>

- Improve perception of roadway and traffic
- Guide traffic – indicate change in direction
- Separate pedestrian/bike traffic from vehicular traffic
- Provide point of interest/identify community entry/improve way-finding
- Storm water detention/ground water infiltration
- Accent informational signage
- Aesthetic enhancement

Rural Interstate/Expressway Corridor

This corridor type includes four lane divided rural interstate highways and expressways, generally having turf medians and partial to fully controlled access. Interchanges and or intersections are widely spaced and right-of-way is usually uniform in width with minimal utilities. Travel time and distances are generally longer than those through the preceding corridors. Adjacent land is primarily in agricultural uses with scattered residences and farm-related structures. This corridor type may connect with the Metropolitan Corridor, the Rural Highway Corridor and sometimes the Community Edge Corridor. This is the primary long distance travel corridor type with a high percentage of heavy vehicles. It is also the primary tourist route through the state.

The needs in this corridor focus on safety related to longer driving time, consistent higher speeds and motorist awareness of their location. Providing features such as wetlands, which may be required for mitigation, creating masses of planting color or varying texture by earth mounding will help vary eye focal length and may help reduce monotony. These focal points can also serve as points of interest and display the regional qualities of the area to the motorist.

<u>Landscape Objectives</u>

- Control of blowing snow
- Frame views (help reduce highway hypnosis)
- Screen headlight glare
- Provide point of interest/identify community entry/improve way-finding
- Guide traffic – indicate change in direction
- Storm water detention/ground water infiltration
- Accent informational signage
- Screen undesirable views – to or from roadway corridor

Rural Highway Corridor

This corridor type includes two lane highways outside of corporate limits. The majority of the highways in the state will fall into this corridor type. These highways have some access control, limited right-of-way and long travel time and distances that are "interrupted" by segments of Community Edge and Community Center corridors through the communities they connect. Some tourists choose this corridor type as an alternative to the Interstate/Expressway Corridor because of slower speed, lower traffic volume, and closer contact with the communities.

There is a need in this corridor to prevent monotony from developing along the corridor. Display of the regional landscape is another goal. The limited amount of right-of-way will not accommodate the use of large trees to frame views and provide points of interest in many areas. Therefore, using grasses, wildflowers or shrubs creatively to provide mass, texture, and color as a way to frame views or as a point of interest will break up monotony and also reinforce the regional character. Plantings or other constructions can help form a backdrop to give the motorist an advance awareness of a "T" intersection or other change in direction of the roadway.

Landscape Objectives

- Control of blowing snow
- Frame views (help reduce highway hypnosis)
- Guide traffic – indicate change in direction
- Screen headlight glare
- Provide point of interest/identify community entry/improve way-finding

Scenic Corridor

This corridor type is most often associated with lower volume two lane highways in rural areas. These roadways are designated and signed as “scenic by-ways” by either state or federal agencies. The corridors display special scenic value that is representative of the landscape region being traversed. These corridors provide pleasant views to landscape and cultural features and are often favored by tourist. The longer travel time and distances are again “interrupted” by communities. This corridor type connects to the Community Edge or the Rural Highway corridor.

A major need in this corridor is to accentuate existing scenic qualities and minimize impacts to them.

Landscape Objectives

- Preserve existing views
- Frame views (help prevent highway hypnosis)
- Screen undesirable views – to or from the roadway corridor

Landscape Region Reports

Regional reports are the bulk of the manual and provide background for a basic awareness of the overall environment that the roadway corridors pass through in each region. The reports point out many sociological and environmental issues that influence the roadside environment.

Reports have been compiled for each of the six landscape regions. Each report begins with a map of that region. This map provides the regional boundaries and displays the counties, rivers, railroads, highways, trails, parks, communities, etc. and any special interest areas in that region. Following that map is a description of the region that contains information concerning a wide variety of environmental and social components of the region. Any hydrology, unique biotic communities, or environmental issues of particular concern to a specific landscape region are noted.

A second regional map was developed that displays the corridor classifications of the highway segments in each region and is also a part of each regional report. This map can be used to determine the highway corridor classification of any highway in the region and therein know the landscape objectives desirable in each corridor. Information on special characteristics of the regional roadway corridors is also discussed and recommendations provided, when appropriate, in each regional report.

Plant material lists are also provided for guidance on grasses, wildflowers and woody plants appropriate to each region. These guidelines are based on plants that are native to that region, our experience in the landscape region and research of other recognized sources.

EXAMPLE OF A REGIONAL REPORT

To follow is an example of a typical Landscape Region report showing the two maps and the basic environmental and sociological information provided and the corridor objectives for the region. The list of plant species has not been included in the example, but is available in the Plan.

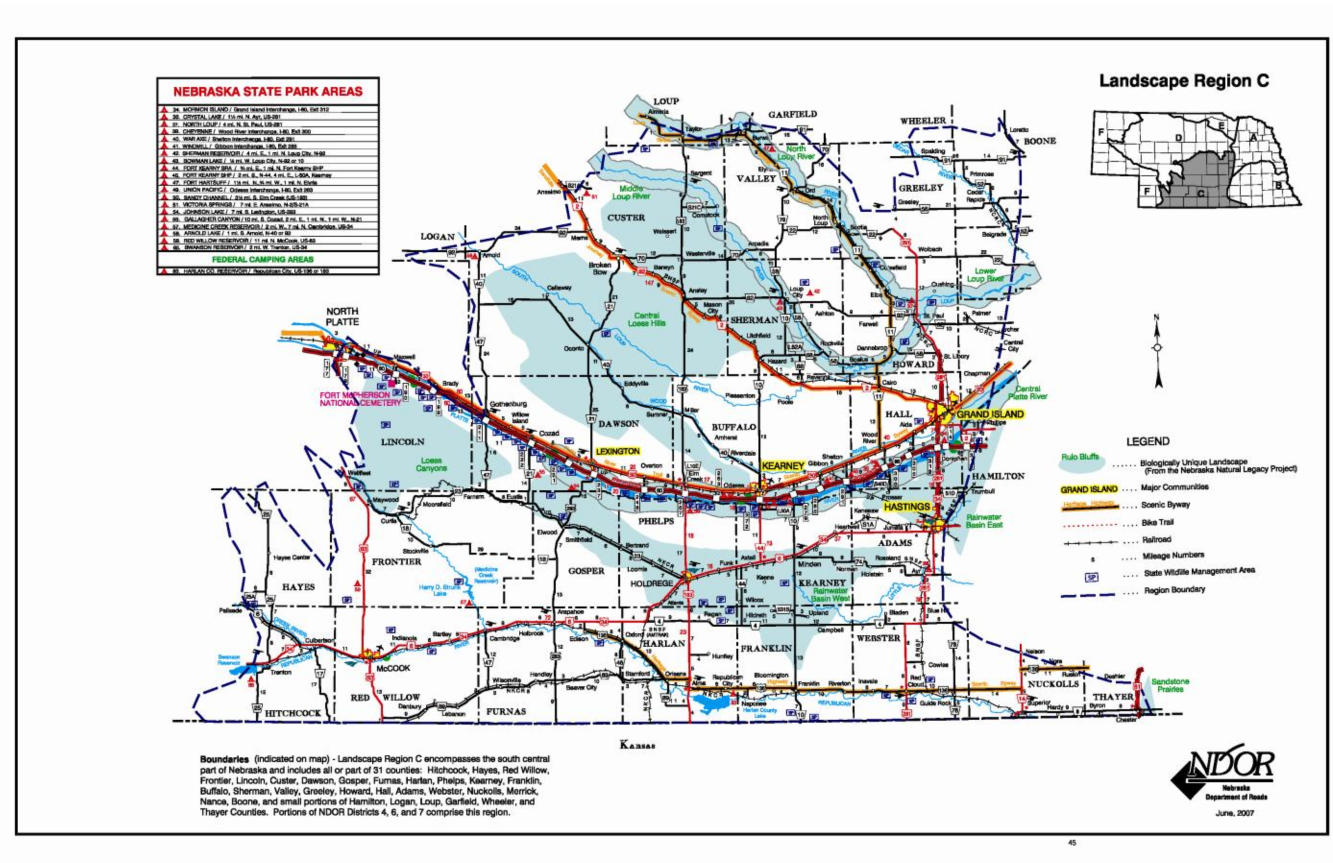

Figure 2. Map of Landscape Region "C".

DESCRIPTION – REGION "C"
ENVIRONMENTAL COMPONENTS

- **Climate**
  - Plant hardiness zone – This region is primarily within Zone 5 of the USDA Plant Material Hardiness Zone Map with a range of annual minimum temperature between -10 to -20 degrees Fahrenheit.
  - Annual rainfall – Considered semi-arid, precipitation ranges from 28 inches per year in the east portion of the region to less than 20 inches in the west.
- **Landform** – The topography consists of nearly level broad plains in the south central part of the Region, gently rolling hills in the north central part of the region, and steep slopes with deeply incised drainages in the southwest portion. The elevation gradually increases from east to west ranging from 1,650 feet to 3,000 feet above sea level. This region is bisected by the broad flat floodplain of the Platte River.
- **General soil types** – Region "C" is characterized by deep loess soils north and south of the Platte River. The loess mantle is deeper north of the river and calcareous with a higher pH than soils south of the river. Some of the state's most erodible soils form the slopes north of the river. The rainwater basin south of the river is poorly designed. The Platte River valley is a poorly drained mix of sand and silt.

- **Hydrology** - The Ogallala aquifer underlies a large portion of Landscape Region "C". Alluvial aquifers are present along rivers and streams. These aquifers are recharged during high flows and contribute water to streams and rivers during low hydro periods. Artificial groundwater mounds have developed near the surface alongside irrigation delivery channels and downstream of irrigation reservoirs.

    - Rivers and streams – The Platte River bisects Landscape Region "C", running from west to east. The Republican River is the primary river in the southern half of the region. A small portion of the Big and Little Blue Rivers occur in the southeast corner of this region.

      The South Loup, Middle Loup, and North Loup Rivers flow through the northern half of Landscape Region "C". They derive their flow from groundwater discharge out of the southern Sandhills which provide a significant source of summer flow for the Platte River where they meet. The Wood River is also in this part of the region.

    - Wetlands and Lakes – Rainwater basins south of the Platte River in this region and in Region "B" to the east are significant for waterfowl needs. Central Table Playa wetlands are found north of the Platte River, especially in Custer County. River floodplains provide extensive subirrigated wet meadows and other semi-permanent wetlands. Some Sandhills wetlands are found in the sandy areas close to the Platte and Loup Rivers and are formed where groundwater intersects the surface.

- **Plant Communities**

    - Herbaceous – This landscape region transitions from the tallgrass prairie on the east to the shortgrass prairie of the west. Prairie hilltops support drought tolerant short grasses such as blue grama and buffalograss, side slopes with species such as side-oats grama, little bluestem, western wheatgrass and sand dropseed. Lower slopes and valleys support tallgrass species such as big bluestem, Indiangrass, switchgrass and Canada wildrye. Hundreds of forbs can occur on good quality sites. Species such as prairie clover, Illinois bundle flower, deer vetch, lead plant, prairie coneflower, stiff sunflower and blazing star are notable examples of these forbs.

      Wet meadows include species such as woolly sedge, spike rush, and prairie cordgrass. Playa wetland contain river bulrush and flatsedge. Riparian wetlands may have an understory of plants such as switchgrass, scouring rush, and bedstraw.

    - Woody – Most tree and shrub areas are found along the watercourses as riparian forest. Cottonwood, green ash, hackberry, and red cedar are the primary trees with shrubs such as roughleaf dogwood, false indigo, and sandbar willow for understory. The eastern edge of the region still has some stands of native bur oak and black walnut. Planted woodlands and shelterbelt plantings are common in the more intensely farmed areas. Eastern red cedar is becoming invasive in some areas, especially prairie, pasture, and rangeland areas in the western part of this region. Control of seed-producing trees may be necessary in these areas.

- ○ Invasive plants – Bromegrass, Canada thistle, leafy spurge and red cedar are examples of invasive species steadily encroaching on prairie remnants, pastures and the roadsides. Phragmities, tamarix, and Reed's canarygrass are examples of the invasives threatening the stream and river courses, as well as wetlands.

- ○ Protected plants – The following plants are listed in this region as threatened or endangered by state and/or federal agencies:

  Western Prairie Fringed Orchid (*Platanthera praeclara*)

  Small White Lady's-Slipper Orchid (*Cypripedium candidum*)

- **Animals** – The following species are listed in this region, as threatened or endangered by state and/or federal agencies:

  River Otter (*Lutra canadensis*)
  Swift Fox (*Vulpes velox*)
  American Burying Beetle (*Nicrophorus americanus*)
  Bald Eagle (*Haliaeetus leucocephalus*)
  Interior Least Tern (*Sterna antillarum athalassos*)
  Whooping Crane (*Grus americana*)
  Piping Plover (*Charadrius melodus*)

- **Biologically Unique Landscapes and Habitats** (as defined in the Nebraska Natural Legacy Project) are areas of the state that have been identified as key habitats that offer the highest likelihood of persistence over the long term. These areas were selected based on known occurrences of ecological communities and at-risk species and offer the best opportunity for conserving the full array of biological diversity in Nebraska. Disturbance to these areas should be minimized. Habitat preservation in the landscape design is highly desirable. Opportunities to enhance and restore critical habitat should be considered in these areas.

  Listed here are the Biologically Unique Landscapes that occur in this landscape region:

  Central Loess Hills – occurs primarily in Custer County extending to Sherman and Dawson County; Central Platte River – includes the river channel and floodplain of the Platte River in the landscape region; Loess Canyons – occur in the southeast portion of Lincoln County; Lower Loup Rivers – the lower reaches of the Middle Loup River, North Loup River, and the Loup River in the northeast portion of Landscape Region "C"; Platte Confluence – the eastern portion of this area occurs in Lincoln County and includes the land between the North Platte and South Platte Rivers; Rainwater Basin-West – occurs in south central part of this region including primarily portions of Gosper, Phelps, Kearney, and Franklin Counties.

Sociological Components

- **Area history** – This mixed grass prairie of Landscape Region "C" transitions between tallgrass prairie to the east and short grass prairie to the west and Sandhills to the north. European settlement was sparse until the late 1860's with the population rising and falling through periods of adequate rainfall and drought. Center pivot irrigation from the 1970's increased the acreage in crop production, currently about two-thirds of the region, with the remainder in grassland.

- **Economic features** – Crop production is the primary economic activity along with other agricultural related segments. Crane viewing and the beginning development of various outdoor recreational opportunities is an emerging economic feature.

- **Land use/Ag type** – Two-thirds of the land in this region is in crop production with most of the remaining lands in grasslands for livestock. The trend is for fewer but larger farms. Federal lands in this region include: Ft. McPherson National Cemetery in Lincoln County.

- **Major communities** – Grand Island, Kearney, Hastings, Lexington, McCook, and Holdrege.

- **Transportation**

  Major highways – portions of US-6 and 34, I-80, N-2, US-83, US-183, US-281.
  Railroads – Nebraska Kansas Colorado Railnet, Burlington Northern Santa Fe Railway, Union Pacific.
  Scenic highways – Heritage Highway US-136 from Edison in Furnas County, east into Landscape Region "B"; Lincoln Highway, US-30 across the entire state. Sandhills Journey, N-2 from Grand Island to Alliance in Landscape Region "D"; and Loup Rivers Byway, N-11/N-91 from Wood River to Dunning in Region "D".

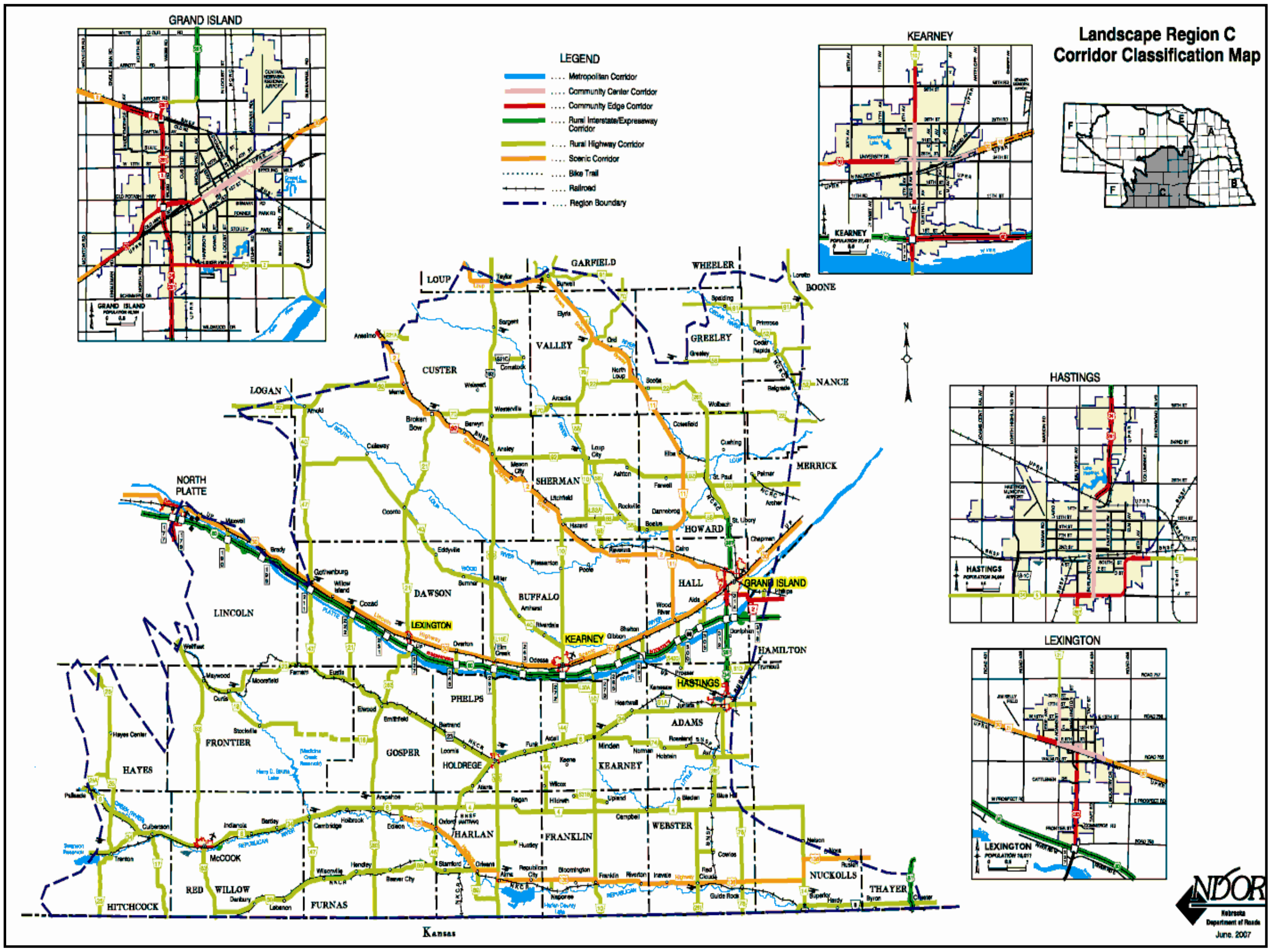

Figure 3. Corridor classification map for Landscape Region "C".

Corridor Objectives – Landscape Region "C"

Landscape Region "C" contains a large area of Biologically Unique Landscapes that will influence construction and landscape treatments in this corridor.

Metropolitan Corridor

This corridor type is not used in this region at this time.

Community Edge and Center Corridors

Landscape Region "C" presents a great diversity of communities for these corridor types. The potential for future regulation of water quality from stormwater runoff may be a concern. Traffic calming and maintaining community identity are primary corridor concerns.

Rural Interstate/Expressway Corridor

Within Landscape Region "C" this corridor type runs parallel to the Platte River through a portion of the river that is the primary staging area of the sandhills crane migration. The central Platte River is designated as critical habitat for the threatened and endangered species of whooping cranes and piping plover in this region. This corridor remains the primary long distance and higher travel speed route.

Rural Highway Corridor

Much of the area adjacent to this corridor is crop ground, range land or pasture. The biologically unique landscape described as the Rainwater Basin West (in the southern part of this region) contains scattered wetlands identified as waterfowl habitat important to the annual spring migration of ducks, geese and shorebirds and other species. A second biologically unique landscape described as the Central Loess Hills (in the north central part of this region) is mixed grass prairie with scattered playa wetlands that are used by the whooping cranes during migration. Highways going through these landscapes need to recognize these issues. This highway corridor is also important for wildlife as a passage between these areas and areas of heavier crop use as well as providing some habitat. Selected plantings may be used to improve safer movement for specific species and keep them away from the roadways. Techniques to help prevent monotony and control blowing snow are important in this region for this corridor type.

Scenic Corridor

Within Landscape Region "C" there are portions of 4 designated scenic highways. Each of these routes has a unique character to be maintained.

The overriding landscape objective in this corridor type is to preserve the existing views and scenic qualities that brought rise to the scenic designation. All work within these corridors should be in context with the adjacent surroundings.

Screening of objectionable views needs to be strongly considered in this corridor type, along with the framing of special views.

End of Example Report

Summary

The Plan was created for use by Nebraska Department of Roads' personnel in developing roadside landscape and mitigation designs. The *Plan for the Roadside Environment* provides the basic concepts and information needed to create a roadside that can better overcome disturbances of construction, withstand the rigors of the Nebraska climate and perform the landscaping objectives that contribute to safe and sustainable roadsides that are maintainable and in context with their surroundings. It provides a common base of information for administrators, planners, designers, construction managers and maintenance supervisors. This information is directed at understanding the integration of environmental concerns, landscape objectives and maintenance requirements. The environmental issues that require mitigation should have that mitigation incorporated into the roadway corridors whenever possible and done in ways that can also accomplish the landscape objectives for that corridor type.

Implementation of the Plan requires roadside environment consultation at the earliest stages of a project's development, when feasibility is being considered through Engineering Review or Location Study. It is intended that the elements identified in the Plan will provide a foundation upon which NEPA analysis will draw, and preliminary through final design activities will be guided, in their various stages of development. During routing, scheduling, and project design reviews, the elements important to the project's landscape region and corridor type will be discussed and incorporated for best design development. The Plan will provide a common base of information to be used in training construction and maintenance supervisors concerning landscape and context sensitive issues.

To fully realize the scope of this plan, additional guidance manuals can be developed. Using information provided in the plan, improved vegetative management plans, designed for each roadway corridor type and adjusted as necessary for each landscape region, can continue to improve on noxious weed control and promote efficiency and reduced costs through expanded native plant usage. New landscape design guidelines should be developed that provide ways to solve local environmental concerns in a creative manner that also fulfill landscape objectives in the plan. These guidelines will be coordinated with the regulatory agencies and developed with input from departmental design and maintenance personnel in an ongoing effort to provide a unique "Nebraska Landscape" for our highway roadsides, resulting in a transportation system that makes the manmade and natural environments compatible and sustainable.

The complete text of the "Plan for the Roadside Environment" is available at the following website: www.nebraskatransportation.org/environment/roadside-plan.html.

Biographical Sketches

Arthur R. Thompson, R.L.A. is the Highway Landscape Architect for the Nebraska Department of Roads. He has almost 40 years of experience working with Nebraska roadsides and safety rest area design and development. He received a Bachelor of Architecture degree from the University of Nebraska and is a Registered Professional Landscape Architect in Nebraska. Currently a member and past president of the Great Plains Chapter ASLA; past member of the Transportation Research Board (TRB) Landscape and Environmental Design Committee TRB A2A05(currently AFB 40); past member and chair of the Nebraska State Board of Landscape Architects and past member and chair of the City of Lincoln, Historic Preservation Commission.

Alison Krohn, R.L.A. is an Environmental Compliance Project Manager with the Nebraska Department of Roads in the southeastern part of the state. The majority of her career was spent with USDA Natural Resources Conservation Service (NRCS) in various locations in the eastern US focusing initially on rural design projects and then environmental design as a member of the southeastern engineering team for NRCS. She also taught Landscape Architecture at North Dakota State University where she was an Assistant Professor from 1999 to 2003. Alison has a BA in Philosophy from Rockford College and a Master's Degree in Landscape Architecture from the University of Illinois. She is a Registered Landscape Architect in Nebraska and Kansas.

Ronald Poe, R.L.A. is a Highway Environmental Program Manager with the Nebraska Department of Roads (NDOR) in Lincoln, Nebraska. He received a Bachelor of Landscape Architecture from Iowa State University in May 1993. He is a Registered Landscape Architect in the state of Nebraska and is also a Certified Professional of Erosion and Sediment Control (CPESC). Ronald has been involved in erosion and sediment control design with NDOR since he was hired in October 1998. His responsibilities at NDOR include overseeing a unit of people dedicated to roadside stabilization, erosion and sediment control design on construction and maintenance projects, as well as managing NDOR's Construction Stormwater and MS4 Permit responsibilities.

Carol E. Wienhold is a Highway Environmental Biologist with the Nebraska Department of Roads (NDOR), Lincoln, Nebraska. She has worked in re-vegetation of reclaimed coal mines (North Dakota), wetlands (mid-Atlantic and midwestern United States), and disturbed roadsides (Nebraska). She earned a B.S. in Biological Sciences from North Dakota State University and a M.S. in Botany (Plant Ecology) from Iowa State University. The best part of her job at NDOR is participating in NDOR-sponsored research projects.

Cindy Veys is the Manager of the Environmental Section for the Nebraska Department of Roads at their headquarters in Lincoln, Nebraska. She has a Master of Arts degree in Environmental and Water Resources Management from the University of Nebraska. She has more than 30 years experience in the fields of environmental and water resources planning and management, utilities construction, hazardous waste remediation, development of National Environmental Policy Act (NEPA) documents and environmental permits for infrastructure projects. The Environmental Section includes an Environmental Documents Unit, Environmental Permits Unit, Roadside Stabilization Unit and Environmental Design Unit.

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SIMILAR IMPACTS, SIMILAR SOLUTIONS? THE EFFECTS OF TRANSPORT INFRASTRUCTURE ON OUTDOOR RECREATION AND WILDLIFE

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Abstract

There is a striking similarity in how ecological and recreational landscape values are affected by transport infrastructure. Roads and railways form barriers to both wildlife and human movements across the infrastructure corridors. Further, they occupy an increasing area of land, they affect health and decrease the quality of life due to pollution and disturbances, and they cause injuries or death in traffic accidents. Despite these similarities, impacts on wildlife and humans are rarely addressed with an integrated approach in the current infrastructure planning practice. Ecological and social sciences use different methods and standards for environmental impact assessment and employ different preventive and mitigation measures. Here, we illustrate the resemblance between recreational and ecological responses to infrastructure, and the options for joint mitigation, with three examples: i) the similar response to traffic noise in breeding birds and in people during outdoor recreation, ii) the similarity in movement patterns of wildlife and people in the vicinity of roads, and its implication on barrier effects and landscape fragmentation, and iii) the combined use of passages such as viaducts and ecoducts. Our overview highlights the common interests between social and ecological nature conservation. We stress that coordinated treatment of social and ecological effects may reveal common performance targets, facilitate the development of practical guidelines, and improve the design of mitigation measures. Our overview may strengthen the political support for integrating recreational and ecological landscape values in infrastructure planning.

Introduction

A current worldwide trend is that roads and railways are upgraded and new transport corridors established, resulting in an increasingly dense infrastructure network. Transport infrastructure provides fast and efficient transport of people and goods, and may promote economic development and human life quality. However, simultaneously transport infrastructure may have significant negative impacts on the ecological, cultural, social and recreational values of the surrounding landscape. The ecological effects include habitat loss, habitat degradation due to pollution and disturbances, movement barriers, fragmentation of natural habitats, and an increased mortality due to animal--vehicle collisions (Forman et al. 2003, Seiler 2003). From a human perspective, land uptake by roads and railways excludes other land use forms and may impede human movements across to the infrastructure corridor. For people dwelling in the immediate vicinity of roads and railways, the traffic may also affect health and decrease the life quality due to pollution and disturbances, and cause human injuries or fatalities (Bies 2003, Panadya 2003).

Procedures have been developed to assess such impacts on humans and wildlife, prior to infrastructure construction, in order to minimize the expected negative effects of the infrastructure and traffic or mitigate these effects to an acceptable level. But despite the obvious similarity between the effects on humans and on wildlife, these two aspects are usually not addressed with an integrated approach in current environmental impact assessment. The ecological and social sciences use different methods and standards to assess infrastructure impacts and, furthermore, usually employ different preventive and mitigation measures.

The aim of this paper is to illustrate the resemblance in impacts of transport infrastructure on outdoor recreation and wildlife, and the potentials to address these impacts simultaneously in transport infrastructure planning and management. We give three examples relating to disturbance and barrier effects, and on barrier mitigation. We discuss how parallels between ecological and recreational responses can form a basis for a better consideration of landscape values in environmental impact assessment, for developing common performance targets and practical guidelines for transport infrastructure planning, and for improving the design of mitigation measures.

Traffic-Noise Disturbance

With the ongoing urbanization and the rise in motorization, areas free from man-made noise have become rare in many industrialized countries, and tranquility is increasingly perceived as a valuable resource (Shaw 1996, Health Council of the Netherlands 2006, National Board of Housing Building and Planning 2007). Technical noise causes an array of physiological and psychological effects in humans, such as raised stress levels, disturbed conversation and sleep, and increased ill-health (WHO 2000). Outdoor environments provide important opportunities for human physical exercise and psychological restoration (Grahn and Stigsdotter 2003, Ottosson 2007, National Board of Housing Building and Planning 2007), but technical noise has a negative impact on the value of outdoor recreation (Nilsson and Berglund 2006). Environments free from technical noise are also important for wildlife. Many species use acoustic signals to attract females, to defend territories and to warn from predators (Brumm and Slabbekoorn 2005, Warren et al. 2006). Noise may cause increased physiological and energetic stress and altered behavior in wild animals, leading to reduced reproductive success and increased mortality risk (Fletcher and Busnel 1978, Rabin et al. 2003, Patricelli and Blickley 2006).

Hence, in both humans and animals, traffic noise affects basic physiological and psychological functions, behavior, communication, and health, and accordingly the life quality in noise disturbed areas is lower. Interestingly, some of the most comprehensive studies on the effects of noise on outdoor recreation and wild bird fauna show strikingly similar dose--response relationships. Visitors in Swedish urban-suburban green areas perceived an environment free from technical noise as more pleasant (Nilsson and Berglund 2006, Nilsson 2007). According to the functions fitted to the data, the maximum noise level corresponding to a good “soundscape” quality (defined by the authors as 80 % of visitors perceiving the soundscape as good or very good) was roughly 48-49 dB LA_{eq} (Fig. 1a). At levels above 55 dB LA_{eq}, less than half of the visitors perceived the soundscape quality as good.

Studies on birds in various habitats in the Netherlands have produced similar results (Reijnen and Foppen 1995, Reijnen et al. 1996). The density of breeding birds increased with distance from noisy roads, and if adopting 80 % bird density compared to the undisturbed surroundings as the criterion for good habitat quality (inspired by the studies on outdoor recreation cited above), the maximum noise level for a good habitat quality was roughly 48-49 dB LA_{eq} (Fig. 1b). At levels above 55 dB LA_{eq}, the bird density was less than half of that in undisturbed habitats.

The generality of the functions and levels presented here can clearly be discussed, and the inference may be sensitive to e.g. the quality indicator or noise level measure chosen. Further research efforts are needed to confirm the similarity in dose--response functions. Still, the studies taken together reveal a promising prospect for a coordinated treatment of noise disturbance on wildlife and outdoor recreation in environmental assessment and mitigation. For example, common tolerance limits for noise propagation in natural environments – relating back to environmental quality objectives, and expressed in dB LA_{eq} – could be suggested on the basis of impact on both wildlife and humans. It appears particularly reasonable to implement noise reduction measures in natural environments of special importance for birds and outdoor recreation, such as nature reserves, lakes and shores, urban--suburban green areas and special bird protection areas.

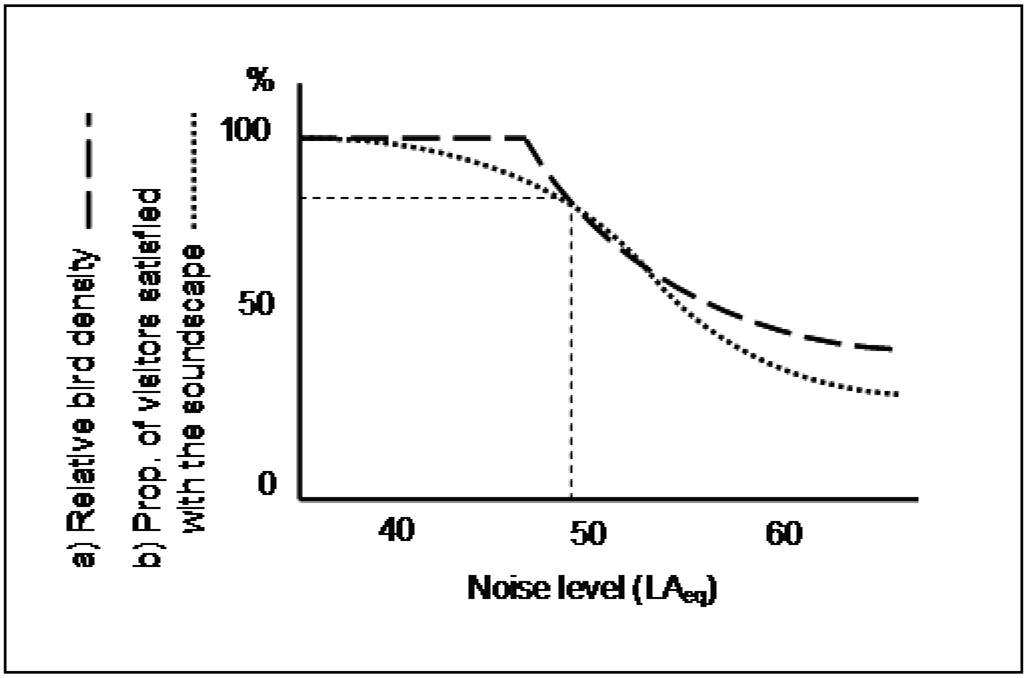

Figure 1. Generalized effects of noise on wild bird fauna and outdoor recreation; a) relative frequency of breeding birds in Dutch grasslands, adopted from Reijnen et al. (1996), and b) proportion of visitors in Swedish urban-suburban green areas perceiving the soundscape as good or very good, adopted from Nilsson (2007). The 80 % "acceptance level"discussed in the text is indicated.

Movement Patterns and Barrier Effects

Infrastructure barriers disrupt movements of terrestrial, and in some also flying, animals. There is ample evidence of barrier effects of large infrastructure in a wide range of species, from beetles to large mammals (Seiler 2003). Highways and railways also impede local human movements across the infrastructure corridor. This is assumed to be a particular problem for outdoor recreation (Swedish Road Administration 2005, Ståhle 2008). Most infrastructure barriers do not completely block movements of wildlife and humans, but reduce the number of crossings, thereby restricting the access to potentially important resources, habitats or restorative environments distributed in the landscape (Hörnsten and Fredman 2000, Seiler 2003). The network of roads and railways splits the landscape in fragments. With the increasing landscape fragmentation, a critical threshold may be reached. The remaining fragments may become too small to allow viable wildlife populations, or to give an impression of an undisturbed, natural landscape. For species with large area requirements, and for people during outdoor recreation, even individual activity ranges may be restricted.

In this respect, some aspects of spatial use of wild mammals and outdoor recreation show noticeable resemblance, illustrated by the following studies. Activity ranges of day visitors on foot in the New Forest National Park in southern England were recorded with GPS (R. Pouwels, unpublished data). Although some of the individuals in the study travelled far, a majority (>60 %) of visitors in the area stayed within 400-1200 m from the starting point (Fig. 2). Most people stayed at one side of a major road during the recorded activity round, which made the road an effective barrier to this type of recreational movements. A small number of individuals (7.5 % of visitors) did pass the major road, at certain points, primarily road intersections. Daily activity ranges of two species of wild deer (fallow deer *Dama dama* and roe deer *Capreolus capreolus*) were recorded during intensive GPS-tracking in Koberg on the southwestern Swedish countryside (P. Kjellander, unpublished data). For most (>80 %) of the studied animals, the activity spanned 400-1200 m (distance between two most separate points, Fig. 2), but animals occasionally conducted long distance movements. A major, fenced road intersecting the study area constituted a barrier to daily movements. The few individuals that occasionally passed the road (9.5 % of the tracked population) did so primarily at road intersections.

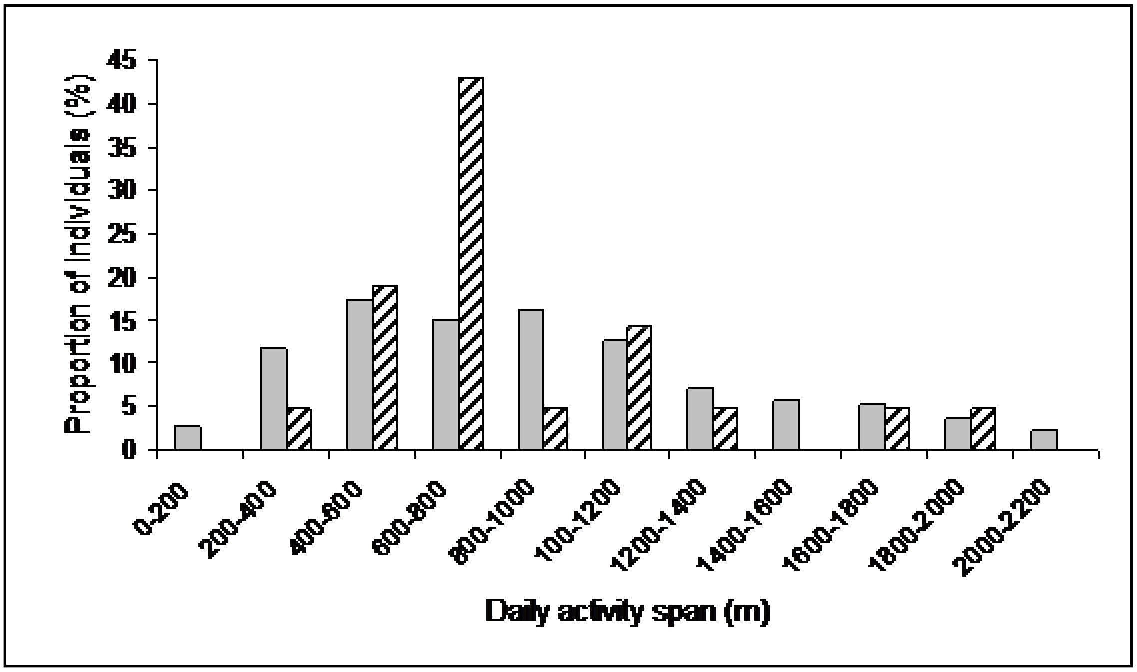

Figure 2. Daily activity span (distance between two most separate points) for outdoor recreation in New Forest, UK (grey bars, sample size=1717) and roe/fallow deer in Koberg, Sweden (striped bars, sample size=21). Data from R. Pouwels (unpublished data) and P. Kjellander (unpublished data), respectively.

Indeed, activity range, area requirements, and barrier effects differ among wildlife species, as well as among people involved in different outdoor activities. Spatial use for both animals and outdoor recreation may also differ between countries and biogeographic regions. Further research may outline the significance and limits of the parallel described here. However, available data indicate that common standards could be found for assessing, preventing and mitigating barrier effects on wildlife and outdoor recreation. More specifically, common limit values could be established for the permeability of barriers, and for the minimum size of landscape fragments that still allow free daily movements for most individuals. Also, common standards could be set for the frequency and location of specially designed passages.

Combined Use of Passages

Bridges and underpasses built to allow local traffic to pass major infrastructure corridors may also be used by wildlife, particularly so if the traffic intensity at the passage is low (Rodríguez et al. 1996, Olsson 2007). Underpasses for traffic may be used even by large mammals such as deer, as long as the dimensions suffice (not too long, not too narrow). Conversely, ecoducts and other passages specially designed for wildlife may be used by hikers, bikers and horse riders (Olsson 2007).

These observations outline prospects for constructing underpasses and bridges that combine the functions for local traffic, outdoor recreation, and wildlife. Under- and overpasses modified for multiple functions are accordingly advocated to minimize the barrier effects and habitat fragmentation caused by transportation infrastructure (Keller et al. 2003). Modifications for multiple functions may include limiting the number of vehicles on the local road, screening the heavy traffic on the highway or railway, providing vegetation and other natural structures and substrates in and around the passage, and carefully selecting site on the basis of surrounding landscape. Some of these modifications can be conducted on existing under- and overpasses, to increase landscape connectivity. At new infrastructure construction, building passages for multiple functions should be a cost-efficient way to limit the impact of the new barrier in the landscape.

An important question in this respect is to what extent combined use of a passages affects the functionality of the measure for wildlife. Research indicate that frequent human use of crossing structures may limit their usefulness for wildlife (Georgii et al. 2007, Olsson 2007, but see Ng et al. 2004, Clevenger and Waltho 2005). Adapting passages to combined use may therefore not always be cost-efficient. Further research is needed to establish under what circumstances a combined use should be aimed at, and to identify factors in design or management that may reduce possible disturbance.

Discussion

We give some examples showing how wildlife (mammals and birds) and people, when in natural environments, tend to experience the landscape at the same geographic scale, with similar senses, and with similar physiologic and behavioral responses. The examples describe concrete common interests between social and ecological nature conservation.

There are also studies linking biodiversity, wilderness and tranquility to the social values of nature on a more theoretical level. In inquiries in Sweden, respondents stated the importance of nature protection, and the conservation of local biodiversity and suburban green areas was given fairly high priority in relation to other societal issues (Lindström et al. 2006). When asked for preferred landscape qualities, a majority (>80%) of respondents in another Swedish survey gave the highest ranks to natural, diverse environments free from noise disturbance, and to road-less areas giving an impression of wilderness (National Board of Housing Building and Planning 2007). Such areas were linked to opportunities to relax and recover from stress, and to opportunities for physical exercise (National Board of Housing Building and Planning 2007). Several studies have shown that people increase their well-being when experiencing a high biological diversity and wild animals in their natural environment (Kaplan and Kaplan 1989, Hartig and Staats 2006, Lindström et al. 2006, National Board of Housing Building and Planning 2007).

The similarity between effects on wildlife and outdoor recreation appears clear: what is bad for one is also bad for the other, and mitigation measures may have dual functions. Obviously, the resemblance has its limits. For example, intense outdoor recreation in an area may in itself have negative effects on wildlife due to disturbance (Liddle 1997). Human disturbance in passages may limit their usefulness for wildlife (Olsson 2007). Disturbance from road and rail traffic may direct recreation away from the infrastructure, and so lead to an increased disturbance zone for wildlife. On the other hand, in regions with high human pressure on scattered natural environments, areas abandoned by people due to disturbance or inaccessibility along highways and railways may function as refuge for wildlife. Not least, infrastructure itself facilitates for people to reach distant nature. Hence, roads and railways may have a complex effect on outdoor recreation.

The results still have important implications for infrastructure planning and management. There is a broad literature describing that natural and landscape values are not well integrated in environmental impact assessment (e.g. Nilsson and Sjölund 2003, de Jong et al. 2004, Antonson 2009). Lack of clear performance targets, efficient tools and effective guidelines has been pointed out as obstacles for integration (Nilsson and Sjölund 2003). We suggest that a door can be opened for a better consideration of landscape values in environmental impact assessment by acknowledging the parallel between ecological and recreational responses to infrastructure and traffic. In practice, this may be in the form of a coordinated analysis of the impact of transport infrastructure on outdoor recreation and wildlife biodiversity, using similar assessment tools and even merging in the same geographical models. Such a coordinated analysis may reveal that common performance targets for the landscape impact of roads and railways can be adopted. It may consequently facilitate the development of practical guidelines, such as limit values for fragmentation or noise propagation as described above. By considering the dual function of mitigation measures – for both outdoor recreation and wildlife – their design can be optimized, and cost-efficiency calculations for mitigation be made more realistic.

Finally, our overview may strengthen the political support for a better integration of recreational and ecological landscape values in infrastructure planning. Respect to public health, nature conservation and environmental quality are key components in a sustainable transportation system (OECD 2002), and therefore major issues for policy and decision makers. The integrated consideration of these key components shows one of the ways towards a sustainable transportation system. In order to reach there, further research is needed to establish dose–response relationships for disturbance and barrier effects on ecological and recreational landscape values, and if possible to find functional thresholds in these relationships. Studies on the landscape scale and jointly addressing wildlife and outdoor recreation appears particularly appealing. Future efforts should also be directed into developing practical tools, for example geographically explicit models, and mitigation such as design of combined passages and noise reduction measures for natural environments.

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Ecological Considerations for Planning and Designing Bridges

Road Infrastructure and Stream Habitat Connectivity: Research to Aid Management and Conservation Plans in a Changing Environment

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Abstract

Poorly-designed road-stream crossings can put both ecosystems and transportation infrastructure at risk. In response to these threats, an interdisciplinary team, using the Connecticut River basin in the northeastern US as a focus area, but extending throughout the northeast and north-central US, is currently investigating two major research questions: 1) What are the demographic and genetic consequences of road-associated fragmentation for stream fish populations, and can genetic surveys and population models be used to assess fragmentation and connectivity? 2) Are crossings that are likely to be barriers to fish passage have a higher probability of structural failure under current and predicted future climate conditions? Our results to date indicate that fragmentation associated with barriers can strongly influence both local and watershed-scale probabilities of extinction for wild brook trout populations, and have potential impacts on the value of recreational fisheries via changes in population size structure. In addition preliminary results indicate that undersized culverts are more likely to be barriers to passage. The results of our current and future work will be used to inform conservation planning and culvert replacement strategies on both federal and non-federal lands, and to assess the success of these efforts in restoring population connectivity and contribute to sustainability of key species and ecosystem services.

Introduction

The ability of aquatic organisms to move upstream and downstream through river systems is critical for their survival. For example, many species of fish take advantage of rich food resources in lowland rivers and lakes during the growth phase of their life cycle, but use small streams, which hold fewer risks for young, vulnerable juveniles, to spawn and rear during early life (Fausch et al. 2002). The ability to move and disperse also allows the 'rescue', via rapid colonization of local populations that have been extirpated or depleted by disturbances such as floods, droughts, and pollutants (Lonzarich et al. 1998, Roghair and Dolloff 2005). These effects are going to be particularly important in the context of climate change, as the ability to find appropriate river flows and temperatures may be critical for species persistence. Unfortunately, human infrastructure in the form of poorly-designed road crossings has placed thousands of barriers to these movements throughout river basins, particularly in the heavily settled and roaded northeastern US ecoregion. Only a subset of these can be strategically removed or replaced to benefit stream fish populations and aquatic ecosystems. Substantial amounts of time and money have been spent identifying, prioritizing, and replacing road-crossing structures that are barriers to fish and other aquatic organisms. Given the scope of the problem and the resources involved, it is incumbent upon research organizations to provide scientific support to fill knowledge gaps and provide appropriate and effective technology.

Federal agencies such as the USDA Forest Service and major conservation organizations such as The Nature Conservancy are increasingly focused on the conservation and management of large, integrated landscapes. An important justification for this approach is the recognized value of connectivity between landscape elements for the maintenance of robust species populations, diverse natural communities, and ecosystems that are productive and provide critical goods and services. In addition, for many organizations, there has been a drive to integrate key aspects of the built and natural environments. In this context the issue of road infrastructure and aquatic ecosystems has received considerable attention and effort. A threat assessment of the Connecticut River Basin, the largest river system in New England and the focus of an integrated landscape conservation effort of The Nature Conservancy identified small-scale barriers to fish passage, including road crossings, as one of the two major threats to the ecological integrity of the basin. They and their partners are currently involved in a major research and conservation effort in this integrated landscape aimed at understanding the effects of barriers to connectivity, prioritizing barriers for removal, and monitoring their effects of removals and populations and ecosystems.

The Forest Service, a partner to the Connecticut River Program, has a long-standing interest in the issue of roads and aquatic ecosystems. Road systems on national forests were frequently developed with little concern for aquatic ecosystems and resources. Poorly-designed forest roads and road crossings have long been recognized as a threat to aquatic ecosystems and fisheries resources on National Forest lands (Jones et al. 2000). With respect to barriers, both research and technology transfer have contributed to our understanding of the issue. Early emphasis on access to spawning streams for anadromous salmonids led to the development of software models which predict passage for these species groups (FishXing 1999, Clarkin et al. 2003). Since then, research has demonstrated the importance of within-river system movements for resident and river-migratory fish (Rieman and Dunham 2000) for population viability. At the same time, Warren and Pardew (1998) demonstrated that road crossings were potential barriers for diverse southeastern warm-water fishes, many of which are endangered, and suggested that road-crossings might be a particular problem for small, weakly-swimming, benthic fishes. In response to this research, the National Aquatic Ecology Laboratory of the National Forest System developed and tested (using experiments with marked fish) a coarse filter approach to classify culverts as passable or impassable to three distinct 'movement guilds' of fishes (Coffman 2005). This method is currently being widely applied on National Forest lands throughout the eastern US. While a large effort has been focused on these federally-owned lands, the Agency has become increasingly aware that it must work with partners as the boundaries of most river systems extends beyond National Forest boundaries, particularly in the eastern US where federal holdings are limited.

The issue of road crossings and aquatic ecosystems presents a range of key issues and continuing challenges for research (Fig. 1). In terms of ecological goals our implicit assumption is that improving crossings will increase aquatic passage and ecosystem connectivity, which will in turn increase population abundance, improve age and size structure, decrease likelihood of local extirpation, and increase species diversity. However, because movements may be episodic, passage may remain undetected, or detected movements may be insufficient to fully connect subpopulations, with major implications for monitoring effectiveness. Even when passage is achieved, predicting effects on populations requires data that are generally unavailable. Restoring passage and connectivity may have also have community and ecosystem effects that go beyond population viability and species diversity. Finally, in terms of overall costs and benefits, we have few data on the relationship between probability of fish passage and probability of crossing failure and threats to road infrastructure. In this paper we discuss several lines of research designed to fill these knowledge gaps and contribute to management and conservation.

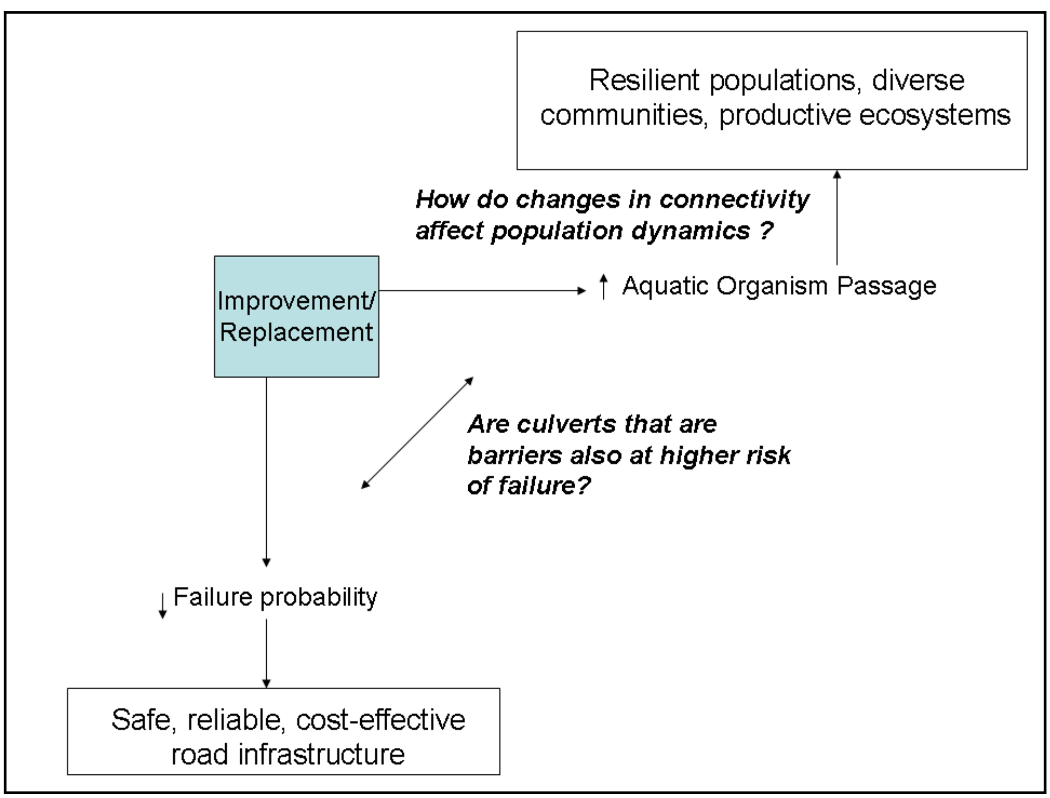

Figure 1. Conceptual framework for research in support of river connectivity in the Connecticut River basin

Discussion

Connectivity, Demography and Population Structure

Major advances in marking and fish detection technologies have greatly increased our ability to document aquatic organism passage. However, the large number of proposed and ongoing road-crossing improvement projects poses a challenge in terms of logistics and expense. This challenge underscores the need to continue to develop cost-effective and reliable assessments of aquatic organism passage. At the same time, the considerable investment of time and money involved in improving road crossings and monitoring effects on passage make it critically important that we understand the consequence of these changes in passage rates on larger management and conservation goals (Fig. 1).

Population connectivity can be defined as genetic exchange between individuals. Genetic exchange is both an indicator of connectivity and a determinant of population viability, as loss of genetic diversity in small populations can increase vulnerability in a number of different ways (Frankham 2005). In theory, given advances in the use of microsatellite DNA to detect spatial population structure, and the continuing decrease in the cost of this technology (King et al. 2005), it should be possible to use genetic methods to determine whether culverts at road crossings are barriers, and whether culvert replacement has reconnected populations (Knaepkens et al. 2004). However, the use of traditional genetic distance measures and measures of heterozygosity present challenges. Many stream fish populations are likely to exhibit substantial spatial population structure (differences in allelic diversity and high levels of genetic dissimilarity) even in the absence of barriers. Also, these standard measures of genetic population structure don't deal effectively with unidirectional barriers to movement, which is characteristic of many culvert barriers.

Perhaps most importantly, exchange of individuals important from a demographic as well as a genetic perspective. In fish populations that function as metapopulations (Hanski 1998) the flow of individuals between subpopulations is critical for preventing local extinction and maintaining positive population growth rate. The critical question is how do flow rates of individuals sufficient to connect populations and prevent loss of allelic diversity compare to rates necessary for demographic rescue?

We are currently using conducting a long term study of brook trout movement and demography in West Brook, western MA, USA with the goal of understanding the effects of connectivity and isolation and population dynamics. The system consists of a 3rd order mainstem and tributaries with different levels of connection and movement rates to the mainstem. By individually marking and frequently sampling essentially all the individuals in the population (~ 4000 individuals), and continually monitoring movements between tributaries and mainstem habitats using stationary antennae, we derive robust estimates of survival, growth, and movement parameters for a stage-based population projection model (Caswell 2001). We then impose simulated changes in connectivity between tributary and mainstem to ask the questions: What does connectivity between tributary and mainstem mean for population viability and demographic characteristics? What are the consequences of isolation?

Our results suggest that restricting the ability of fish to access tributaries can cause local extirpation in the tributaries, and under some scenarios, can cause extinction of the entire metapopulation (Letcher et al. 2007). Further, in situations where isolated subpopulations persist, we observed major changes in age and size-structure of the population, with selection against large fish. We are currently scaling this model up to assess the consequences of connectivity at the subwatershed scales throughout the Connecticut River basin, with the ultimate goal of providing a prioritization tool allowing managers to target barriers with the greatest likely impact on population dynamics.

Combining Ecological and Infrastructure Risk

The primary function of road crossings is to protect roads during high flow events. Underdesigned culverts (too small for their drainage area) put road infrastructure at risk. If a given road crossing is underdesigned for flow, it may also be more likely to be a barrier to aquatic organism passage. Culverts that are too narrow are less likely to have and maintain natural substrate, an important determinant of passage in small streams and a key element of stream simulation. Perhaps most importantly overly-narrow culverts can cause scour at the culvert outlet, creating a jump barrier for fishes moving upstream. Establishing the general relationship between risk of failure and barrier risk can be used to inform culvert removal/replacement prioritization strategies. However, while this relationship makes sense on the basis of first principles, culverts can be barriers to fish for a wide range of reasons, and there are few data that have addressed this issue.

To explicitly assess the relationship between the risk of failure and risk to Aquatic Organism Passage, we are currently analyzing a large dataset of road crossings on National Forest lands in the northeastern region of the US. These crossings were surveyed using the Coffman coarse filter method (Coffman 2005) and were scored as passable, impassable, or indeterminate for three movement guilds of stream fishes. Physical data on channel and culvert dimensions collected during the course of the surveys, in combination with flow data generated by drainage area – flow relationships will allow us to determine for which culverts capacity will be exceeded during floods of known frequency (predicted 2, 5, 10, 25, 50, 100 and 500-year events) and whether these culverts whose capacity is more likely to be exceeded are also more likely to be classified as barriers.

Preliminary analyses indicate a potential relationship between capacity and passage. In a test set of 41 (20 passable; 21 impassable) road crossings on tributaries of the West River basin in southeastern Vermont, we calculated the ratio of culvert width to bankful width, and compared these ratios for passable and impassable crossings. Width ratios for culverts classified as passable were significantly greater (0.7 $\pm$ 0.02 S.E.) than culverts which were classified as impassable (0.41 $\pm$ 0.008 S.E.) (*t*-test; n = 41; $p < 0.001$) (Fig. 2). These analyses will be expanded to the full culvert dataset in the near future.

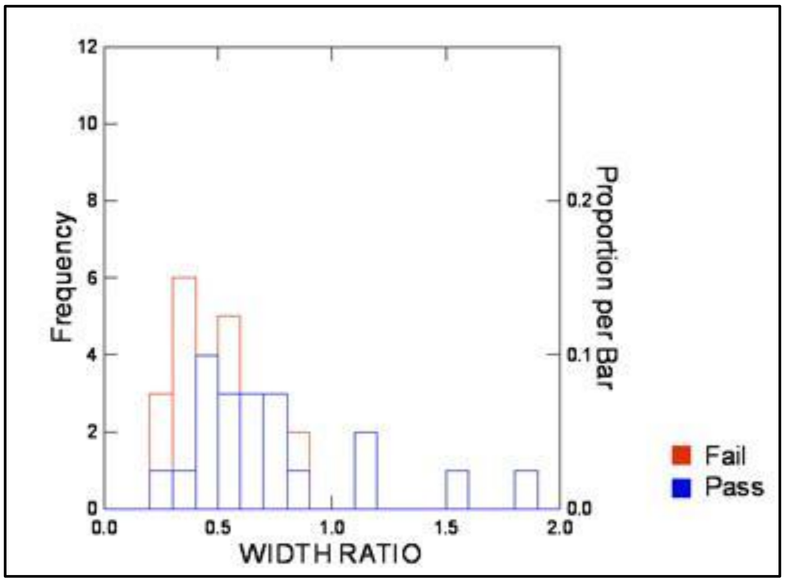

Figure 2. Frequency distributions of culvert width/bankful width for 41 surveyed road crossings in the Green Mountain National Forest, southern Vermont, USA. 'Fail' crossings (in red) are considered to be barriers to stream fish passage under the Coffman survey method, 'Pass' crossings (in blue) are considered to be passable.

Road-Stream Crossings in the Context of Climate Change

The way that we manage road crossings has special significance for the sustainability of both infrastructure and river ecosystems under a changing climate. The ability of aquatic organisms, particularly those dependent on cold, stable, stream temperatures, to disperse along river corridors in search of thermal refugia will be critical to their persistence. In addition, large, connected populations are likely to be more persistent under changing disturbance regimes than are the small isolated population characteristic of river systems with high levels of fragmentation. On both these accounts, increasing connectivity and removing barriers is one of the most effective ways to mitigate the effects of climate change. This advantage is magnified when simultaneously considering infrastructure sustainability. Current predictions of increased frequency and magnitude of extreme flows (Moore et al. 1997) make it likely that culverts designed to pass floods of a specified recurrence interval will fail under predicted future conditions. With management and conservation organizations under pressure to incorporate climate change predictions in their long-range plans, combined with the increasing available and quality of downscaled climate and hydrologic models, improving road crossings and river connectivity offers a real opportunity to demonstrate tangible ecological and infrastructure benefits for the present and the future.

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Biographical Sketch

Dr. Keith H. Nislow is a Research Fisheries Biologist and director of the Fish and Wildlife Habitat Relationships Team of the USDA Forest Service Northern Research Station located in Amherst, Massachusetts. His research deals with the effects of change in habitat, land use, hydrology, and food web structure on Atlantic salmon and co-occurring species in north Atlantic region freshwater ecosystems. Working with a wide array of academic, federal, state, and private-sector partners, his goal is to understand the effects of past, present, and future management decisions on restoration and conservation of aquatic biodiversity and productivity in the region. In turn, these management 'experiments' to help to improve understanding of the basic determinants of species abundance and distribution as well as ecosystem structure and function.

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MASSHIGHWAY GUIDANCE HANDBOOK:
DESIGN OF BRIDGES AND CULVERTS FOR WILDLIFE PASSAGES

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Abstract

The Massachusetts Highway Department (MassHighway) has jurisdiction over numerous roadway stream crossings. Existing bridges and culverts, as well as future structures, could potentially affect aquatic and terrestrial wildlife movement along the streams and riparian corridors. MassHighway considers it important to design new and replacement stream crossings to accommodate wildlife passage and prevent adverse impacts to important ecological systems. Therefore, MassHighway is developing guidance for its planning and design staff and consultants to address wildlife passage issues at new and replacement bridges and culverts and to comply with regulatory standards for stream crossings.

The guidance handbook is a "work in progress" undergoing review and refinement in coordination with MassHighway staff and state and federal environmental resource agencies. The evolving guidance document addresses the following:

1. Criteria for Wildlife Passage: guidance on planning, selection, and design of new stream crossing structures and the reconstruction or replacement of existing bridges and culverts, with consideration of the needs for wildlife passage.
2. Applicable Regulatory Standards: an overview of the rationale for integrating wildlife passage elements into the design of bridges and culverts, and a description of the state and federal regulatory framework for developing stream crossing structures that provide habitat connectivity, based on guidance issued in the *Massachusetts River and Stream Crossing Standards* (2006).
3. Design Approaches: examination of an array of design approaches for conveyance of flows at stream crossings, while accommodating the passage of wildlife. The approaches include the entire range from full aquatic and terrestrial passage, to flood conveyance only, with an emphasis on accommodation to the maximum extent practicable within applicable project constraints. Referenced techniques include clear-span structures, "stream simulation" design, other embedded culvert designs, baffled culverts, and associated upstream and downstream ancillary measures to enhance wildlife movement. The document is not an exhaustive technical reference, but introduces suitable measures and provides citations to technical reference materials for detailed design procedures.
4. Design and Implementation Constraints: identification of common constraints that apply to the development of bridge and culvert designs, particularly at replacement crossings, to enable collection of pertinent information for choosing a structure that would maximize wildlife passage, while addressing other critical design parameters such as flood control, right-of-way limitations, structural integrity, other regulatory requirements, and construction feasibility.
5. Development and Design Process: explanation of how MassHighway integrates wildlife passage design into its process for project initiation, planning, development, and design.

Project planners and designers will use this guidance in conjunction other standard MassHighway technical references to evaluate, select, and design stream crossings for conveyance capacity, structural integrity, and wildlife habitat continuity.

Introduction

MassHighway transportation facilities, including existing and potential new roadways, involve numerous bridge and culvert crossings of streams and rivers. These crossing structures potentially affect the ability of both aquatic and terrestrial wildlife to move along the streambeds and riparian corridors, which in turn potentially affects the viability of wildlife populations and ecological systems. MassHighway is therefore developing guidance for its professional staff and consultants to comply with applicable regulatory standards and address wildlife passage issues at new and replacement bridges and culverts.

The guidance is founded upon the overall guiding principles provided by MassHighway's *Project Development and Design Guide* (2006), which states:

> *"The Commonwealth of Massachusetts is committed to caring for the built and natural environments by promoting sustainable development practices that minimize negative impacts on natural resources, historic, scenic and other community values, while also recognizing that transportation improvements have significant potential to contribute to local, regional, and statewide quality of life and economic development objectives…*
>
> *"…Well-designed transportation infrastructure that is responsive to its context is the product of thoughtful planning. By bringing together transportation professionals, local residents, and interest groups, transportation planning can produce public facilities and programs that support community goals, provide safe and efficient transportation for individuals and goods, enhance the economy, and protect the natural environment."*

In keeping with the overall direction established by the *Guidebook*, the guidance document addresses the following, as discussed further in the remainder of this paper:

1. MassHighway Criteria for Wildlife Passage at Bridges and Culverts.
2. Applicable Regulatory Standards.
3. Design Approaches for Wildlife Passage at Stream Crossings.
4. Constraints on Providing Passable Stream Crossings.
5. Project Development and Design for Stream Crossings.

Discussion

MassHighway Criteria for Wildlife Passage

Where roads cross streams, the crossing can obstruct the movement of wildlife and result in the fragmentation of habitat. This loss of "habitat continuity" can result in significant impacts to wildlife, including both aquatic and terrestrial species.

From the roadway design perspective, crossings of streams using bridges or culverts must be designed for the roadway to have a width, slope, and surface treatment that provides for the free flow of traffic across the structure. Bridges and culvert crossings must be continuous in horizontal and vertical alignment with the approaching roadway, and accommodate the vehicle types, sizes, speeds, and traffic volumes using the approaching roadways. Crossings not meeting all these criteria would impede traffic movement.

From the habitat perspective, a bridge or culvert crossing must provide an opening that has a width, slope, and surface treatment that provides for the free conveyance of water, sediment, and debris - and in addition, both the upstream and downstream movement of aquatic and terrestrial organisms. For habitat continuity, a crossing must be continuous with the horizontal and vertical alignment of the upstream and downstream channel, convey the flow of sediment and debris as well as water, and accommodate the full range of wildlife types, life stages, movement abilities, and movement behaviors found in the nearby stream system. Crossings not meeting all these criteria would obstruct the passage of wildlife. The potential consequences of such obstructions include reduced access to vital habitats, such as spawning or seasonal feeding areas; population fragmentation and isolation, affecting genetic processes that maintain healthy regional populations; and loss of opportunity for populations to expand or re-establish themselves by colonizing otherwise viable locations in the stream system.

The roadway designer's challenge is to provide bridges or culverts that do not result in obstructions, and thus maintain habitat continuity. Note that "habitat continuity" is not just a concern for anadromous fish, or even just for "fish," but for a full range of aquatic and terrestrial species that depend on access to habitat within and along a stream.

The preservation and restoration of habitat continuity is particularly challenging at existing crossings, where past design decisions and historic land use impacts have resulted in barriers to wildlife movement. At these locations, site constraints often limit the choice of options for the replacement of bridge and culvert structures.

To promote a sound approach to the design of bridges and culverts that address wildlife passage, MassHighway is developing a guidance document that establishes criteria for the consideration of wildlife accommodation in the context of site constraints, when planning, selecting, and designing new and replacement stream crossing structures. MassHighway's bridge and culvert installation, repair, and replacement activities fall into three major categories: maintenance repairs and bridge preservation, reconstruction of existing facilities, and new construction. For each of these broad categories of activities, there are differing opportunities and constraints for the provision of wildlife passage. MassHighway is considering the following basic criteria for each of these categories of activities:

Maintenance Repairs and Bridge Preservation

MassHighway maintains roadway infrastructure to provide for the continuing safety and serviceability of existing roadways. These activities sometimes require immediate repair or replacement of part or all of an existing culvert or bridge structure, to prevent a failure of the road surface, supporting structure, and embankment. Because of the immediacy of such repairs, there are only limited opportunities for modifications to address wildlife passage during these activities.

<u>Criteria</u>:

- Repair or replacement of each structure would be essentially "in-kind," providing a design that maintains hydraulic capacity, does not significantly increase flow velocities or flood elevations, and provides for similar embedment as the replaced structure. The type of structure and its material may vary (for example, a collapsing corrugated metal pipe could be replaced by a concrete pipe), as long as these conditions are met.
- Such repairs and replacements would be limited to the damaged or deteriorated structure, and not extend into adjacent resource areas except as required to complete the required repair.
- The replacement structure invert may be modified to offset an existing drop (e.g., a "perched culvert" may be reconstructed with a lower invert), if the replacement structure is designed in such a way that it does not increase inlet or outlet velocities, does not increase scour at the inlet or the outlet of the structure; and does not expose the upstream channel to potential erosive scour, which could result in "head-cutting" of the upstream channel.
- At the time the repair is executed, MassHighway would note conditions at the crossing structure that may affect the accommodation of wildlife, so that future roadway and structure improvement projects address these conditions.

Reconstruction

Many MassHighway projects are planned and designed for the reconstruction and replacement of existing bridges and culverts at stream crossings to improve and upgrade existing roadways to meet evolving transportation needs and safety standards. These projects proceed under the Development and Design Process, as described in MassHighway's *Project Development and Design Guide* (2006), which requires the consideration of environmental context in the selection and design of stream crossings. Design must address wildlife accommodation in conjunction with other project objectives. Generally replacement structures would consider wildlife accommodation to the extent practicable within project constraints, and with consideration of the type and significance of the habitat affected by the crossing.

<u>Criteria</u>:

- Bridges and culverts that currently do not comprise significant barriers to <u>aquatic</u> passage may be replaced in-kind or with an alternative structure with a comparable or greater span and waterway opening.
- Bridges and culverts that are currently significant barriers to aquatic passage would be evaluated to determine acceptable criteria for addressing the obstruction.
- If a design proposes the replacement of an existing a bridge span with a design requiring additional intermediate piers, a single span box culvert, or a multiple span box culvert, then MassHighway would evaluate the structure in coordination with the other affected natural resource agencies early in the development and design process, to determine acceptable criteria for the structure.
- Where prudent when considered in conjunction with project costs and other engineering design criteria applicable to the crossing, the bridge or culvert selection process would evaluate alternatives for enhanced wildlife accommodation, addressing terrestrial as well as aquatic species. This evaluation would consider site-specific stream and floodplain characteristics, habitat significance, and structural and economic feasibility.

- Generally, evaluation of practicable alternatives for replacement of such structures would follow the order of preference in Table 1.
- In considering wildlife accommodation for replacement structures, the designer must consider the applicable constraints, as described later in this paper.

Order of Preference	**Alternative Design Measure** (see note)	**Remarks**
1	Valley Span or Stream Span	At a minimum, strive for a clear span of stream, 1.2 times bankfull width; Valley Span may be considered where practicable.
2	Stream Simulation or No-Slope Culvert	Embedded culvert with "stream simulation" or "no slope" design, with span of 1.2 times bankfull width.
3	Integral Abutment Bridge Replacement, Full-Span Multiple Barrel Box Culvert, Roughened Channel Design,	Bridge span, open bottom culvert, or embedded culvert, less than 1.2 times bankfull width, with stable bed material design (e.g., "roughened channel design") This also includes but is not limited to the following options: • Integral abutment bridge replacements, with less than 1.2 times bankfull width between existing abutments. • Multiple barrel culvert designs, even if combined width of all barrels exceeds 1.2 times bankfull width.
4	Simple Embedded Culvert	Generally should only be considered where bed material is self-sustaining, and does not warrant a "roughened channel design" to assure bed material stability.
5	Fish Passage Hydraulic Design	Culvert or bridge with provisions for fish passage if applicable species are present.
6	Flow Conveyance Design	All structures must address flow conveyance criteria under MassHighway and other regulatory standards. However, this alternative does not explicitly address wildlife passage accommodation, and is considered the minimum criteria for stream crossing design.

Note: See discussion of alternative design measures under "Design Approaches."

Table 1. Order of Preference for Alternative Design Measures for Maximizing Wildlife Passage

New Construction

MassHighway undertakes construction of new roadways to meet the transportation needs of the Commonwealth of Massachusetts. Where these projects require new stream crossings, the selection and design of structures will require integration of wildlife accommodation.

Criteria:

- The structure would be designed to meet guidelines for span width, open area and clearance, and stream bed composition set forth in "General Standards" in the Massachusetts River and Stream Crossing Standards (discussed further under "Applicable Regulatory Standards"). Bridge or spanning techniques are preferred, but pipe, box, and arch pipe culverts may be used where they can be designed to meet the specified dimensional, hydraulic, and streambed material requirements.
- Spanning or bridging techniques, including bridges, open bottom arches, and open bottom culverts, would be required for certain state-designated Outstanding Resource Waters.

- In locations where state resource agencies have identified habitat of particular importance because of regional habitat connectivity, the bridge selection process would evaluate alternatives that would meet certain "Optimum Standards" offered by the Massachusetts River and Stream Crossing Standards. The evaluation would consider these alternatives in light of site-specific stream and floodplain characteristics, habitat significance, and structural and economic feasibility.
- Where a bridge is proposed and the width of the crossing is such that a clear span is not structurally feasible and a multiple span structure is necessary, MassHighway would engage in early coordination with natural resource agencies to establish acceptable criteria for the placement of intermediate piers or other supporting structures within the affected streambed or stream bank.
- In designing for wildlife accommodation at new crossings, the designer must consider the applicable constraints, as described later in this paper.

Applicable Regulatory Standards

The guidance will present an overview of the rationale for integrating wildlife passage elements into the design of bridges and culverts, describe a method for assessing the degree of wildlife passage afforded by a structure, summarize key elements of the *Massachusetts River and Stream Crossing Standards*, and describe the regulatory framework for developing stream crossing structures that provide habitat connectivity.

Traditionally, bridges and culverts have been designed based on structural integrity and hydraulic capacity and efficiency. We have learned over time that the hydraulic efficiency of these structures results in significant constraints on passage of fish and other wildlife. For example, aquatic organisms must overcome a series of thresholds to pass the full length of a "typical" culvert, including physical drops at the outlet and inlet of the structure; inadequate depths of flow within the structure during base flow conditions; high flow velocities over relatively long distances; and differences from natural conditions such as lighting, bottom composition, air movement, and other conditions that impose behavioral deterrents to passage.

Natural streambeds offer multiple opportunities for movement in the water column at any given time, including diverse velocity conditions and resting pools under a wide range of flow conditions; and opportunities for movement under varying discharge events, including flood flows. Natural streams also offer opportunities for movement of aquatic species on and within the stream bed as well as terrestrial passage along the stream banks.

Because of such conditions, natural stream beds provide a potential model for culvert and bridge design that would accommodate wildlife. Crossing structures designed to span the existing stream bed, or replicate the natural stream bed within the structure, and provide an opening capable of passing flood flows while maintaining stream bed stability, offer the greatest potential for accommodating a wide range of wildlife at these crossings. The River and Stream Continuity Partnership, which includes the University of Massachusetts Amherst, Massachusetts Department of Fish and Game Riverways Program, and The Nature Conservancy, developed the *Massachusetts River and Stream Crossing Standards,* to provide guidance in developing such stream crossings. This guidance document offers standards that derive from a "Stream Simulation" design approach. Stream simulation addresses wildlife accommodation by providing a continuous natural or "near-natural" stream bed <u>and</u> stream banks within the crossing, maintaining connectivity with the existing stream system. The *Massachusetts River and Stream Crossing Standards* are not in themselves regulatory (although state and federal permitting programs now reference the standards), but were developed to help guide planning and design of structures for wildlife accommodation.

These standards generally provide for the following:

1. Bridge spans are preferred, but well designed culverts and open-bottom arches may be appropriate;
2. If culverts are used, then they should be embedded (varies with type of culvert);
3. Span the channel a minimum of 1.2 times the bankfull width;
4. Provide natural bottom substrate (streambed material) within the structure;
5. Design the bottom substrate with appropriate bed forms and streambed characteristics so that water depths and velocities are comparable to the natural channel for a variety of flows; and
6. Provide an "openness ratio" (area of opening divided by length of conduit) that fosters wildlife use of the structure. This ratio varies from 0.25 meters to 0.75 meters, depending on the significance of the stream to regional habitat connectivity, and the characteristics of the transportation crossing.

MassHighway's criteria for crossing structures (discussed in the previous section of this paper) are being developed to address these recommended standards to the extent practicable.

The Regulatory Framework

Federal and state regulatory and wildlife agencies seek designs that preserve and restore habitat continuity. Knowing that natural stream features provide this continuity, this regulatory interest has led to permit programs that reference the *Massachusetts River and Stream Crossing Standards* to promote crossing design techniques that foster the preservation or replication of natural stream features at culverts and bridges. The permit programs essentially require new crossings to comply with this guidance. Regulatory programs also strive to implement the guidance at projects involving replacement or reconstruction of culverts and bridges on streams throughout the state. The *Stream Crossing Standards* contain specific recommendations for replacement of existing structures, acknowledging the limits imposed by site constraints at existing crossings.

The primary regulatory framework for Massachusetts highway projects consists of federal review under the jurisdiction of the U.S. Army Corps of Engineers (USACE), and state review under the Massachusetts 401 Water Quality Certification process.

The New England District of the U.S. Army Corps of Engineers (USACE) issued a Programmatic General Permit (PGP) for the Commonwealth of Massachusetts in January 2005, and modified the permit in December 2006. The PGP expedites review of activities that would have minimal impact in coastal and inland waters and wetlands in Massachusetts. The PGP covers activities in resource areas regulated by the USACE under Section 10 of the Rivers and Harbors Act of 1899, Section 404 of the Clean Water Act (CWA), and Section 103 of the Marine Protection, Research and Sanctuaries Act. The PGP establishes conditions for Category 1 (non-reporting) and Category 2 (reporting-requiring screening) activities.

The PGP requirements for all temporary and permanent crossings to have crossing structures designed to withstand and prevent the restriction of high flows, and so as not to obstruct the movement of aquatic life indigenous to the waterbody beyond the actual duration of construction. The PGP also requires <u>new</u> permanent crossings to conform to the General Standards contained in the *Massachusetts River and Stream Crossing Standards.*

The Massachusetts DEP 401 Water Quality Certification regulations are found in *314 CMR 9.00: 401 Water Quality Certification for Discharge of Dredged or Fill Material, Dredging, and Dredged Material Disposal in Waters of the United States Within the Commonwealth*. This regulation governs the placement of fill in wetlands and waterways, in addition to regulating dredging activity and the handling of dredged materials. Under 314 CMR 9.00, certain projects do not require filing of a separate 401 Certification application, provided the projects meet specified conditions, including conformance to the requirements of the USACE PGP.

314 CMR 9.04 requires a 401 Water Quality Certification Application for certain types of projects, including activities that result in dredging or filling in any Outstanding Resource Water (ORW), or activities involving greater than 5,000 square feet of cumulative loss of bordering and isolated vegetated wetlands and land under water. For public roadway projects subject to this 401 Water Quality Certification review and involving a crossing of an ORW, a span or other bridging technique is required unless an alternative has been documented and approved under the application process.

MassHighway anticipates that new crossings – that is, roads built across streams where there currently exists no structure – will be designed to meet the *Stream Crossing Standards*, consistent with both the regulations and with MassHighway's road and bridge design practices. For existing crossings, a balanced approach will be needed, so that the requirements of the *Stream Crossing Standards* are considered in light of site constraints on a project by project basis.

MassHighway's Project Development & Design Guide, together with the Bridge Design Manual, provides direction to the design of projects that involve bridges and culverts. Both of these existing guides require early consideration of environmental conditions – including wildlife passage. They also call for early coordination with affected resource agencies, so that particular environmental issues are identified and addressed during the development and design process.

Design Approaches

The MassHighway guidance considers an array of design approaches for conveyance of flows at stream crossings, while accommodating the passage of wildlife. The approaches range from full aquatic/terrestrial passage, to general aquatic passage, to passage of specific aquatic species and life stages, to flood conveyance only. Referenced techniques include clear-span structures, “stream simulation” design, other embedded culvert designs, baffled culverts, and associated upstream and downstream ancillary measures to enhance wildlife movement. The document will not be an exhaustive technical reference, but will introduce suitable measures and provide citations to technical reference materials for detailed design procedures (e.g., stream simulation design as described in the USDA Forest Service manual: *Stream Simulation: An Ecological Approach to Providing Passage of Aquatic Organisms at Road-Stream Crossings*).

Table 2 presents a list of general design approaches available for stream crossings to achieve varying degrees of stream continuity, ranging from “valley process” design to flood capacity design. A brief description of each of the design approaches follows. Figures 1.a. and 1.b. compare these approaches with the degree to which each is likely to address the provisions of the *Massachusetts River and Stream Crossing Standards*.

	Type	**Provides Opening ≥ 1.2 x Bankfull Width**
1	Valley Span	Yes
2	Stream Span	Yes
3	Stream Simulation	Yes
4	No Slope Culvert	Yes
5	Integral Abutment Bridge Replacement	No (see Note 1)
6	Full Span Embedded Multiple-Box Culvert	Yes (see Note 2)
7	Roughened Channel Embedded Culvert	No
8	Simple Embedded Culvert	No
9	Fish Passage Hydraulic Design	No
10	Flow Conveyance Design	No

Note 1: Full span integral abutment replacement is considered a “stream span” design.
Note 2: Combined width of openings ≥ 1.2 x bankfull width.

Table 2. Stream Crossing Design Approaches

Note that the Valley Span, Stream Span, Stream Simulation, and No-Slope Culvert techniques (measures 1 through 4 in Table 2) would likely fully meet the *Stream Crossing Standards*, if appropriate openness ratios are provided. Because each river or stream crossing is unique, and because there are often significant constraints for replacement crossings, there will likely be conditions where replacement structures cannot be designed according to the techniques described for measures 1 through 4. In such cases, alternative measures will need to be considered to optimize the provision of passage for wildlife within applicable design constraints. Therefore, the other design approaches presented as measures 5 through 10 are described, to help aid in selection of an approach that can address the Standards to the maximum extent practicable.

1. Valley Span

   “Valley Span” crossing design involves the construction of a new bridge that completely spans the active floodplain of an existing stream, without disturbance of the streambed or its banks. This type of design allows for essentially unimpeded natural geologic, hydraulic, and ecological function of the stream and its floodplain. With specified clearances for wildlife passage, it would fully meet the *Stream Crossing Standards*, and would likely accommodate the movement of a full range of wildlife, including large mammals. This type of span might have intermediate structural supports founded within the floodplain. This design approach is not likely to be used for a replacement crossing, unless the existing crossing is itself a valley-span structure.

2. Stream Span

   Stream Span crossing design involves the construction of a new bridge, bottomless arch, or three-sided culvert over an existing stream without disturbance of the stream channel or its banks. A Stream Span crossing can also be provided for a replacement structure, where the existing structure spans the stream channel. In the case of replacement structures, some stabilization or restoration of the existing stream or river may be required. If extensive work within the stream channel is necessary, then the design should be performed according to the "Stream Simulation" design approach discussed in this guidance document.

3. Stream Simulation

Stream Simulation design comprises a technique in which the culvert or bridge crossing is constructed with an integral, naturalized stream channel within the structure. The approach is intended to mimic the natural stream processes within the structure. The culvert or bridge opening is sized to meet or exceed the width specified in the *Stream Crossing Standards*. A streambed is constructed within the structure based on a geomorphologic evaluation of the existing streambed near or at the crossing, or a comparable "reference stream." A "reference stream" consists of a stream reach with a drainage area, slope, and morphology similar to the proposed section of constructed streambed.

A culvert or bridge that that is designed by the Stream Simulation technique maintains continuity of natural stream processes, including sediment transport, flood debris passage, fish passage, and the movement of other aquatic wildlife. The Forest Service Stream Simulation Working Group (2008) describes this design method in detail.

4. No-Slope Culvert

The "No-Slope Culvert" design is a special type of embedded culvert, with features intended to comply with the *Stream Crossing Standards*. A No-Slope Culvert consists of a typical box, arch, or pipe culvert installed with an invert slope of zero percent, embedded to a specified depth designed to retain a dynamically stable stream bed within the structure. Under the MassHighway criteria, the No-Slope design would require the culvert width to equal or exceed 1.2 times the bankfull channel width, and the flow area to comply with the openness ratio specified by the *Standards*. Where a clear-span bridge or bottomless culvert design cannot be used, a No-Slope Culvert may be a reasonable option. Bates (2003) describes the design of this type of structure.

5. Integral Abutment Bridge Replacement

Integral Abutment Bridge Replacement (Figure 2) involves the construction of a new bridge structure founded on new abutments installed on the upland side of the existing bridge abutments. The existing abutments serve as coffer dams during construction. These abutments are kept in place permanently, but the tops of them are removed to provide clearance for the new bridge structural elements. Sometimes these old abutments are kept as short retaining walls; in other instances, they are cut off below the elevation of the stream bed. Generally, this design approach allows the bridge replacement to be conducted without performing work within the active stream channel, except when the old abutments are cut off below stream bed elevation.

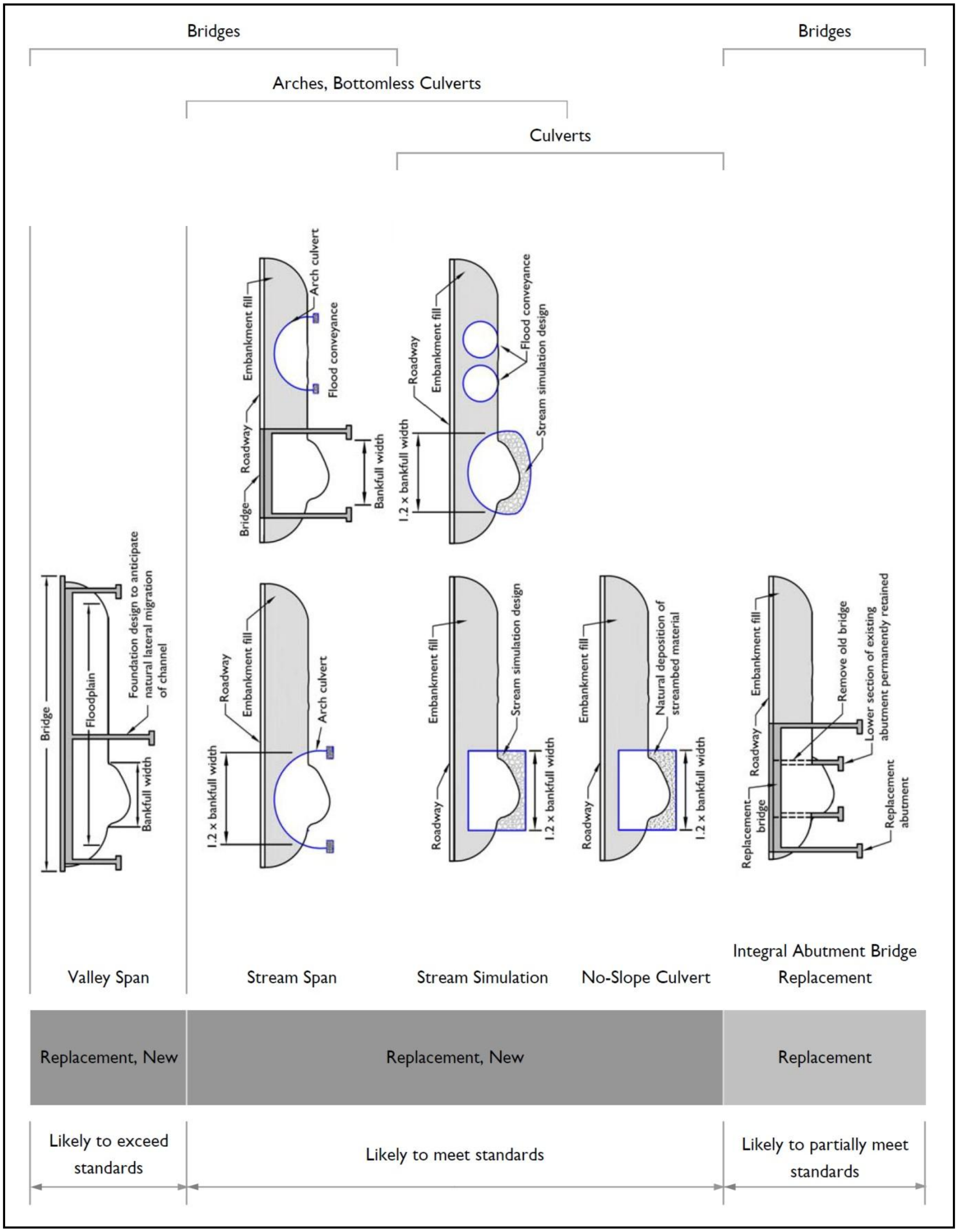

Figure 1.a. Range of Stream Crossing Design Approaches (Adapted from Forest Service Stream-Simulation Working Group, 2008).

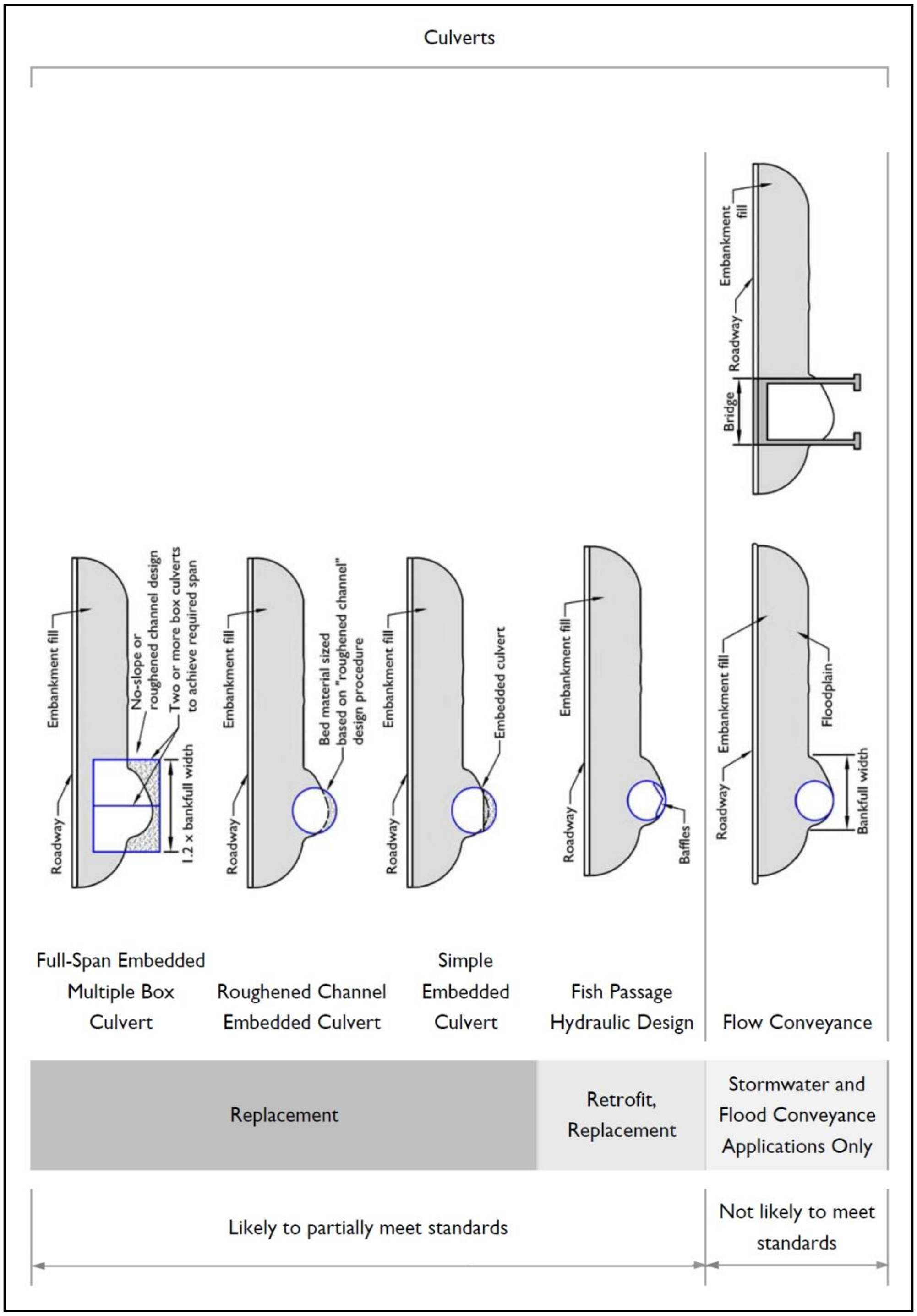

Figure 1.b. Range of Stream Crossing Design Approaches (continued). (Adapted from Forest Service Stream-Simulation Working Group, 2008).

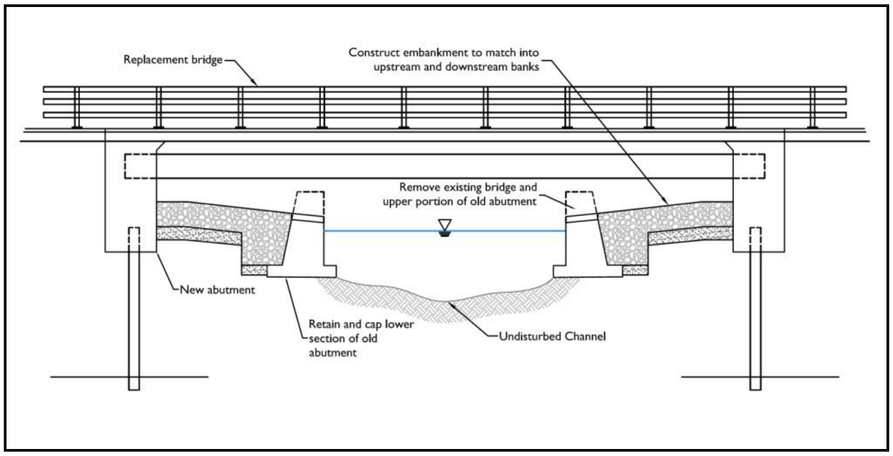

Figure 2: Integral Abutment Bridge Replacement.

6. Full Span Embedded Multiple-Box Culvert

   The Full Span Embedded Multiple-Box Culvert consists of two or more box culverts installed with an overall width equal to or exceeding 1.2 times the bankfull width of the stream. The inverts of the culverts are countersunk below the channel invert, allowing for the placement or natural accumulation of streambed material within the culvert. At least one of the culverts is designed to provide the openness requirement specified by the Massachusetts Stream Crossing Standards. Depending on the nature of the stream bed material, this type of culvert may require design similar to the “No-Slope” design with the invert of the culvert allowed to fill naturally, as a result of bed load movement through the structure. This process is referred to as “substrate recruitment”. In other cases, a stable substrate may need to be installed, following a design procedure similar to that required for the “Roughened Channel” design discussed below.

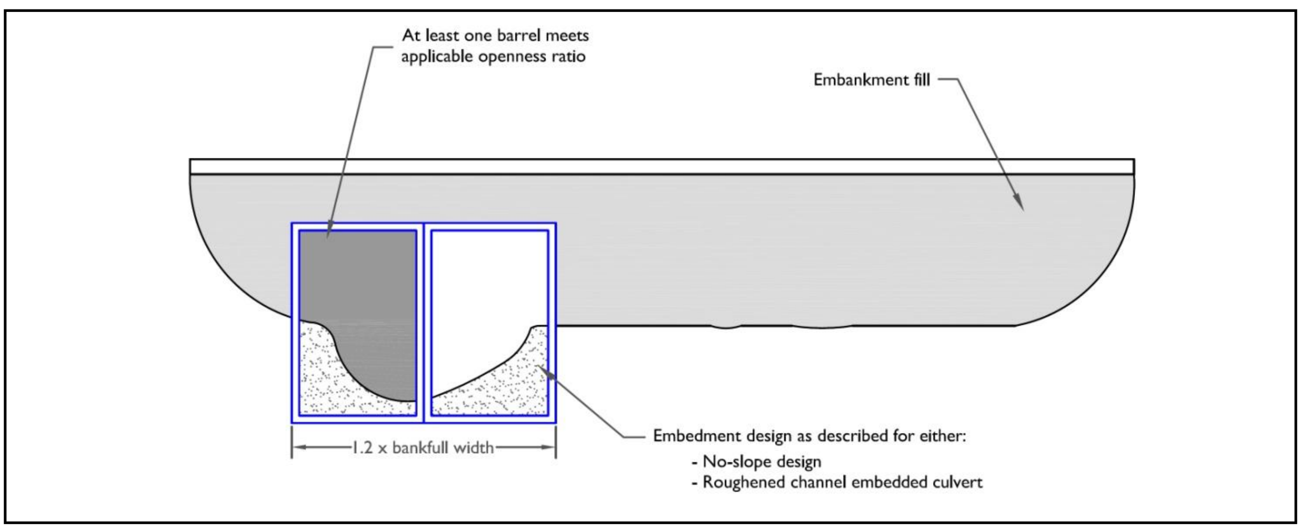

Figure 3. Full Span Embedded Multiple-Box Culvert.

7. Roughened Channel Embedded Culvert

   The Roughened Channel Embedded Culvert is one that may have a lesser width than specified by the *Stream Crossing Standards*, but has an engineered bed material designed to resist displacement from the culvert, prevent “subsurface flow,” and in some cases provide hydraulic conditions suitable for passage of specific fish species. Subsurface flow is a condition where flow through the culvert during low flow periods occurs within the void spaces in the substrate, as might occur through coarse material such as riprap. The Roughened

Channel Design procedure involves the sizing and gradation of material to sustain surface flow through the culvert, while meeting stability requirements. This design procedure is described by Bates (2003).

8. Simple Embedded Culvert

   The Simple Embedded Culvert is a typical box, arch, or pipe culvert installed to maintain the slope of bed material in the culvert equal to that of the natural streambed. The culvert invert is countersunk below the channel invert and the culvert is usually filled with substrate graded to maintain surface flow and provide a stable bed form. The hydraulic capacity of the embedded culvert is evaluated based on the available flow area (deducting the embedded portion of the culvert from the cross sectional area of the culvert), with roughness based on the substrate material.

   In some cases, embedded culverts can be installed with the invert depressed below the adjacent streambed, but without placement of substrate within the structure at the time of installation. Instead, the invert of the culvert is allowed to fill naturally, through "substrate recruitment".

   Unlike some of the other embedded culvert designs described above, Simple Embedded Culverts may not avoid or mitigate over the long term conditions such as hydraulic drops associated with the flow transition into the culvert under "inlet control" conditions, physical drops at the inlet and outlet, flow contraction at the inlet, scour pool formation at the outlet, or channel degradation downstream of the outlet. Also, the substrate may be subject to movement under flow conditions where the adjacent stream channel is stable. Because of the constricted flow area, higher velocities in the culvert may displace the bed material from within the culvert. Culverts designed according to the "No-Slope Culvert" and "Stream Simulation" design approaches are special cases of "embedded culverts" but are addressed separately because of their ability to accommodate the full width and stream substrate conditions specified by the *Stream Crossing Standards*.

9. Fish Passage Hydraulic Design

   This type of design involves the engineering of culverts and, in some cases, bridges to provide for the passage of specific species of fish, usually at specific life stages within those target species. This design approach applies measures to control heights of vertical transitions, flow velocities, and flow depths to within ranges that can be negotiated by the specific fish species. An example is the design of a structure to accommodate river herring, smelt, or salmon during seasonal spawning migration periods.

   This method can be of limited value for general stream continuity, as it generally provides for passage for a narrow range of species, and within species a narrow range of swimming/jumping abilities. Examples of structures that provide for hydraulic conditions suitable for fish passage include:

   - Low gradient culverts, designed for suitable flow depths and velocities for fish passage during low flows and flows associated with migration periods;
   - Culverts with baffles, designed to introduce roughness or to alter flow regime within the culvert, thus controlling velocities and depths to specified ranges;
   - Some embedded culverts (e.g., using "roughened channel design"), engineered to control depths and velocities of flow; and
   - Bridges or large culverts that are retrofitted with fishways (*e.g.*, "fish ladders").

10. Flow Conveyance Design

    This is the conventional approach for designing hydraulically and structurally efficient bridges and culverts. MassHighway guidance documents describe the hydraulic and structural design criteria in detail. Flow Conveyance Design is based on the capacity to carry specified design flows, consistent with the provision of a structurally sound structure that supports the required roadway. This approach also provides for adequate scour protection, flow transition at the inlet and outlet, and energy dissipation at the outlet. However, when bridges and culverts are designed solely for efficient flow conveyance, there are a number of features that can adversely affect aquatic and terrestrial wildlife passage. Structures must meet MassHighway flow conveyance criteria at a minimum, but in many cases other measures identified above are more likely to address the accommodation of wildlife.

Design and Implementation Constraints

The designer must address multiple design standards and regulatory criteria when designing a roadway stream crossing. The designer must also consider these criteria within the various constraints on the roadway and crossing structure design. The MassHighway guidance document will identify key constraints that may affect the selection and implementation of a design strategy for a stream crossing that accommodates wildlife. Definition of the constraints will enable collection of pertinent information for choosing a structure that would maximize wildlife passage, while addressing other critical design parameters such as flood control (for example, see Figure 4), right-of-way limitations, structural integrity, other regulatory requirements, and construction feasibility.

The proposed guidance document will describe common conditions that affect the design of road/stream crossings, particularly where the crossing already exists and must be considered in the context of existing land uses, utilities, flood plain elevations, and protected resource areas such as wetlands proximate to the crossing.

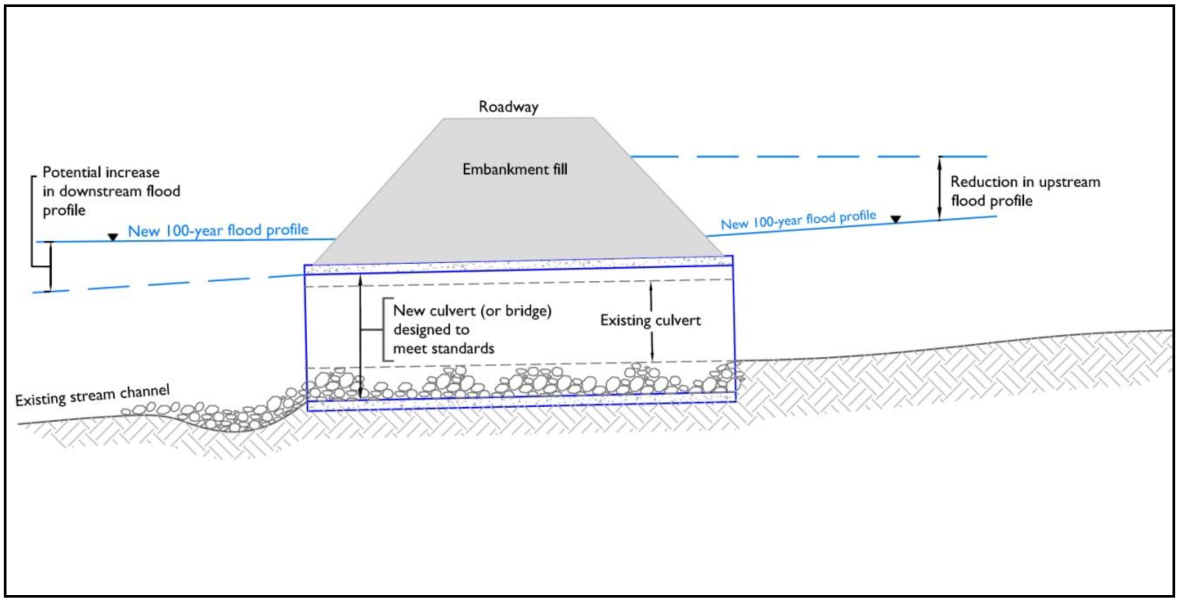

Figure 4. Potential Alteration of Flood Elevations as a Result Culvert Replacement. Replacing an existing culvert with a culvert or bridge having a greater width and open area to meet wildlife accommodation objectives may result in sufficient increase in flood conveyance capacity to increase the downstream flood profile. This potential constraint must be considered in the design of replacement structures.

In addressing wildlife accommodation at new crossings and for replacement of existing bridges or culverts, the designer must consider the applicable constraints, including but not limited to those identified in Table 3. If any of these constraints affect the practicability of meeting wildlife accommodation objectives, then the designer would consult with MassHighway environmental staff and affected environmental resource agencies to establish acceptable criteria for the crossing.

Development and Design Process

The MassHighway handbook for *Design of Bridges and Culverts for Wildlife Passage* will not be a stand-alone document. The design of stream crossings with adequate flow capacity, structural integrity, and wildlife habitat continuity will require the designer to use this guidance in conjunction with other MassHighway reference manuals as well as other technical references specific to the design of the various alternative techniques presented in the discussion of “Design Approaches.”

MassHighway design guidance and practices include provisions to ensure that the project initiation, planning, development, and design process considers habitat continuity at stream crossings, provides for coordination with affected environmental agencies, and incorporates crossing design measures to achieve compliance with applicable regulations. MassHighway projects advance from the identification of need to the construction of new and reconstructed roads and bridges in accordance with the Massachusetts Highway *Development and Design Guide* (2006). In addition, MassHighway's *Bridge Design Manual* also governs the design of bridges as well as many culverts. The design of stream crossing structures must proceed in accordance with these fundamental MassHighway guidance documents and related MassHighway practices.

CATEGORY	CONSTRAINT
Cultural/ Social	Site of crossing contains archaeological resources. Crossing is a historic structure. Adjacent historic structures may be affected by modifications to the crossing. Stream crossing must be navigable by recreational and/or commercial watercraft.
Infrastructure	Approaching road grades are constrained by existing land use. Available width of replacement structure is limited by minimum clearance to nearby buildings or other structures. Utilities are located above, below, or on the existing crossing structure. Utilities are located adjacent to the watercourse and may be affected by the crossing.
Structural	Lengths of bridge spans are limited by structural engineering requirements, as specified in the Bridge Manual. Sizes of bridge components, manufactured arches, and culverts are limited to sizes that can be shipped overland to the construction site. "Aspect ratios" of manufactured arches are constrained by structural requirements, limiting available options within vertical alignment constraints. Feasibility of bridge construction may be affected by potential for scour.
Hydrologic/ Hydraulic	Natural channel dynamics could result in potential channel adjustment (both vertical and lateral). If existing structure provides flood flow attenuation, modification could affect downstream flood profile. This could require detailed flood study, preparation of LOMR under FEMA, and negotiations with downstream property owners. Modification of crossing may result in potential for head-cutting of streambed upstream and/or sediment deposition downstream. Modification of structure or adjacent channel may alter channel velocities or turbulence patterns. Potential for scour at the structure may affect the choice of structure and foundation design. Potential for scour at the outlet of the structure may affect the choice of structure design. If downstream channel has undergone degradation, this may affect vertical alignment and choice of in-channel modifications, to achieve an effective passable crossing design. Existing urbanization of the upstream and downstream channel may make it difficult or impossible to develop a "natural" crossing design. (Bankfull width may be indeterminate.) On a coastal stream, an existing culvert may provide flood protection to inland areas, because its hydraulic capacity may prevent inundation by tidal floods.

CATEGORY	CONSTRAINT
Biological/ Ecological	Roadway impounded wetlands may have formed as a result of the existing structure alignment and hydraulics. Protected resource areas at the toe of the existing embankment may constrain choice of structure and its horizontal and vertical alignment. Upstream and downstream conditions may have highly favorable habitat conditions, and the new or replacement structure may be critical to habitat linkage (design of the local crossing must be considered in context of the stream system). Upstream and downstream conditions may severely impede development of stream continuity (design of the local crossing must be considered in context of the stream system). The construction process itself can have an adverse impact, depending on type of structure. In some unique situations, the existing structure may provide a desirable obstacle to the passage of undesirable species.
Economic	Design costs of some structural systems may be prohibitive, depending on scale of project. Construction costs of some structural systems may be prohibitive, depending on scale of project. Costs to maintain some alternative crossing types may not be sustainable by the party responsible for long-term maintenance. Additional right-of-way or easements may be required if work extends outside the right-of-way (e.g., upstream or downstream channel restoration required to accommodate crossing design).
Constructability	Choice of structure type may be affected by accessibility of work site. Choice of structure type may be affected by a need to maintain traffic during construction. Choice of structure type may be affected by feasibility of conducting construction operations within the limits of the stream or by other construction phase water handling requirements. Choice of structure type may be affected permit time restrictions ("work in water" seasonal time limits). Choice of structure type may be affected by feasibility of performing construction required construction operations (e.g., placement of materials within a culvert or beneath a bridge span) or other factors.
Maintainability	Choice of structure type may be affected by accessibility for required maintenance. Choice of structure type may be affected by other maintenance considerations.

Table 3: Potential Constraints Affecting Design of Stream Crossings for Wildlife Accommodation

MassHighway's Project *Development and Design Guide* sets forth specific requirements focused on the design of projects to address environmental context and to comply with regulatory programs. Pertinent sections of that guidance specifically apply to the design of new and replacement stream crossings. The design of stream crossings to address wildlife passage parameters and constraints is consistent with and required by the Design Guide.

The MassHighway *Bridge Manual* includes provisions that require the consideration of environmental context and pertinent design requirements in the development of bridge designs. The proposed new guidance would provide that the bridge type selection process consider wildlife accommodation at stream crossings, by considering streams and rivers "environmentally sensitive areas" and addressing aquatic and other wildlife passage issues early in the evaluation of alternative structures for both new and replacement crossings.

The design of stream crossings to accommodate wildlife requires that the criteria for such passage be integral to the entire design process. The design cannot successfully implement stream continuity by introducing accommodation considerations near the end of the design process as an "add-on" feature. If a project will be required to meet the width, opening, and embedment requirements of the *River and Stream Crossing Standards*, the original analysis of the crossing and the structure selection process should address these criteria.

The integration of stream habitat continuity into all phases of crossing structure analysis and design development is essential to the successful implementation of stream crossings that functionally accommodate wildlife movement.

Biographical Sketches

David Nyman is Chief Engineer at Comprehensive Environmental Incorporated (CEI), with over 38 years of civil engineering experience. A leader in the storm water management field, Mr. Nyman's consulting experience focuses on stormwater management and water resource protection and restoration issues for municipal and state projects, as well as private clients. Mr. Nyman has contributed as key author and project manager to the development of MassHighway's *Storm Water Handbook*, New Hampshire Department of Environmental Service's *Statewide Stormwater BMP Manual*, and the Massachusetts DEP's *Hydrology Handbook for Conservation Commissioners.* He has participated river and stream habitat restoration projects, including culverts designed for wildlife accommodation, in Massachusetts, Connecticut, and Pennsylvania. He currently advises MassHighway on stream crossing design for habitat continuity, as well as on storm water management permitting and design issues. He is the primary author of the pending MassHighway Guidance Handbook: *Design of Bridges and Culverts for Wildlife Passage.*

Henry Barbaro, since 1993, has served as the Supervisor of the Wetlands & Water Resources Unit within MassHighway's Environmental Services Division. During that time, he has worked on developing environmental management and compliance policies for MassHighway, including those for storm water management, standards for drainage tie-ins, and mitigation practices for snow and ice control. In addition, he is working with the U.S. Geological Survey to calibrate a highway contaminant loading model for TMDL compliance. Mr. Barbaro's involvement with the stream crossing guidelines, described herein, is to develop cost-effective measures for enhancing aquatic ecosystems, and engage MassHighway's design community in the application of these measures in coordination with state and federal regulatory programs.

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Do Bridges Affect Migrating Juvenile Salmon: Tracking Juvenile Salmon and Predator Fish Movements and Habitat Use Near the SR 520 Bridge in Lake Washington

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Project Description

Results of a two-year fish tracking study evaluating the behavior and habitat use by both outmigrating juvenile salmon and their predators in the vicinity of the SR 520 bridge on Lake Washington near Seattle, WA.

Abstract

Large anthropogenic infrastructure such as major bridges in and near waterways can influence the ecological dynamics of the nearby aquatic environment. These influences may affect behavior, habitat use, fitness, and survival of fishes. Chinook salmon (*Oncoryhnchus tshawytscha*) spawning in tributaries to Lake Washington typically spend three to five months rearing in Lake Washington before travelling through the Lake Washington Ship Canal to Puget Sound. Most salmon smolts in Lake Washington must pass beneath the SR520 Bridge en route to Puget Sound. Plans to replace the existing bridge have sparked interest in how smolts and potential predators behave around and use the bridge.

To address this interest, we tracked Chinook smolts, smallmouth bass and northern pikeminnow in a 17.2 ha area along a 560 m stretch of the SR520 bridge during June-July 2007 and 2008 using fine-scale acoustic tracking. During the 2007 tracking season a total of 171 smolts were released in three June release groups and 162 were successfully tracked in the study area. Repeating the study design in 2008, 181 smolts were released and 133 were successfully tracked in the study area during a total of four release groups occurring in June and July. Although this study focused on the SR 520 bridge, many fish were also observed at a downstream tracking station approximately 2-miles downstream allowing us to evaluate movements within and between sites. Different release groups appear to exhibit different behaviors, some release groups rapidly migrated through the SR 520 tracking area in < 3 h ("migrating"), while other release groups were often detected ≥ 2 days ("holding"). The bridge appeared to delay some migrating smolts. These delays were typically short in duration as salmon would move along the bridge – typically towards the shoreline – prior to migrating past the bridge. Many holding smolts used areas near the bridge extensively. Timing of migrational cues, physiological smolt status, water temperature and clarity, and macrophytes may have influenced movement timing and habitat use. During the same study periods small numbers of northern pikeminnow and smallmouth bass were also tracked. Bass preferred habitats under overwater structures, including the bridge – particularly near bridge columns. Pikeminnow preferred macrophytes and overwater structures other than the bridge. Predator diets and abundance were also evaluated in and near the study area.

These results suggest that the bridge in its current form may affect the movements of some Chinook smolts and may be preferred habitats for some salmon predators. The SR 520 Bridge Replacement Project is continuing to evaluate these results to help inform design of the proposed bridge replacement.

Introduction

Puget Sound Chinook salmon *Oncoryhnchus tshawytscha* (listed as threatened under the Endangered Species Act) are an important component of the Lake Washington ecosystem. Within this ecosystem, juvenile Chinook salmon primarily rear in the south end of the lake from January to May (Tabor et al. 2006), with migration throughout the lake, through the ship canal and into the marine environment occurring between May and July. The lake lies within an urbanized area and has been modified in many ways to suit human uses. Modifications to the lake that affect salmon include increases in impervious surface within the tributary systems that have decreased baseflows (Horner and May 1998) and increased flooding (Moscrip and Montgomery 1997), shoreline armoring that has replaced native vegetation and covers 81% of the shoreline combined with approximately 2700 residential piers (Toft 2001), and the construction of a ship canal connecting Lake Washington to marine waters (NOAA 2008). In 1916, drainage from Lake Washington into the Black River was blocked and the Ship Canal and Hiram M. Chittenden Locks were constructed to allow navigable passage between Puget Sound, Lake Union, and Lake Washington and provide better flushing in Lake Washington.

Furthermore, the timing of the natural hydrologic cycle has been reversed so that today lake elevations are at their highest in summer to support recreation activities and at their lowest in winter.

The existing State Route (SR) 520 bridge completely spans the lake connecting Seattle with its eastern suburbs including Bellevue and Redmond. The bridge location is a transition area between Lake Washington and the ship canal where Chinook salmon smolts are presumed to concentrate in large numbers during the outmigration period. Wild fish populations from the Cedar River at the south end of the lake must pass under the bridge to exit to salt water, and juvenile hatchery fish appear widely distributed in the lake and a substantial portion of them also likely pass under the bridge. The existing bridge was completed in 1963 and is nearing the end of its functional lifespan leading to plans for a replacement structure that would be less vulnerable to wind and wave storms, seismic events and improve movement of people and goods (WSDOT 2006). Following the release of the Draft Environmental Impact Statement (EIS) for the SR 520 Bridge Replacement and HOV Project (WSDOT 2006), resource agencies and tribes voiced concerns about potential impacts to fishery resources from the existing and proposed replacement for the SR 520 bridge. These concerns focused primarily on either the potential for the existing and future bridge to act as a barrier to migrating juvenile salmonids or the potential for the bridge and related structures to provide habitat for piscivorous fish, thereby potentially increasing predation rates on outmigrating juvenile salmon. Predation risk is an important factor influencing juvenile Chinook salmon which can cause changes in habitat use, movements, and behavior. Unlike other structures that juvenile Chinook can avoid by moving into deeper water away from the structure and predators, the bridge extends from shoreline to shoreline.

Important fish predators of juvenile salmon in Lake Washington include cutthroat trout (Nowak et al. 2004), northern pikeminnow (Olney 1975; Brocksmith 1999), and smallmouth bass (Tabor et al. 2007). Predaceous cutthroat trout inhabitat the pelagic zone and are highly mobile (Nowak and Quinn 2002) and would therefore be difficult to study at the SR 520 bridge. Northern pikeminnow inhabit the littoral zone as water temperatures increase and may be abundant at our study site in response to increases in juvenile salmon abundances during outmigration. Pikeminnow have been shown to congregate in other areas in Lake Washington (Olney 1975) and in other systems (Collis et al. 1995) where prey is abundant. Little is known about their use of overwater structures as habitat or to ambush prey. They have been shown to congregate near structures at dams, but their presence is believed to be related to prey abundance or water velocity, not necessarily the structure.

In contrast to northern pikeminnow, smallmouth bass have been documented to use overwater structures. For example, Fresh et al. (2001) found 49% of all smallmouth bass observed in Lake Washington were within 2 m of an overwater structure. Other factors influencing smallmouth bass habitat use include substrate type with cobble and boulders being preferred over finer substrates (Fresh et al. 2001) and steep slopes (Hubert and Lackey 1980).

In efforts to improve bridge design and to respond to concerns from resource agencies, Washington State Department of Transportation (WSDOT) partnered with US Fish and Wildlife Service (USFWS) to develop and implement a study that uses a combination of fine-scale acoustic tracking system to monitor fish movements and habitat movements near the bridge with conventional field techniques to evaluate the interactions of fisheries with the existing bridge. The objectives of the study were to: 1) document juvenile Chinook salmon migration patterns near the existing bridge; and 2) determine the relationship in space and time between outmigrating juvenile Chinook salmon and piscivorous fishes. In developing this research project we created an initial conceptual model for fish activity near the SR 520 bridge. This conceptual model generated several expectations which guided the study design and formed testable hypotheses. With regard to Chinook salmon smolts, we predicted that the bridge would not influence movement or habitat use of tracked fish. We assumed that the intent of tagged fish to migrate through the study area and beyond the bridge would be clear, and that abrupt changes in direction of travel at the bridge would indicate a bridge effect. For both Chinook salmon smolts and predators we predicted that habitat selection would be similar in areas near and away from the bridge, and that areas near the bridge would not be selected any more or less than areas away from the bridge. Differences in habitat selection ratios between areas near the bridge compared with areas away from the bridge would suggest a bridge effect. Field research began in 2007 (Celedonia et al. 2008) and continued through the 2008 field season.

Methods

Fine-Scale Acoustic Tracking System

Tracking was performed using a fine-scale acoustic system developed by Hydroacoustic Technology, Inc. (HTI), Seattle, Washington. This system uses acoustic tag transmitters implanted within the study fish, and a fixed array of underwater listening devices - termed hydrophones - to track fish movements in a specific study area. Tag transmitters are programmed to periodically emit a signal, or ping. The system uses time differentials to triangulate a 3-dimensional position for the origin of each ping. Calculated positions are relatively accurate, estimated to be ± 0.5 m in the horizontal plane when the fish is within the perimeter of the hydrophone array. Accuracy declines outside the array perimeter, but has been estimated to be approximately ± 3 m in the horizontal plane at a distance of 1 array width from the array perimeter. In general, we accepted calculated fish positions from both within and outside the array perimeters.

Study Site

The study site was located on the western shore of Lake Washington and included an approximately 560 m stretch of the bridge (Figure 1). This general area comprises a transition between the 60 m-deep Lake Washington proper, and the much shallower 10-12 m-deep Union Bay and entrance to the LWSC. The shoreline within the study area changed abruptly from a north-south orientation to a west-east orientation at the opening to Union Bay. The study site had a gently sloping gradient extending north and east from the shoreline. On the east side of the site the gradient steepened considerably starting at ~ 10-12 m depth. Prominent features of the study area in addition to the bridge included: a large condominium building that extended over the water on the very southern edge of the site; two small boat docks along the southern shoreline; dense and abundant macrophytes (primarily the non-natives Brazilian elodea *Egeria densa* and Eurasian milfoil *Myriophyllum spicatum*) generally in most areas < 6 m deep and particularly on the south side of the bridge; and, an anomalous peninsula-like ledge with shallower water (4-6 m depth) extending northward from the bridge on the east side of the site. Substrate throughout the area appeared to consist largely of sand and silt, although we did not perform a formal substrate survey to verify this.

The SR 520 bridge is approximately 19 m (60 feet) wide. It generally runs east-west across Lake Washington; however, the portion contained within the study site had a slight east-southeast – west-northwest tilt. On the east side of the site depth contours were oriented perpendicular to the bridge. However, at the transition to Union Bay, depth contours were parallel with the bridge. The bridge at the very east end of the site included a high span approximately 20 m above the water surface. Moving west from this span, a gradual downward gradient brings the bridge closer to the water surface. At the west side of the site, the bridge was within 1-2 m of the water surface. Concrete columns served as support structures for the bridge and were located along the entire length of the bridge within the study area. Columns are approximately 1 m in diameter. Bents of six columns apiece ran perpendicular to the bridge at approximately 30-m (100 foot) intervals. Sixteen bents of columns were contained within the study site, totaling 96 columns

Water Quality, Aquatic Vegetation and Substrate

Aquatic vegetation and substrate were surveyed by collecting a large number point observation samples within and near the tracking area. Sample points were collected along transects at 20 m intervals perpendicular to shore, and survey points every 15 m along each transect. At each sampling point an underwater camera was lowered and the following data was collected: presence/absence of vegetation; density of vegetation; and total depth. Vegetation density, primarily aquatic macrophytes, was categorized according to coverage within the camera viewfinder: >95% cover was categorized as “very dense”; 75-95% as “dense”; 25-75% as “moderate”; 1-25% as “sparse.” Plant densities were collected at the end of the field season in both years, and during the second year growth was tracked along four transects during the study period. Substrate was collected using the same methods as the macrophyte survey and categorized into two categories – cobble and boulder or silt during the 2008 study year.

Water quality was periodically sampled throughout the tracking area during the study period. Six sample points were established on the south side of the bridge, and two points on the north side (figure 2). Sample point locations represent the variety of habitat types throughout the study area: shallow water and deep water; vegetated areas and unvegetated areas; nearshore and offshore; and areas near the bridge and not near the bridge. At each point Secchi depth, temperature, dissolved oxygen, conductivity, and salinity were collected. Where appropriate, parameters were sampled at 1 m depth and then 2-m depth intervals thereafter.

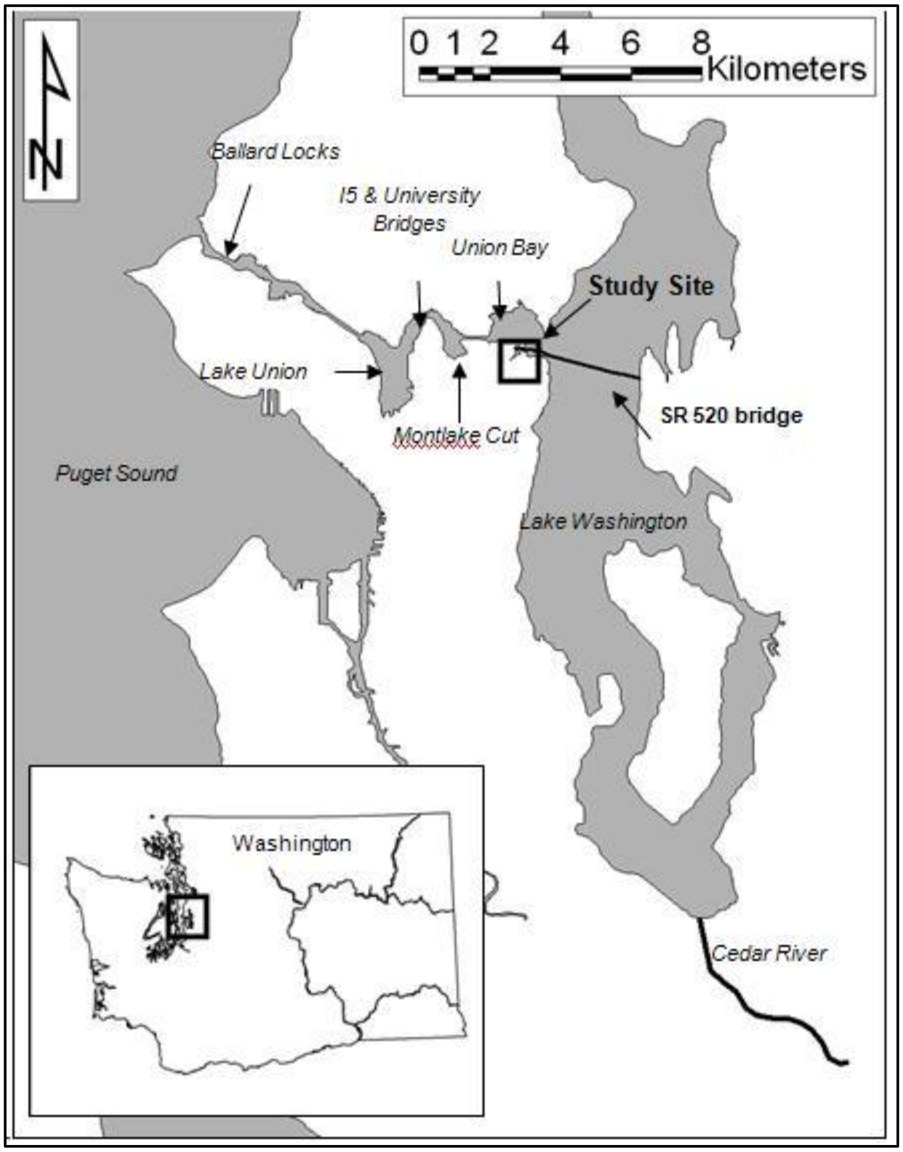

Figure 1. Map of Lake Washington showing 2008 study site location at the west end of the SR 520 bridge.

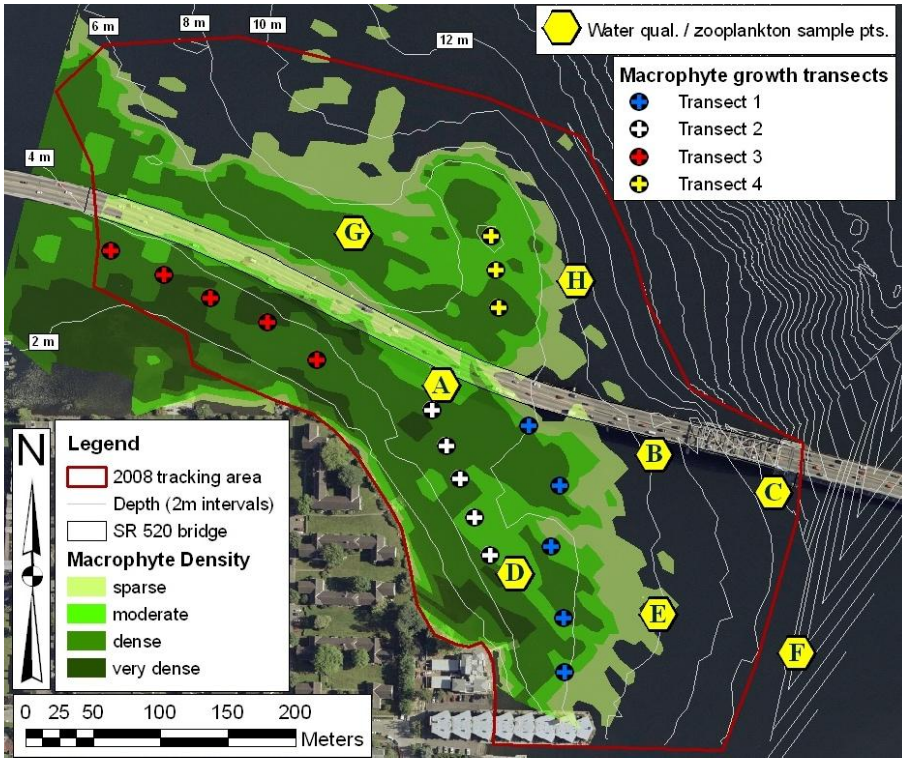

Figure 2. Sampling locations for water quality and zooplankton - May 31 - July 11, 2008.

Chinook Salmon Smolt Tagging and Tracking

Juvenile Chinook salmon from the Washington State Department of Fish and Wildlife's Issaquah hatchery were used in 2007 and 2008. In 2007 tags were turned on after surgery and immediately prior to release, whereas in 2008 Chinook salmon tags were programmed and switched on at the time of implant. We expected tag batteries to last approximately 12 days after the fish were released.

General behavioral patterns, movement times, residence times, and behaviors associated with the bridge were evaluated. Data were represented and evaluated with parametric or nonparametric statistics depending on the type of distribution observed (Zar 1999; Sheskin 2000). Unless otherwise noted, statistical significance was established at $\alpha = 0.05$.

Actual time fish spent in the tracking area (i.e., time spent on-site) was evaluated using the number of data points obtained for each fish as a surrogate for time. To correct data point observations for underestimates of the actual time spent on site, we randomly subsampled 166 fish days to calculate an equation for adjusting time estimates.

We used habitat selection equations described by Manly et al. (2002). These equations avoid take each animal as the experimental unit and evaluate each animal's proportional use of habitats and depths. Issues associated with pseudoreplication and serial correlation are therefore avoided regardless of which equations are used (Aebischer et al. 1993; Garton et al. 2001; Rogers and White 2007).

From Manly et al. (2002), the selection ratio for the *j*th fish and the *i*th habitat or depth category, was calculated as

$$\hat{w}_{ij} = (u_{ij} / u_{+j}) / \pi_i$$

where u_{ij} is the amount of time spent in habitat type (table 1) or depth category *i* by fish *j*, u_{+j} is the amount of time fish *j* was tracked across all habitat types or depth categories, and π_i is the proportion of available habitat or depth in category *i* relative to all available habitats or depths at the study site. For each release group of fish, a mean population-level selection ratio for each habitat or depth category was calculated as

$$\hat{w}_i' = \sum_{j=1}^{n} \hat{w}_{ij} / n$$

where n is the number of fish tracked across all habitat types or depth categories.

Habitat type	Abbreviation	Description	Area (ha)	Percent
Near shore	NS	Unvegetated areas close to the shoreline.	0.17	1.06
Very dense vegetation	VDV	Area of very dense macrophytes not including areas in types OWS, CE, BR, NBR.	0.53	3.33
Dense vegetation	DV	Area of dense macrophytes not including areas in types OWS, CE, BR, NBR.	3.28	20.63
Moderately dense vegetation	MV	Area of moderately dense macrophytes not including areas in types OWS, CE, BR, NBR.	1.90	11.97
Sparsely dense vegetation plus offshore edge of vegetation	SV/VE	Area of sparsely dense macrophytes including 20 m from the offshore edge of macrophytes, not including areas in types OWS, CE, BR, NBR.	2.59	16.27
Open offshore area	OO	Open offshore area that is not within 20 m of macrophytes and does not include areas in types OWS, CE, BR, NBR.	3.69	23.21
Other overwater structures	OWS	Area that is directly under the Lakeshore West Condominiums and that is directly under or within 5 m of the boat docks at the Edgewater Apartments and Madison Point Condominiums.	0.26	1.64
Condo edge	CE	Area extending from the edge of the Lakeshore West Condominiums to 20 m from the edge.	0.23	1.43
SR 520 bridge	BR	Area that is directly beneath the SR 520 bridge.	1.07	6.71
Area near SR 520 bridge	NBR	Area extending from the edge of the bridge to 20 m from the edge of the bridge	2.19	13.76

Table 1. Ten habitat types used to determine habitat selection at the 15.9 ha SR 520 bridge study site.

Selection for a habitat or depth occurs if the lower confidence interval is > 1, and selection against a habitat or depth occurs if the upper confidence interval is < 1. Confidence intervals that include 1 indicate proportional distribution across that habitat type or depth category. That is, the habitat type or depth category is neither selected for nor selected against, but rather is used in proportion to its availability.

Northern Pikeminnow and Smallmouth Bass Acoustic Tracking

In 2007 and 2008, we primarily used sinking horizontal gill nets to collect predatory fishes. The gill nets were variable-mesh, monofilament nylon nets, which consisted of 2.5, 3.2, 3.8, 5.1, and 6.4-cm square-mesh panels. The nets were 38 m long and 2.4 m high. Two or three nets were set each sampling night. In addition to gill nets, we also tried to collect predatory fish through angling; however, catch rates were low.

After each fish was anesthetized, the weight (g) and fork length (mm) was measured. The same tagging procedures used with juvenile Chinook salmon were used for predatory fishes except we used larger suture material. Fish were allowed to recover before being released at their approximate capture location.

Data points for the first 24 h after release were not used to allow time for the fish to recover and start to behave naturally. Predator tracking data were separated into dawn, day, dusk, and night time periods to examine diel behavior. Selection for the SR 520 bridge structure and other habitat types was estimated by determining the number of data points observed in each habitat category. Habitat and depth selection were determined in a similar manner as that for Chinook salmon smolts.

Predator Field Sampling and Fish Processing

To determine the abundance and diet of northern pikeminnow and other predatory fishes, we set a series of gill nets at five locations: 1) SR 520 bridge, 2) Wolf Bay 3) Webster Point, 4) Madison Park North Beach, and 5) Seattle Tennis Club (Figure 3). Two sites were north of the bridge and two were south of the bridge. We set two nets at each site; both running parallel to the shore. Nets were placed along the 5 and 10 m depth contours. At the SR 520 bridge site, the nets were set directly under the bridge and perpendicular to the structure. Nets were deployed once each week for six weeks from May 29 to July 1, 2008. On the first sampling date, nets were deployed shortly before sunset and retrieved shortly after sunrise.

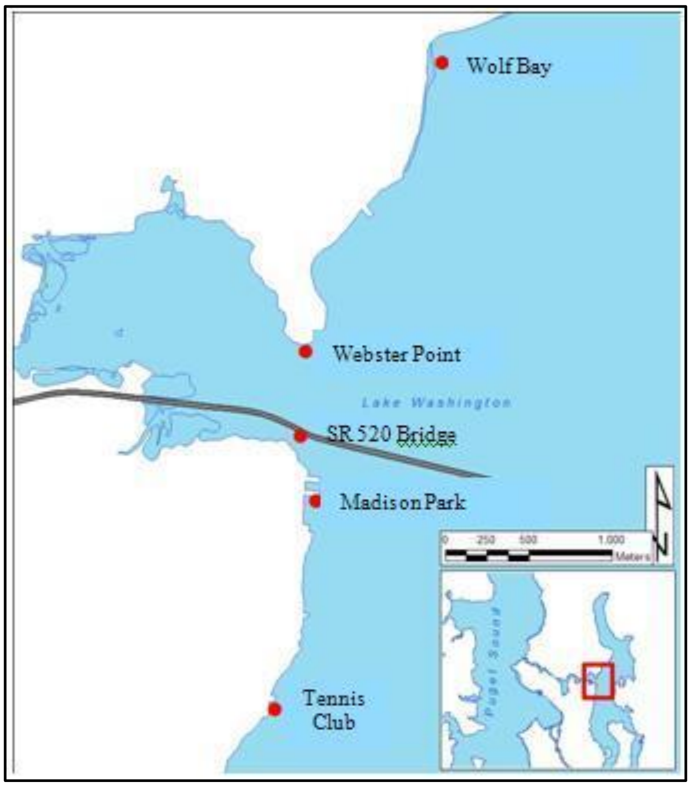

Figure 3. Map of central Lake Washington displaying the five gill-netting sites for piscivorous fish.

Laboratory Analysis

In the laboratory, each sample was thawed and placed under a dissecting microscope. Stomach contents were separated into major prey taxa. Insects and crustaceans were identified to order while other invertebrate prey items were identified to a convenient, major taxonomic group.

Results

Juvenile Salmon Tagging and Tracking

Hatchery fish were released in a total of seven release groups across two out-migration seasons (Table 2). The first release group of each season had fewer fish than later release groups because an insufficient number of fish had reached the minimum size necessary to tolerate tagging. Fish size was similar among release groups, however lengths and weights were not the statistically the same within release years based on single-factor analysis of variance (Zar 1999). In general later release groups included slightly longer and heavier fish.

Release date	Release time	No. fish released	Mean FL [SD] (mm)	Mean wt. [SD] (g)	% detected at 520 (no. fish)	% tracked at 520 (no. fish)	% detected in LWSC (no. fish)
				2007			
June 1	10:08	37	105.7 [3.1]	13.3 [1.0]	97% (36)	97% (36)	83% (31)
June 14	9:42	68	106.0 [2.7]	12.9 [0.9]	90% (61)	87% (59)	46% (31)
June 28	13:03	66	108.5 [4.9]	14.3 [2.2]	98% (65)	97% (64)	38% (25)
				2008			
June 12	9:06	27	101.6 [2.0]	11.4 [0.6]	89% (24)	85% (23)	17% (4)
June 26	9:28	50	103.0 [1.9]	11.3 [0.5]	80% (40)	78% (39)	60% (24)
July 3	9:33	53	105.5 [2.3]	12.5 [0.7]	79% (42)	75% (40)	69% (29)
July 10	9:08	51	109.3 [4.0]	13.6 [0.9]	84% (43)	80% (41)	30% (13)

Table 2. Seven groups of tagged Chinook salmon smolts released during June 2007 and June-July 2008 and tracked at the SR 520 study site, including percentage of tagged fish detected at the SR 520 bridge hydrophone arrays, the percentage of tagged fish that yielded tracks, and the percentage of fish detected at the SR 520 bridge that were also detected in the LWSC.

The substantial majority of tagged fish from all release groups were both detected (heard by at least one hydrophone) and tracked (heard by at least 3 hydrophones) at the SR 520 bridge arrays. Between 79% and 98% of tagged fish were detected at the SR 520 arrays and 75% to 97% of tagged fish yielded point location data (tracks). Between 17% and 83% of released fish were also detected at the University Bridge study site, approximately 2 miles further along the migration route to saltwater (table 2). No fish reached the University Bridge site without first being detected at the SR 520 bridge site.

Fish were typically detected at the study site the day of release. In general, fish traveled more quickly from release to the study site as the season progressed: median travel times were 10.2, 4.9, 3.7, and 1.5 h, respectively, for the June 12, June 26, July 3, and July 10, 2008 releases. Site area residence time (time between first and last detection) also shortened as the season progressed. Given the relatively short battery life of the tags, it is uncertain how many non-LWSC fish may have entered the LWSC after the tag battery died.

Juvenile Salmon Behavior and Habitat Selection

Generally, fish released during this study expressed one of two dominant behavioral types described here as type A (migrating) and type B (holding). Fish expressing these different behavioral types showed differences in their bridge approach, encounter, pass and post-pass behaviors. Type A behaviors would generally move in a direct line with little deviation or changes in speed during each phase of the bridge encounter and never be detected within the monitoring site after leaving the area. Type B behaviors would meander or mill within the site and may change direction and swim parallel to the bridge upon bridge encounter or travel underneath the bridge. Type B behavior also includes fish that might return to the study site on multiple days or multiple bridge passage events from south to north.

Spatial distribution, habitat selection, and depth selection were largely similar in release groups dominated by on-site holding behaviors (i.e., the June 12, June 26, and July 3 releases), and reflected similar patterns as those observed in 2007 (Celedonia et al. 2008). Highest frequencies of occurrence appeared: around the Lakeshore West Condominium (condo); in shallow water (< 6 m) with dense and moderately dense macrophytes that were not near the surface of the water; along the northern and southern edges of the bridge in areas with macrophytes and in deeper (> 6 m) open water areas without macrophytes; and, under the bridge in areas where the bridge was elevated above the surface of the water. These observations were reflected in habitat and depth selection calculations. The most common and consistently selected habitat was near the bridge (i.e., areas lying within 20 m of the edge of the bridge but not directly underneath) (Figure 4). The condo edge usually had the highest selection ratios, but extremely large confidence intervals precluded statistical significance in all but three occasions (Figure 4). Other habitats that were occasionally selected for included areas directly under the bridge, and dense vegetation. Habitat most often selected against included offshore open water areas, sparse vegetation and the offshore edge of vegetation, and unvegetated nearshore areas. Very dense vegetation, dense vegetation, moderately dense vegetation, and areas directly under the bridge were sometimes selected against depending on release date and diel period.

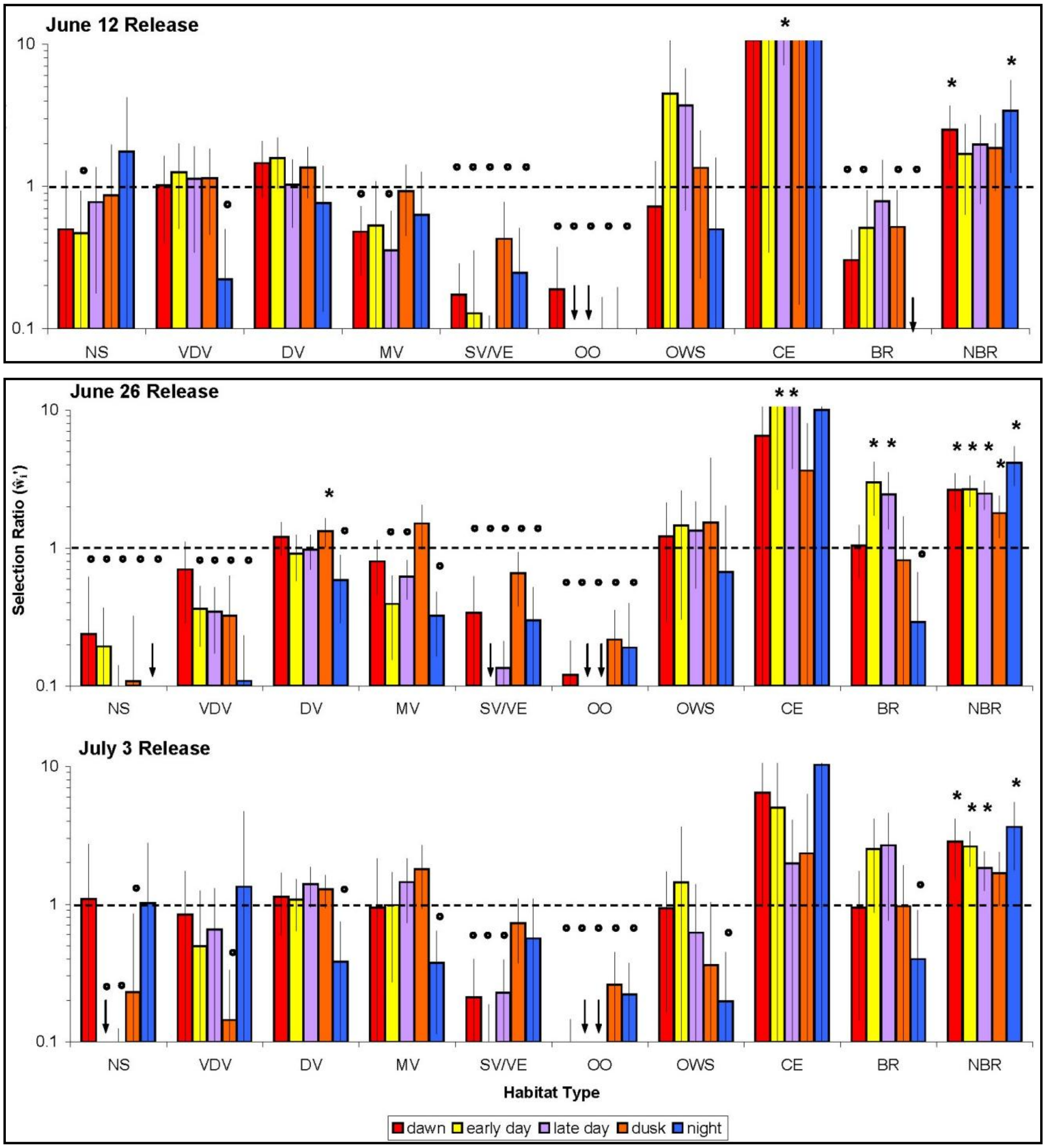

Figure 4. Diel habitat selection (ŵᵢ', selection ratio; log scale) of Chinook salmon in the SR 520 bridge tracking area, June-July, 2008. Error bars represent Bonferroni-adjusted 90% confidence intervals. Error bars indicate if selection for (>1) or against (<1) a habitat type occurred. An asterisk (*) denotes selection for a habitat and a circle (o) denotes selection against. Habitat types are described in Table 1.

Fish selected for deeper water when they were near or under the bridge or near the condo, particularly during the day. When fish were not near either structure, peak selection was observed for 2-5 m water column depth. Offshore sites, both north and south of the bridge, had higher abundances of zooplankton than nearshore sites (figure 5). Difference in depth selection relative to structure proximity was less pronounced or non-existent during crepuscular periods and at night. These corroborated similar observations in 2007, although the condo was not included in the 2007 analyses. A subtle yet noticeable shift to deeper water was also observable as the study period progressed. This was evident in both spatial frequency distribution plots and depth selection, and was observed throughout the site except near the condo.

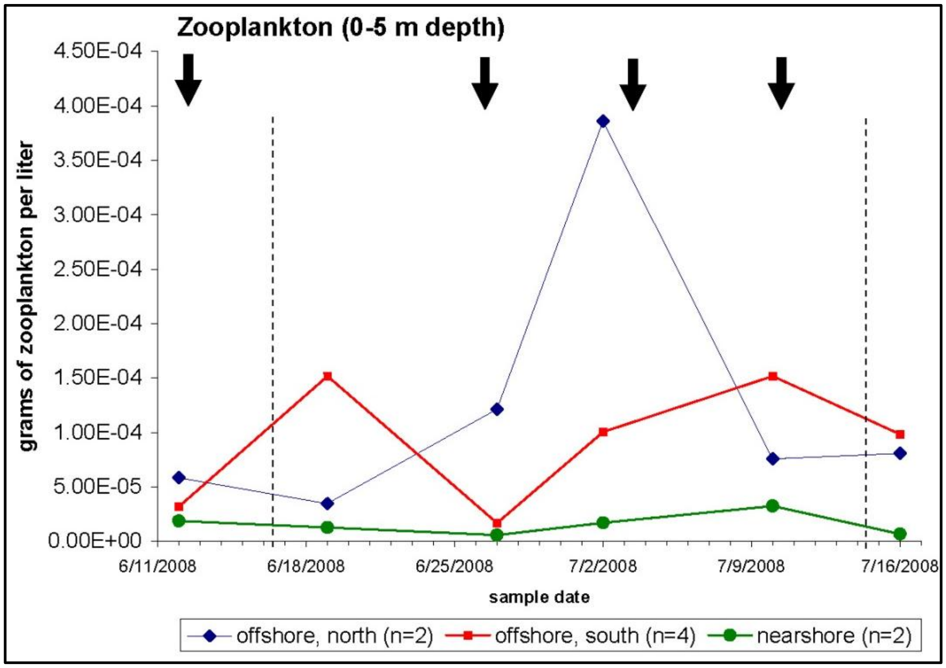

Figure 5. Mean zooplankton mass collected from 0-5 m water column depth at the SR 520 bridge study site, June 12 - July 16, 2008. Black arrows indicate when tagged Chinook salmon were released. Vertical black lines indicate moon apogee.

Most fish that were known to have passed beneath the bridge - 92% of seven release groups - were directly observed passing beneath the bridge within the study site (Table 3; Figure 6). Some fish in the multiple pass groupings may have been tracked moving from south to north on multiple occasions with no corresponding north to south movement observed. A small proportion from three releases were not directly observed passing beneath the bridge but were detected north of the bridge and/or in the LWSC, and were therefore known to have passed beneath the bridge outside of the tracking area. Three-quarters of the fish that passed under the bridge off-site did so to the west of the tracking area. These fish were initially tracked on-site on the south side of the bridge and were observed moving off-site to the west without first passing beneath the bridge. These fish were later observed on the north side of the bridge or in the LWSC.

The most common bridge passing behaviors suggested that most fish were not inhibited by the presence of the bridge. These behaviors included fish crossing beneath the bridge on multiple occasions (multiple passes), and fish milling directly beneath the bridge and/or travelling laterally beneath the bridge for distances of 10 m or more (table 3). In both years fish that were holding in and near the study area as opposed to actively migrating through often exhibited multiple and/or complex passes. In both 2007 and 2008 single, simple passes were often observed by actively migrating fish as well as by some holding fish.

Only that portion of study fish that actively migrated through the approach, encounter and pass portion of the study site were used to evaluate the effect of the bridge on migration. In 2008, only 11 observations fit this description, and of these 6 (55%) delayed by either paralleling or milling near the bridge. Those that delayed did so for an average of approximately 20 minutes. In 2007, 46 observations were used to evaluate migratory delay, and of those, 31 (67%) delayed by paralleling or milling near the bridge. Of those that delayed, the average delay was approximately 10 minutes (range of 14 s to 2774 s). Combined, these observations demonstrate that the bridge may create a delay in migration for some fish, however that delay is relatively short in duration, and for the 37 fish observed to delay, none did so for more than 47 minutes.

	Release group						
Observed bridge passing characteristics	June 1	June 14	June 28	June 12	June 26	July 3	July 10
Single, simple pass	0.72 (26)	0.12 (8)	0.26 (17)	0.07 (2)	0.10 (5)	0.08 (4)	0.40 (21)
Multiple and/or complex pass	0.14 (5)	0.59 (40)	0.57 (37)	0.41 (11)	0.60 (30)	0.57 (30)	0.38 (20)
Passed off-site							
West of site	0.11 (4)	0.06 (4)	0.02 (1)	0.11 (3)	0.04 (2)	0.04 (2)	0.00 (0)
East of site	0.00 (0)	0.03 (2)	0.05 (3)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Partial pass only	0.00 (0)	0.00 (0)	0.03 (2)	0.07 (2)	0.00 (0)	0.00 (0)	0.00 (0)
No known pass							
detected and/or tracked on-site	0.00 (0)	0.07 (5)	0.06 (4)	0.22 (6)	0.06 (3)	0.11 (6)	0.04 (2)
not detected on-site	0.03 (1)	0.13 (9)	0.02 (1)	0.11 (3)	0.20 (10)	0.21 (11)	0.15 (8)

Table 3. SR 520 bridge passing characteristics of tagged Chinook salmon, June 2007 and June-July 2008. Fish that were observed passing beneath the bridge only once without lingering beneath the bridge or crossing back to the south were labeled "single, simple pass." Fish that were observed passing beneath the bridge more than once and/or that were observed lingering or milling around directly under the bridge were labeled "multiple and/or complex pass." Fish that were observed directly beneath the bridge without ever crossing beyond the north edge of the bridge were labeled "partial pass." Fish that were never detected north of the bridge (i.e., in either the SR 520 or the LWSC arrays) were labeled "no known pass."

Fish Response to Roadway Lighting

During review of the 2008 study data, prominent groupings along the southern and northern edges of the bridge prompted further attention. Review of these data showed that they were night-time observation which led to an evaluation of the distribution of fish at night versus the location of street lights along the bridge. High concentration areas were on the same side of the bridge as the light. Areas on the opposite side of the bridge from the light usually did not show elevated fish usage. A weaker area of fish attraction appeared as a line of elevated fish usage running parallel with the bridge approximately 15-27 m from both the northern and southern edges. This appeared in both the June 12 and June 26 releases (Figure 28). This may be caused by lights on the opposite side of the bridge. Typical luminare mounting height is 40 feet from the roadway surface. Furthermore, 6 inches (height) by 13.5 inches (width) house/water-side shields are installed on the luminares mounted over water to reduce light spillage.

Review of tracking data found no evidence for a response to lighting by smallmouth bass, and density plots indicated northern pikeminnow may have a slight attraction to light or lighted areas may overlap with substrate types where pikeminnow preferentially prey at night (cobbles and boulders).

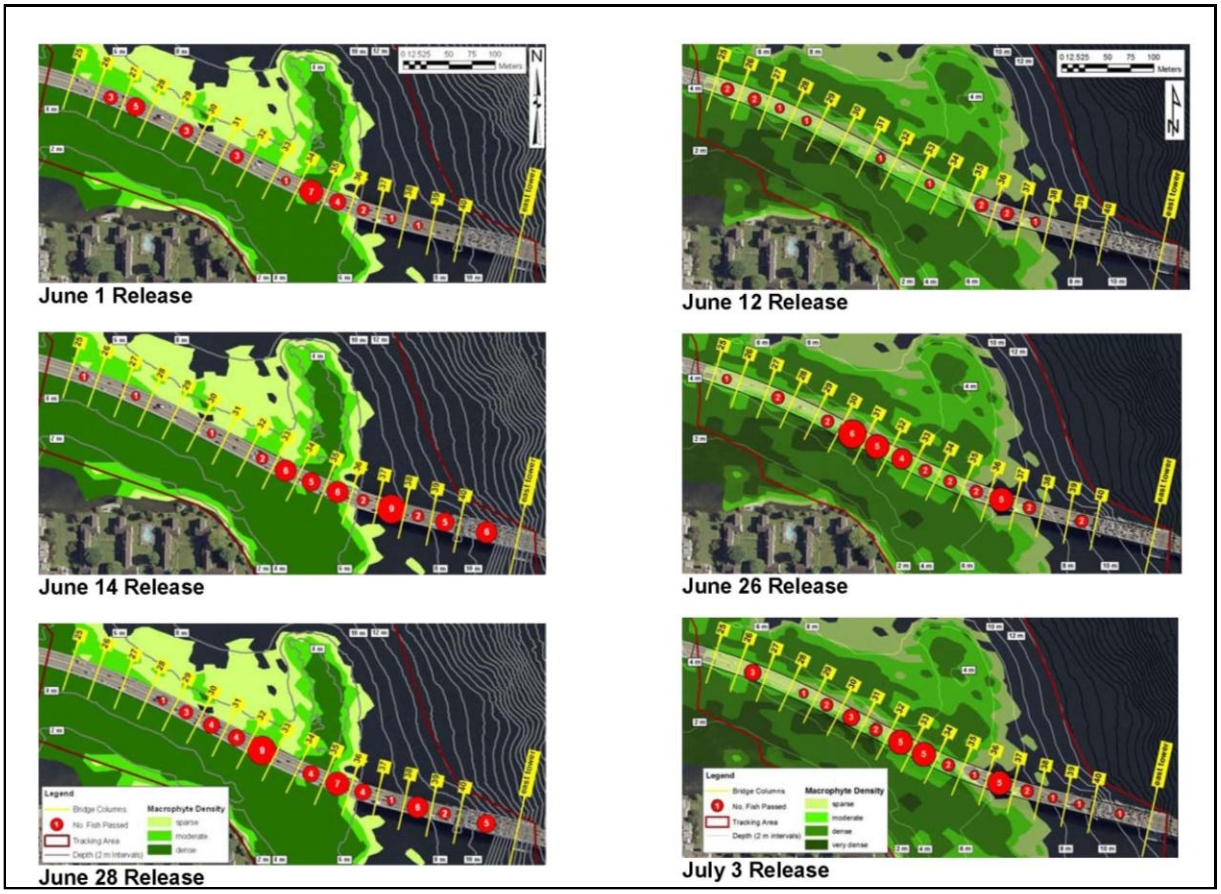

Figure 6. Locations where tagged Chinook salmon first crossed beneath the SR 520 bridge, June-July 2008. Bridge column locations are shown in yellow. Size of the red circle is relative to the number of fish that passed (white). The number of fish known to have initially passed beneath the bridge outside the tracking area is also shown: n_w and n_e are the numbers of fish that passed west and east of the site, respectively. Note that some fish passed beneath the bridge more than once (table 3). Additional passes are not shown here.

Predator Abundance and Diet Composition

A total of 337 fish were captured with gill nets, of which 135 (40%) were northern pikeminnow and 111 (33%) were peamouth (Mylocheilus caurinus). The highest mean catch per unit effort (CPUE) measured in fish per hour was observed at the Seattle Tennis Club site; however, CPUE was not statistically different between sites (Friedman test; T = 1.47; P = 0.83). Overall CPUE of smallmouth bass was much higher at the Webster Point site (0.32 fish/h); however catch and lengths were not significantly different between sites.

Diet composition for northern pikeminnow was similar between most sites (Figure 8) with fish comprising 71% of the overall diet. A large portion of the diet at Webster Point was composed of crayfish, while it made up a small proportion of the diet at Seattle Tennis Club and Wolf Bay with the other sites having intermediate abundances (Figure 9). Although the amount of food in the digestive tracts of northern pikeminnow varied widely among individuals, no there was significant differences in food per body weight between sites (Kruskal-Wallis test = 4.9; P = 0.30). All salmonids that were identifiable to species were Chinook salmon.

Overall, 50% of the smallmouth bass had an empty stomach, with sixty percent (6 of 10) from the SR 520 bridge having empty stomachs. Smallmouth bass diet was comprised primarily of either salmonids (50%), yellow perch (13.2%), crayfish (12.9%) or sculpin (9.2%). There was no apparent difference in diet between sites.

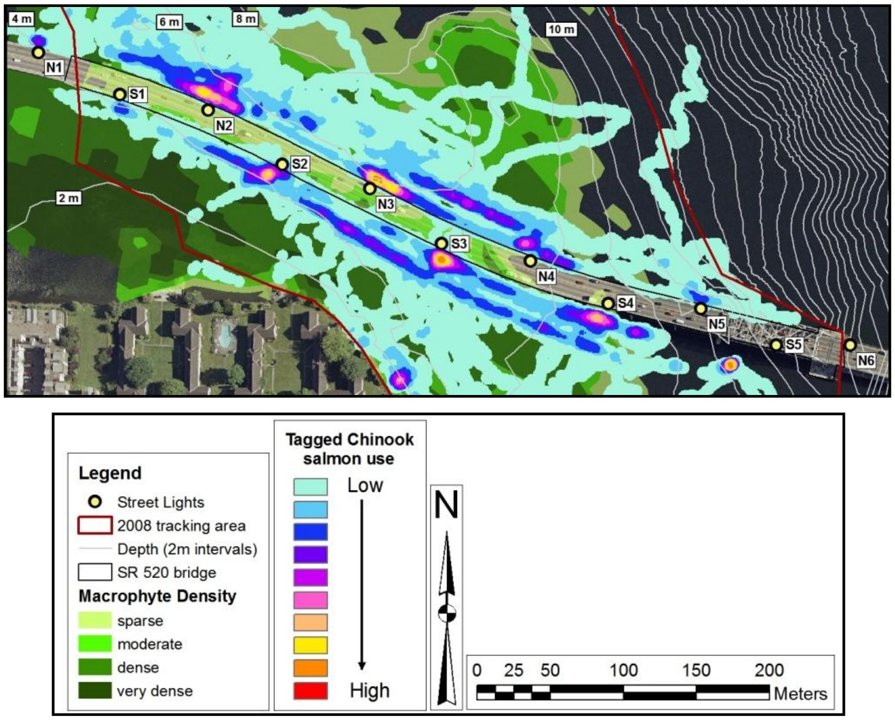

Figure 7. Night density plots of tagged Chinook salmon released on June 12 (similar patterns appear on June 26, and July 3, 2008) and tracked near the SR 520 bridge. Relative amount of time spent is indicated by the color bar, with red showing areas where fish spent the most amount of time, and blue the least. Locations of street lights on the bridge are also shown.

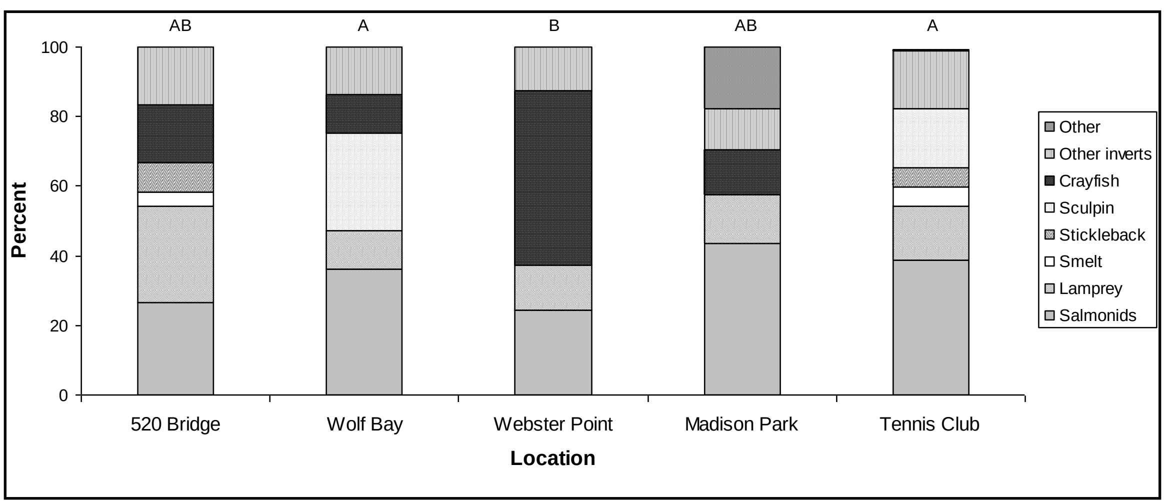

Figure 8. Mean proportion by weight (%MW_i) of northern pikeminnow at five sites in central-west Lake Washington, May-July, 2008. All sample dates were combined. Groups of bars with different letters are significantly different (Schoener's diet overlap index, C < 0.6).

Discussion

Fine-scale acoustic tracking of juvenile Chinook salmon proved to be a useful tool for evaluating Chinook movements, behavior and habitat selection.

Bridge Delays to Migration

Prior to this study, it was suggested that migration delays could present a significant source of mortality by either causing outmigrating fish to miss opportunities to outmigrate when the water temperature and other factors are more favorable to fish survival and smoltification, or by encouraging fish to delay and concentration at locations that might either attract predatory fish or provide favorable habitat for predatory fish. These two years of inquiry demonstrate that while some fish do delay at their first encounter with the bridge, these delays are, on average, relatively short in duration and that the bridge does not pose a migratory barrier for juvenile Chinook salmon. It is unknown, though possible that fish behaviors may change slightly as additional bridges are encountered. For fish tracked in this study, the SR 520 bridge is their first encounter with a bridge, while wild fish migrating to this location will have already passed under at least one additional bridge, and will pass under several additional bridges with the Ship Canal prior to migrating to salt water. Furthermore, the bridge appears to be sited in an area that juvenile Chinook salmon use both for migratory and rearing behaviors. Those fish exhibiting rearing behavior may use the bridge as habitat for feeding opportunities or as cover to access habitats not otherwise accessible.

The study area represents a transition from the steeper shoreline areas to the south that provide relatively little area within the preferred depth range for juvenile salmonids, to a more gradual lake bottom gradient that provides a wider area for outmigrating salmonids to use. This habitat characteristic allows fish to use a larger area within the bridge study area than along other shorelines further south and appears to reduce the concentrations of outmigrants at any given location. The bridge does not interfere with this distribution of juvenile salmonids as even those fish that are delayed and initially parallel the bridge, frequently pass under the bridge at or near the location of initial encounter.

Only that portion of study fish that actively migrated through the approach, encounter and pass portion of the study site were used to evaluate the effect of the bridge on migration. In 2008, only 11 observations fit this description, and of these 6 (55%) delayed by either paralleling or milling near the bridge. Those that delayed did so for an average of approximately 20 minutes. In 2007, 46 observations were used to evaluate migratory delay, and of those, 31 (67%) delayed by paralleling or milling near the bridge. Of those that delayed, the average delay was approximately 10 minutes (range of 14 s to 2774 s). Combined, these observations demonstrate that the bridge may create a delay in migration for some fish, however that delay is relatively short in duration, and for the 37 fish observed to delay, none did so for more than 47 minutes.

Piscivorous Fishes at the SR 520 Bridge

We found no evidence that northern pikeminnow were congregated at the SR 520 bridge in comparison to four other nearby sites. Tracking data found pikeminnow have a diurnal pattern to their habitat selection for soft substrates preferred during daylight hours and cobble and boulder substrates preferred at night. While some individuals expressed habitat selection for overwater structures, that trend was driven by habitat selection related to a pier in the southern portion of the study area, not the SR 520 bridge. Diet composition of northern pikeminnow found at the SR 520 bridge suggests that northern pikeminnow appear to be feeding on juvenile salmonids at a similar rates at the bridge and other nearby areas. We found no evidence to support the hypothesis that juvenile salmonids are more vulnerable to pikeminnow predation due to the bridge structure. Similarly, Ward et al. (1994) found no difference in the frequency of occurrence of juvenile salmonids in northern pikeminnow between developed and undeveloped areas of the lower Willamette River.

In contrast, tracking data suggests that smallmouth bass do appear to use the bridge and in particular the bridge columns as preferred habitat. However, when five sites were evaluated for predator abundance, smallmouth bass abundance at the SR 520 bridge was not elevated over other sites, and a single site – Webster Point – accounted for nearly half the smallmouth bass that were caught. Smallmouth bass prefer steep slopes and large substrates such as cobble and boulders (Hubert and Lackey 1980; Fresh et al. 2001). Of the five sites, Webster Point has the steepest slope between 2 and 8 m deep.

Methods for Evaluating Habitat Selection

The methods used in this study for evaluating habitat selection - namely selection ratios, spatial frequency distributions, and density plots - provide useful information in determining which areas are used more often and by more fish. However, these results can easily be misinterpreted (Garshelis 2000; Alldredge and Griswold 2006). Selection for a particular habitat type does not necessarily mean that that habitat is essential or even preferred. Conversely, habitats apparently selected against may actually be quite important to fitness and survival. These issues may arise through differences in activity specific habitat use that are not accounted for in the study (Garshelis 2000; Alldredge and Griswold 2006). For example, a habitat critical for feeding may appear infrequently used relative to resting habitat. Furthermore, less preferred habitats may become frequently used if animals are forced into them due to external factors such as habitat configuration or predation risk. Thus, habitat selection itself does not necessarily indicate preference, nor does it provide an indicator of how various habitats contribute to overall fitness and survival.

Habitat selection results must be considered for their biological significance in the proper context. For example, selection ratios and spatial frequency distributions showed that actively migrating Chinook salmon smolts (e.g., most fish from the June 1, 2007 release) selected for overwater structures (other than the bridge). This appears to have arisen because the large overwater condo on the south edge of the site lay across the preferred migrational corridor for these fish. Migrating juvenile Chinook salmon are known to avoid overwater structures (Kemp et al. 2005; Celedonia et al. 2008; Tabor et al. 2006). Thus, most fish swam along the outside perimeter of the structure rather than moving underneath. These fish also spent little time on site, which inflated the relative amount of time spent along the structure. Thus, the statistically significant selection ratio that resulted was due to lack of preferred migrational conditions (i.e., shallow water with no overwater structure) caused by spatial configuration of the area (i.e., large structure) and concomitant avoidance behavior.

Effects of Replacement Bridge on Juvenile Salmon

Ultimately, this study helps inform the design of the future replacement bridge to minimize impacts juvenile Chinook salmon. Design of the future bridge is continuing to be evaluated through NEPA and several design options are still under consideration. However, all design options currently under evaluation share some commonalities within this study area. The future bridge will be approximately 115 feet wide in this part of the lake, nearly twice as wide as the current span, and will be situated to the north of the existing span (Figures 9 and 10). While design is ongoing, it is possible that the bridge profile will be slightly higher than the existing span and the bridge will be on two separate structures with a small (approximately 7 feet) gap between the structures. Span lengths will increase from 100 feet to approximately 200 feet, and while the total cross section area of shafts will increase slightly as the diameter of individual shafts increases, the total number of shafts will decrease with fewer shafts per bent and fewer total bents (Figure 10). Roadway lighting may ultimately be eliminated from portions of the bridge including the study area, and where lights are used they are likely to have shielding to limit the leakage of light to the lake.

The projected effects from the future bridge to salmon are difficult to extrapolate. Some effects may be indirect such responses to changes to macrophyte densities caused by bridge shading. Other effects may be more direct, as the wider bridge may create a wider, darker area for fish to migrate through, however the bridge may be higher and will have a gap between the structures which may offset those effects. Further effects may result from changes in the area and distribution of shafts. Of the species studied, only smallmouth bass appeared to respond directly to in-water structures, and it is unclear if the greater spacing between shaft and shaft bents or the greater size of individual shafts will generate a population level response from smallmouth bass. If lighting is reduced either because roadway lighting is not included in this portion of the bridge or because sound walls or shielding lessens light leakage to the lake, it is likely that aggregations of juvenile salmon observed during nighttime hours will be reduced or eliminated. It is unclear what, if any, difference shifting the bridge location slightly to the north may have. Actively migrating juvenile salmon appear to change the directionality of their movements somewhat to the north of the existing span, as they begin to move in a westerly direction. This could lead to some fish attempting to pass the bridge at an angle making the transit longer, whereas most actively migrating fish currently encounter the bridge perpendicular to the bridge and continue in that orientation to take the shortest possible route under the bridge.

While the permanent effects of the new bridge are uncertain, it is likely that construction effects will impact salmonids as construction lighting, pile driving, temporary work bridges, and other in-water work will occur in the project vicinity for several years. Impacts to juvenile salmonids will be minimized by timing in-water work to avoid active migration periods. Temporary and permanent impacts to fisheries will be offset through habitat mitigation efforts.

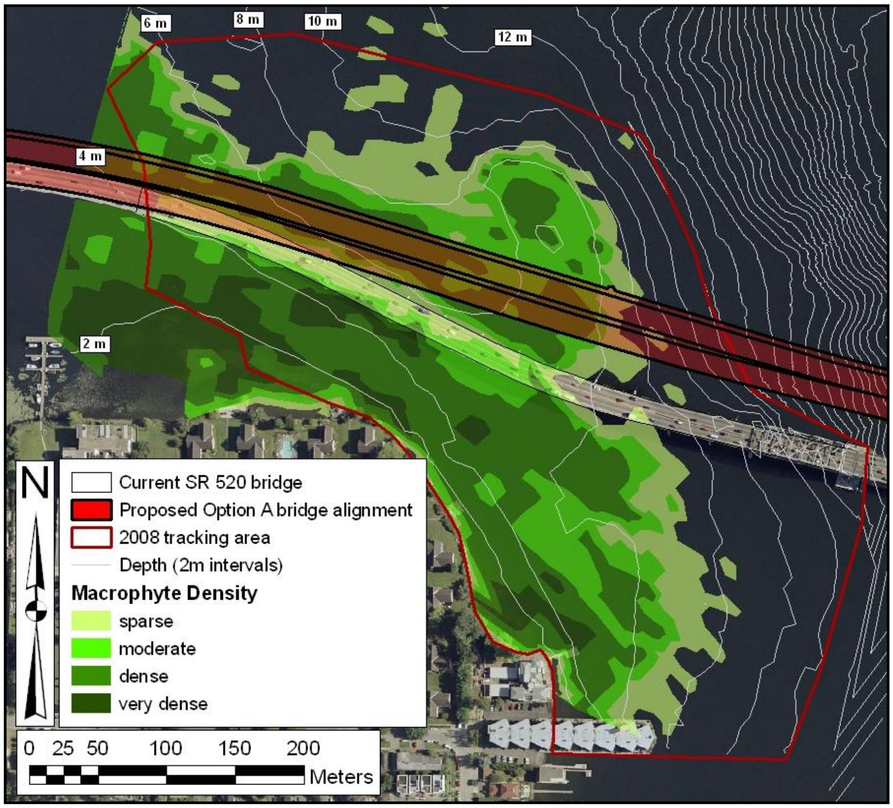

Figure 9. Proposed SR 520 bridge alignment relative to the current bridge.

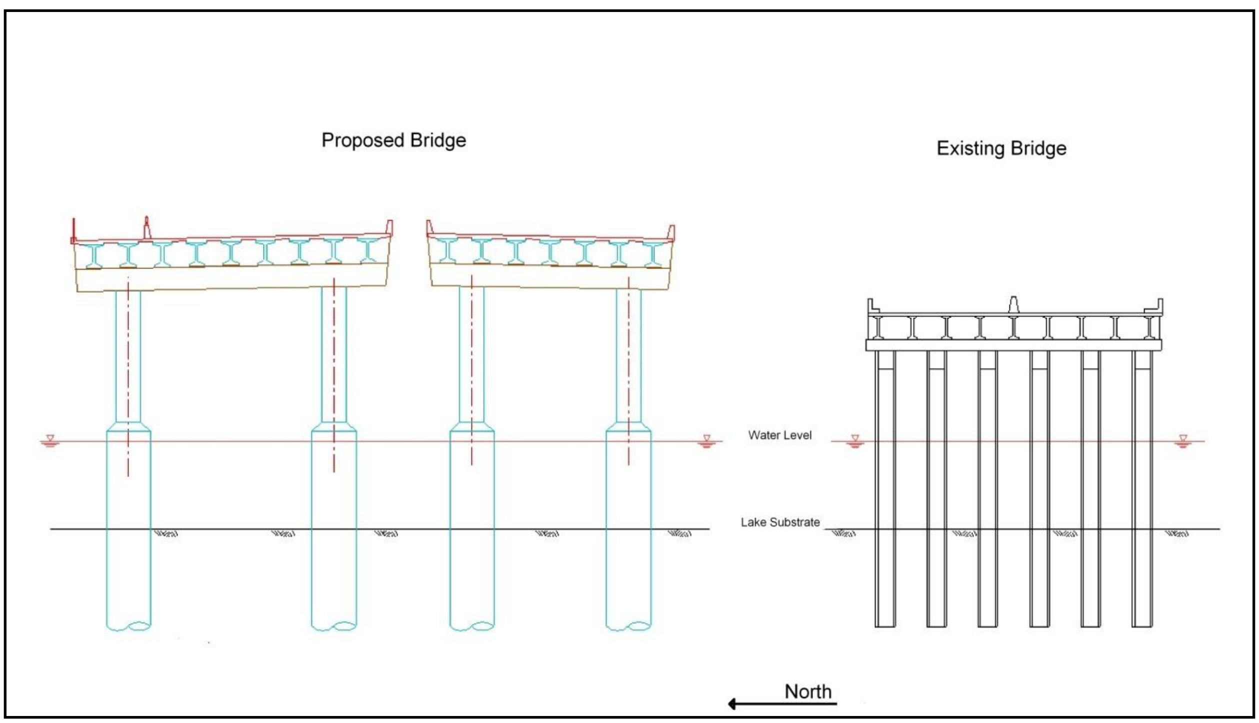

Figure 10. Cross section of existing and proposed bridge structures in study area.

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Are Non-Wildlife Underpasses Effective Passages for Wildlife?

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Abstract

In order to mitigate barrier effects of highways and exclusion fences on wildlife, many countries have invested in specific wildlife crossing structures placed at selected strategic locations. While such structures may be significant to species conservation or management at local scale, they may not necessarily suffice to maintain landscape connectivity at broad scale. Conventional, non-wildlife road bridges, tunnels and culverts, however, are usually abundant along the major infrastructure corridors and are known to be used by animals at least occasionally. Given the large number and density of such passages, their accumulative effect may well be underestimated. On the other hand, there is uncertainty about how effectiveness of wildlife passages should be judged, because clear objectives and performance targets are undeveloped. We used track inventories to study the relative use of a total of 57 conventional road underpasses in south-central Sweden by common wildlife species such as moose (*Alces alces*), roe deer (*Capreolus capreolus*), red fox (*Vulpes vulpes*), badger (*Meles meles*) and hares (*Lepus* spp.). We studied the influence of passage dimensions, design, human disturbance and landscape factors and derived recommendations on limits in size and openness based on selected multiple regressions. Our results support earlier findings in that ungulates are more sensitive to underpass dimensions as medium-sized carnivores and hares. In general, moose and, to some degree also roe deer, used underpasses much less than expected from their occurrence in the surrounding habitat, whereas badgers and foxes, in particular, showed clear preference towards the underpasses. Openness appeared as a strong predictor for the relative use by most species, but also traffic within the underpasses and distance to nearest forest cover were important variables. Landscape attributes, such as habitat composition within 500 m around the passage or the distance to the nearest alternative crossing option, were of less significance to the relative use of underpasses. We estimated that underpasses with a relative openness of 2.3 (and minimum width of 11m), with limited human and vehicular traffic (12 passages per day) and nearby forest cover (distance <15 m) are likely to be used by moose at random, i.e., as much as expected from moose activity on control track beds. Smaller animals, including roe deer, will use such passages more frequently. We propose establishing random passage use (use as expected) as a performance target for non-wildlife crossing structures. Higher targets should be set for adapted wildlife passages. Additional, ecologically scaled performance targets must address the distance between adjacent crossing facilities. We conclude that, at least in Sweden, only a minor proportion of conventional road underpasses built for local access roads provide effective passages to roe deer and smaller species, and only very few to moose. It is worthwhile studying, however, whether other facilities can be created to provide safe passage for wildlife across roads or whether additional protective features can increase the attractiveness of existing structures and thereby provide more cost-efficient mitigation than the investment in new, adapted wildlife passages.

Introduction

For more than three decades, exclusion fencing to prevent wildlife-vehicle collisions has become a standard for new highways in Sweden (Almkvist et al 1980). Over 7000 km of public roads are fenced by now and more is planned as part of road upgrading and traffic safety programs (Anders Sjölund, Swedish Road Administration, pers. comm.). Recently, however, road planners started to acknowledge barrier effects on wildlife induced by fencing and realized that not all major roads can be fenced without providing passages to wildlife (Björckebaum and Mossberg 2007). The first deer overpasses have been built (Olsson, Widén and Larkin 2008, Olsson & Widén 2008), and there is evidence, that already conventional road bridges and underpasses may reduce the risk for moose-vehicle collisions (Seiler 2004), suggesting that combining fences with passages may both enhance traffic safety and safeguard wildlife movements (Ward 1982, Dodd et al 2009). Mitigation action plans are now under development to counteract the increasing barrier effects of roads on animals as well as on humans (e.g., Swedish Road and Rail Administrations 2005).

Given the extent of the fenced road network in Sweden, however, it may not suffice, to install a few well-designed ecoducts or green bridges. Neither will it be necessary to invest in wildlife passages every two to three kilometers. Rather, it appears more effective and desirable to integrate wildlife crossing solutions in the regular road-planning scheme and use them as part of a more general landscape permeability concept (Iuell et al. 2003). This may include various options including automated deer-warning systems installed in fence openings (Huijser and McGowen 2003), traffic rerouting and calming (Jaarsma and Willems 2002), speed reduction (Seiler 2005), and the adjustment of conventional road crossings for a combined use by humans and wildlife (e.g., Rosell et al. 1997, Mata et al. 2008).

In Sweden, thousands of non-wildlife underpasses (and bridges) separate highway traffic from privately owned local access roads, human and cattle trails. Many more underpasses exist for creeks and rivers, while a few viaducts span over entire valleys or wetlands. Although presumably none of these structures has been build with respect to wildlife or provides any fauna adjustments, they may nevertheless be used to a varying degree by deer and other larger mammals. Anecdotal observations (by the authors) and unpublished inventories from Sweden (Seiler & Rydin 1998) suggest that even moose (*Alces alces*) may eventually use pedestrian culverts as small as 2 meter in diameter, while roe deer (*Capreolus capreolus*) may regularly utilize unprotected road bridges (4 m width and 40 m length) over motorways. Also other studies have documented a more or less frequent use of conventional, non-wildlife road passages by animals (e.g., Olbrich 1984, Yanes et al 1995, Rodriquez et al 1996, Ng et al. 2006, Mata et al. 2008). Given the large number of existing road passages in the Swedish countryside and the relative low degree of disturbance by humans or local traffic, the beneficial effect of these unintended crossing structures might thus be underestimated.

However, the mere occurrence of animal tracks within an underpass does not automatically imply that the structure is efficient for the species in question. The observed pattern could simply result from a high animal abundance in the surrounding habitat but still express avoidance behavior. To control for this, the number of tracks found in an underpass must be related to some measure of animal abundance or activity outside the passage (Clevenger and Waltho, 2000, 2005). At a proximate level, when the number of tracks going through a passage is equal or higher than expected from chance, i.e., from the species' occurrence in the surrounding, the passage could be considered as at least locally effective. Ultimately, however, this does not imply that this single structure will be efficient in preventing genetic isolation or demographic divergence at large. To achieve this, many more effective passages may be needed along the barrier line.

While the understanding of passage effectiveness is still weak, knowledge about the use of crossing structures by wildlife and the factors that discourage or promote their use is quickly increasing (see Glista et al. 2009, for review). Three main classes of factors determining passage use can be distinguished: passage structure and dimension, surrounding landscape features including habitat distribution, and human disturbances (e.g., Rodriguez et al. 1997, Cain et al. 2003, Clevenger and Waltho 2000, Ascensão and Mira 2007). The effect of these variables is highly species specific. Ungulates, for example, are generally more reluctant to use narrow road underpasses than medium-sized carnivores (e.g. Mata et al. 2008), whereas larger carnivores may be more sensitive to human disturbances in crossing structures than to dimensions (Clevenger and Waltho 2000). However, only few of all relevant variables can be addressed in the planning of conventional road passages. In practice, it is mainly the width of an underpass, the vegetation cover at its immediate surrounding, the fencing of the road above, and additional structural components such as noise or light shields, that can be adjusted by road engineers with relative ease. All other variables are either limited by constraints for traffic safety, road standard or other technical matters, or cannot be controlled for by the transport sector (habitat composition, topography, human use of underpass).

In our study, we therefore put special emphasis on the effect of underpass dimensions but included other ecologically meaningful parameters as well, such as distance to nearest alternative passage or frequency of vehicles and humans trespassing the underpass. Our main concern was to evaluate whether or not, and under what conditions, conventional road underpasses can be regarded as effective wildlife passages. We conclude by proposing limit values for passage dimensions that at least will ensure a random use by wildlife.

Materials and Methods

Study Sites

During 1997 to 2005, we conducted a series of inventories of the use of conventional road crossing structures by wildlife. Here, we present results from 57 typical minor road underpasses built under 6 major motorways, (E4, E6, E18, E22, RV40, RV44) in southwestern and southeastern Sweden (figure 1). The locations were selected in order to be representative for road underpasses made for forestry or agricultural local access roads under motorways, while maximizing the variation in passage dimensions (figure 2) and reducing the variation in road characteristics, traffic volume, habitat composition, and species occurrences. The underpasses were located in areas dominated by coniferous, semi-boreal forest, with no permanent housing in immediate vicinity and with no or only very limited trespassing vehicular traffic or human disturbance. None of these passages, except one large culvert (E6-9), was originally designed for wildlife and none was equipped with protective shields to reduce disturbance of animals by traffic noise or light. Most passages (N=49) were standard concrete bridges (figure 3), while some contained steel-tunnels built primarily for pedestrians (N=8). Some underpasses (N=12) consisted of two adjacent constructions separated by a small opening for the central reserve between the motorway lanes, but most were closed, single buildings. A few underpasses contained both road or trail and a small watercourse (N=5), while the majority was dry (N=52). All structures were considered large enough to at least in theory provide passage for moose, i.e., their opening was larger than 2 m in diameter. All motorways were fenced against larger wildlife (standard moose fences of 2 m in height), and carried a traffic load above 10,000 vehicles per average day (National Road Database 2007). Local traffic, pedestrians, as well as larger animals were not supposed or able to cross the motorways at grate.

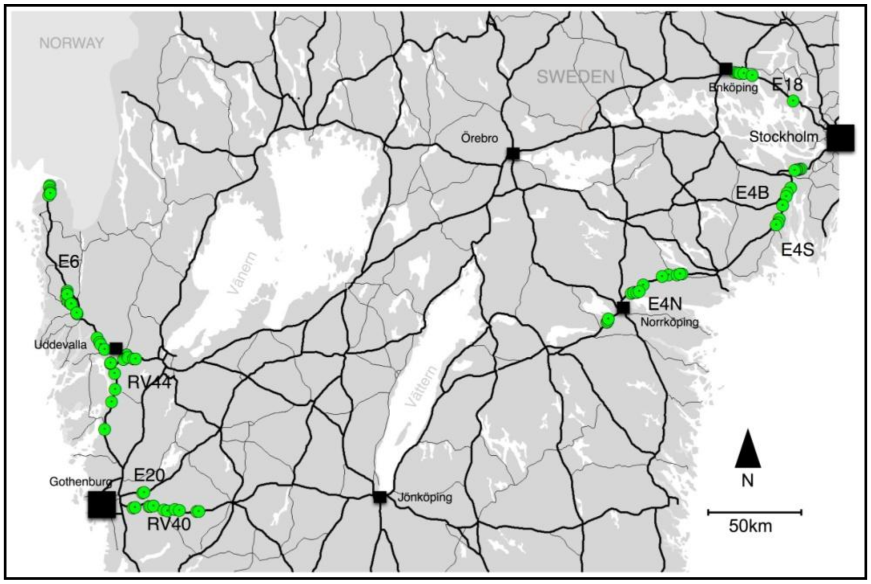

Figure 1: Map over south-central Sweden with study sites.

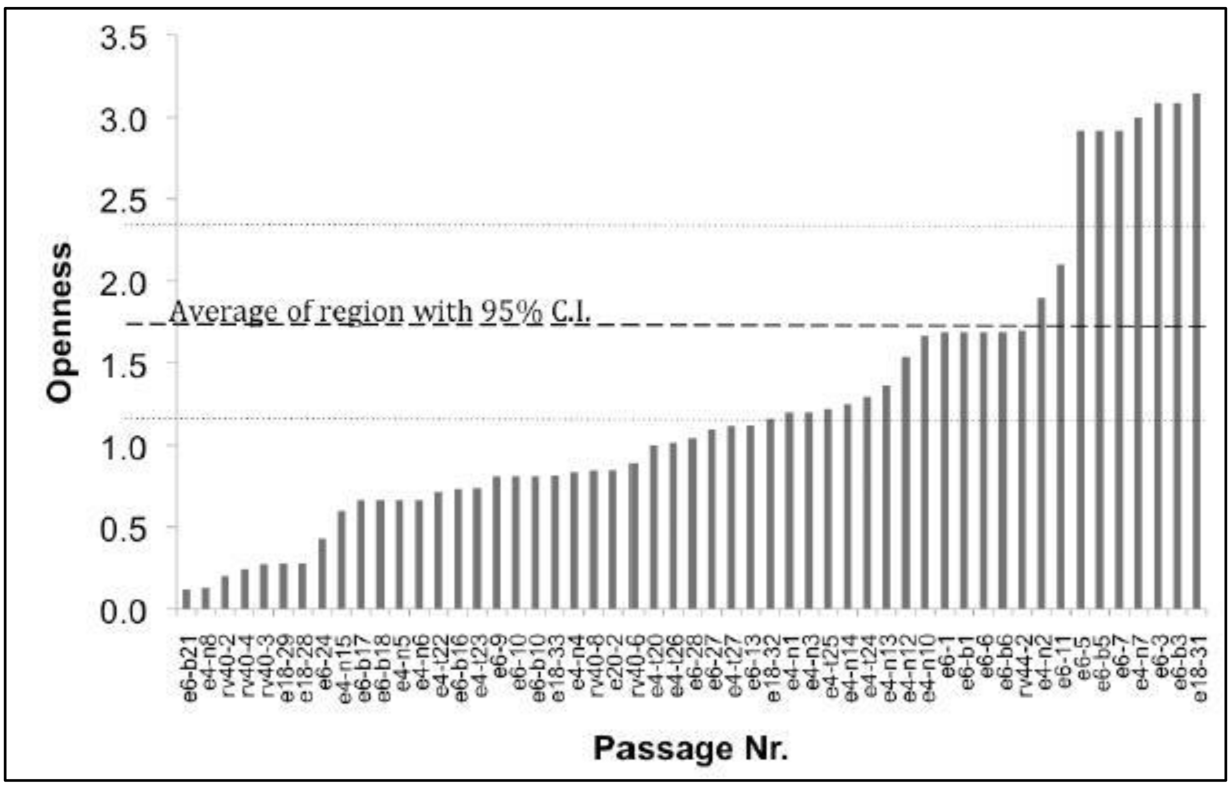

Figure 2: Variation in openness among the studied underpasses.
Dotted lines indicate the average openness calculated for all similar underpasses (N=185) under motorways in the region VMN of the Swedish Road administration (SRA bridge database 2007).

Figure 3: Picture of a typical road underpass for local but publicly used gravel road in Sweden. The picture shows underpass E4N-12 (width 8m, height 5m, length 26m, openness 1.54) that has been completely avoided by moose (U=0), but used to some degree by roe deer (U=0.32), more often by foxes (U=0.63) and very frequently by hares (U=0.96). Photo Andreas Seiler.

On each location (table 1), we measured the structural dimensions of the underpass, and the distance to the nearest bridge, tunnel or fence opening that eventually could be used by wildlife to cross the highway. Vehicular traffic passing through the underpasses was estimated based on vehicle counts made during the inventories and specific visits, averaged as number of vehicles per daytime hour. Land cover proportions (within 200 m distance from underpass) and the number of and the distance to houses and nearest continuous forest (within 500 m distance) were quantified from topographic satellite maps (Swedish Land Survey, SMD maps). Road and road traffic data was obtained from the National Road Database of the Swedish Road Administration (SNRA 2007).

Variable	Description
Tracks on test bed	Averaged number of tracks found per day on the sand bed within the underpass
Tracks on controls	Averaged number of tracks found per day on all control sand beds
Usage of underpass	Response variable, Proportion of tracks in underpass of all tracks recorded
LENGTH	length of the underpass ceiling (in meter)
WIDHT	maximum width of the underpass (in meter)
HEIGHT	maximum height of the underpass (in meter)
OPEN	Openness = width * height / length
TRAFFIC	Average number of cars recorded per hour within the underpass
HOUSES	Number of buildings within 500 m from the underpass (on topographic map)
HOUSE_DIST	Distance to the nearest building (on topographic map)
FOREST_DIST	Distance to nearest forest cover (on topographic map)
FOREST_RATIO	Ratio of forest cover within 200 m between the opposite road sides
PASS_DIST	Distance to the nearest crossing structure (tunnel, bridge, end of fence)
ROADS	Density of roads within 500 m radius from the underpass (km/km2)
URBAN	Percentage of urban land cover within 200 m radius
AGRICULT	Percentage of agricultural land within 200 m radius
FOREST	Percentage of forest within 200 m radius (sum of dec, con, mix)

Table 1: Description of measured variables.
Land cover percentages and usage proportions were arcsine transformed.

Tracking

We used track beds to record animal movements within and nearby the selected road underpasses. Track beds consisted of sand layers (1 m in width, about 3-5 cm in depth, and length equal to the diameter of the underpass) placed within each underpass (test bed) and in the nearer surrounding on either side of the road (control beds). Depending on topography and vegetation, one to three control beds of the same size as the test bed were placed on either side within 100 m from the entrances of the passage. Animal tracks recorded on the control beds of a given site were averaged over all controls and both roadsides.

The track beds were re-visited for new tracks on a weekly basis in intervals of usually 1-3 days. Each track was identified and counted, if the sand layers were found operational, that is not disturbed by heavy rain, vehicles or animals. However, it was not possible to determine the number of individuals that crossed each bed. After each visit, the sand beds were raked smooth in preparation of the next visit.

A total of 57 road underpasses were studied in this way, however, the final sample that could be used in the analysis for each respective species was smaller (table 2). In order to combine data collected during different years and by different field personnel, we imposed the following qualitative and quantitative restrictions:

- Only data from inventories made during June to November was used, which was the period of year where data existed in all passages.
- Each location must have been re-visited and measured at least 9 times independently.
- For a location to be included the analysis of one species, it had to be visited at least 3 visits by the species in question (i.e., tracks were found on either test or control beds).
- Inventories were considered valid when the time interval between consecutive measurements was 1-3 days, in moose <7 days, however, provided that the sand layers were found operative.

Species	N sites studied	N repeated visits	Mean N of visits per site	N tracks in underpass	N tracks in mean control
Moose	26	912	35	77	204
Roe deer	51	1344	26	306	777
Badger	18	667	37	130	195
Red fox	25	905	36	203	231
Hares	10	466	47	75	106

Table 2. Sample sizes (*number* of sites and number of visits) and number of visits where animal tracks were found on either test or control sand beds, respectively.

On average, we obtained 36 operative visits per location and between 10 to 51 valid sites per species (table 2). Various wildlife species including wild boar (*Sus scrofa*), lynx (*Felis lynx*), red deer (*Cervus elaphus*), otter (*Lutra lutra*) were found to use some of the sites occasionally, but only moose, roe deer, red fox (*Vulpes vulpes*), badger (*Meles meles*) and hares (*Lepus europeaus and Lepus timidus*) produced sufficient data to be included in this analysis.

Index of Use

We calculated the relative use of an underpass by a given species as the ratio of tracks found in the underpass per operative day to all tracks found in underpass and control beds combined. Hence, the relative use is given as $U = P / (P + C)$, where P is the number of tracks found on the test bed within the underpass per day and C is the average number of tracks per day found on all control beds combined. The index value ranges hence from zero to one, with 0.5 indicating that the passage was used as much as what could be expected from the controls. In other words, if $U = 0.5$, the underpass is neither repelling nor attracting wildlife and has the same chance of being visited as an average control sand bed in the surroundings. For the regression analysis, U values were arcsine transformed to compensate for the skewed distribution (Zar 1998) and averaged over all measurements per location and species.

Statistical Analysis

We used Mann-Whitney U tests to distinguish different types of underpasses in their effect on passage use by wildlife (concrete rectangular underpass versus steel tunnel; closed versus divided passage; dry passage versus combined with water). However, since we did not find a differential effect on passage use in any of these pairs (minimum p-value=0.235, U=46, adj. Z=-1.185, N=19,7), passage type was not maintained as predictor variable in the further analysis.

We then used univariate regression models to identify which of the independent (continuous) variables correlated with passage use. To reduce intercorrelation among these predictor variables, we used only the most effective variable of those that, after a sequential Bonferroni correction (Rice 1989), significantly correlated with each other. The remaining variables were entered in general regression models with the response variable being the arcsine transformed relative use per species. The models were ranked using Akaike's Information Criteria (AIC) to identify the most parsimonious subsets (Burnham & Anderson 2002). Among these subsets (difference from model with lowest AIC value < 2), we chose the model that combined most factors that that are subject to road planning, i.e. passage dimensions (width, height, openness), location (distance to nearest alternative passage and distance to nearest forest cover) and human disturbance (trespassing vehicular traffic, vicinity to houses, density of roads). Calculations were performed with the statistical software package STATISTICA (StatSoft 2008).

Results

We observed clear differences among the species in how readily they used conventional road underpasses (table 3). On average, moose was significantly reluctant to cross through the passages (mean U=0.33), while foxes clearly selected using the underpasses. Roe deer and badgers, correspondingly, showed similar but not significant behavior (at 95% level). In all species except hares, the frequency of tracks found within the underpasses was strongly correlated with track frequency on control beds (p<0.001). The relative use, however, was affected by passage dimensions, passage location and the surrounding habitat. As expected, the variables acted differently on the different species. Overall, passage openness provided a better predictor for the relative use than passage width, length or height, individually or combined. Human and vehicles using the underpass were a valuable predictor for the use by most species, whereas the distance to the nearest alternative crossing structure (ca 800 m on average) had little effect on underpass use. As intended by the design of our study, location and landscape variables such as the distance to the nearest building, number of houses, forest cover, etc. (table 4), varied only little and provided therefore weaker predictors.

Species	Mean relative use	SD	t	df	p
Moose	0.33	0.31	-2.84	25	0.009
Roe deer	0.44	0.25	-1.81	50	0.077
Badger	0.63	0.27	1.98	17	0.064
Red fox	0.76	0.12	10.88	24	0.000
Hares	0.63	0.32	1.23	9	0.250

Table 3. Test of means of relative underpass use against the reference constant U=0.5 (relative use as expected from controls).

	MOOSE (N=26)					ROE DEER (N=51)				
Variable	Mean	±	S.D.	R	*p*	Mean	±	S.D.	R	*p*
Tracks on testbed	0.026	±	0.036			0.095	±	0.122		
Tracks on controls	0.025	±	0.032			0.090	±	0.091		
Usage of underpass	**0.325**	**±**	**0.314**			**0.437**	**±**	**0.247**		
LENGTH	25.715	±	3.999	-0.504	*0.009*	26.849	±	7.105	-0.138	*0.335*
WIDHT	6.958	±	3.270	0.409	*0.038*	6.569	±	3.108	0.257	*0.069*
HEIGHT	4.896	±	0.867	0.167	*0.414*	4.571	±	1.219	0.200	*0.159*
OPENNESS	1.462	±	0.896	0.498	*0.010*	1.269	±	0.841	0.275	*0.051*
TRAFFIC	0.952	±	2.167	-0.250	*0.219*	0.874	±	1.761	-0.330	*0.018*
HOUSES	2.885	±	2.658	0.258	*0.204*	3.765	±	4.407	0.345	*0.013*
HOUSE_DIST	294.0	±	165.8	-0.270	*0.183*	310.3	±	194.0	-0.037	*0.798*
FOREST_DIST	5.032	±	12.178	-0.189	*0.356*	16.468	±	36.330	0.253	*0.073*
FOREST_RATIO	0.469	±	0.134	-0.143	*0.486*	0.501	±	0.197	0.010	*0.943*
PASS_DIST	812.3	±	339.9	-0.160	*0.436*	807.9	±	378.1	-0.129	*0.369*
ROADS	1.380	±	0.872	-0.522	*0.006*	1.504	±	0.789	-0.258	*0.067*
URBAN	11.878	±	6.085	-0.551	*0.004*	14.871	±	6.422	-0.180	*0.207*
AGRICULT	21.706	±	11.320	0.049	*0.814*	23.590	±	13.668	0.333	*0.017*
PASTURE	12.594	±	7.506	0.167	*0.415*	12.805	±	7.205	0.318	*0.023*
DECIDUOUS	14.549	±	6.396	0.184	*0.369*	13.015	±	5.962	-0.171	*0.230*
CONIFEROUS	39.677	±	10.152	-0.096	*0.641*	38.423	±	11.417	-0.282	*0.045*
MIXED	2.539	±	2.627	-0.174	*0.397*	2.502	±	2.806	0.163	*0.253*
FOREST	56.765	±	12.330	-0.021	*0.920*	53.941	±	13.508	-0.280	*0.047*

	BADGER (N=18)					FOX (N=25)				
Variable	Mean	±	S.D.	R	*p*	Mean	±	S.D.	R	*p*
Tracks on testbed	0.066	±	0.084			0.066	±	0.051		
Tracks on controls	0.039	±	0.072			0.017	±	0.013		
Usage of underpass	**0.627**	**±**	**0.271**			**0.763**	**±**	**0.121**		
LENGTH	29.122	±	7.778	0.300	*0.227*	26.028	±	8.361	0.065	*0.758*
WIDHT	6.200	±	2.939	-0.127	*0.617*	6.656	±	3.144	-0.368	*0.071*
HEIGHT	4.694	±	1.446	0.003	*0.992*	4.456	±	1.306	-0.234	*0.261*
OPENNESS	1.153	±	0.818	-0.127	*0.616*	1.302	±	0.888	-0.401	*0.047*
TRAFFIC	0.524	±	1.107	-0.651	*0.003*	0.789	±	1.422	0.205	*0.326*
HOUSES	2.222	±	1.927	0.183	*0.468*	4.320	±	4.534	0.017	*0.936*
HOUSE_DIST	372.6	±	187.9	0.042	*0.867*	339.7	±	234.1	0.134	*0.523*
FOREST_DIST	12.667	±	27.788	0.033	*0.896*	21.822	±	40.127	-0.072	*0.733*
FOREST_RATIO	0.504	±	0.177	0.298	*0.229*	0.476	±	0.194	0.272	*0.189*
PASS_DIST	869.1	±	368.8	-0.276	*0.267*	831.5	±	386.1	0.107	*0.611*
ROADS	1.330	±	0.863	-0.456	*0.057*	1.430	±	0.691	0.067	*0.749*
URBAN	14.583	±	5.927	-0.167	*0.509*	15.513	±	6.546	0.363	*0.075*
AGRICULT	24.251	±	15.065	-0.014	*0.955*	25.258	±	14.139	-0.165	*0.431*
PASTURE	10.737	±	7.345	-0.006	*0.980*	11.434	±	7.067	-0.337	*0.099*
DECIDUOUS	12.783	±	4.855	0.018	*0.945*	12.450	±	5.072	0.054	*0.798*
CONIFEROUS	39.776	±	12.843	0.103	*0.685*	38.630	±	11.802	0.101	*0.631*
MIXED	3.188	±	3.104	0.354	*0.150*	2.873	±	3.091	-0.025	*0.907*
FOREST	55.748	±	14.412	0.174	*0.491*	53.952	±	13.665	0.102	*0.629*

	HARE (N=10)				
Variable	Mean	±	S.D.	R	*p*
Tracks on testbed	0.023	±	0.022		
Tracks on controls	0.009	±	0.010		
Usage of underpass	**0.626**	**±**	**0.323**		
LENGTH	24.960	±	3.956	-0.558	*0.094*
WIDHT	7.700	±	2.936	0.502	*0.139*
HEIGHT	5.150	±	0.280	0.208	*0.564*
OPENNESS	1.674	±	0.810	0.510	*0.132*
TRAFFIC	1.189	±	1.802	0.279	*0.435*
HOUSES	2.800	±	2.700	0.236	*0.511*
HOUSE_DIST	330.6	±	206.2	-0.409	*0.240*
FOREST_DIST	9.794	±	18.670	0.002	*0.996*
FOREST_RATIO	0.503	±	0.124	0.209	*0.563*
PASS_DIST	837.0	±	365.0	0.397	*0.256*
ROADS	1.614	±	1.059	0.114	*0.753*
URBAN	13.907	±	5.971	-0.249	*0.488*
AGRICULT	20.786	±	8.772	0.627	*0.052*
PASTURE	12.039	±	5.538	0.076	*0.835*
DECIDUOUS	14.994	±	3.686	-0.522	*0.122*
CONIFEROUS	39.458	±	9.212	-0.113	*0.755*
MIXED	3.047	±	3.195	-0.643	*0.045*
FOREST	57.499	±	12.152	-0.413	*0.235*

Table 4. Descriptive statistics of the selected variables and their univariate correlation (R-value) with the usage of underpasses by the given species.

Moose

Underpass use by moose increased significantly with openness (R^2=0.248, $F_{1,24}$=7.92, p<0.010) and width (R^2=0.167, $F_{1,24}$=4.82, p<0.038), as well as with reduced passage length (R^2=0.254, $F_{1,24}$=8.17, p<0.008). Openness together with the amount of traffic through the underpass and the distance to the nearest forest cover comprised one of the best variable subsets according to AIC comparison (table 5), but still explained only a small part of the observed variation in use (adjusted R^2 = 0.29). Overall, passage use by moose was adversely affected by human disturbance (roads, houses, agriculture) in the surroundings, by human use of the underpass (traffic), and by the distance to nearest forest cover. However, these variables were only effective if combined with passage dimensions, and decreased only slightly the residual variation.

Roe deer

Roe deer was generally less affected by passage dimensions than moose (OPEN: R^2=0.076, $F_{1,49}$=4.016, p<0.051; WIDTH: R^2=0.066, $F_{1,49}$=3.455, p<0.069), but more sensitive to traffic (R^2=0.109, $F_{1,49}$=5.982, p<0.018). As in moose, openness combined with traffic and distance to forest cover, produced one of the best variable subsets explaining underpass use by roe deer (table 4, adj. multiple R^2=0.184, $F_{4,21}$=4.757, p<0.006). Usage also increased significantly with more houses, more agriculture and less forest cover in the surroundings of the underpass, thus reflecting the species' habitat preferences. However, despite the comparably large sample size in roe deer, these models resolved only little of the observed variation (table 5).

Badger

Badgers appeared indifferent to passage dimensions as they frequently used even the smallest underpasses (R^2=0.055, $F_{1,16}$=0.117, p>0.737). In fact, their tracks were found more often in the underpasses than expected from track frequency on the control beds, although the difference was not significant (table 3). On the other hand, badgers responded negatively to traffic, and as in roe deer, this factor was by far the single most influential predictor of the relative underpass use by this species (table 4; R^2=0.423, $F_{1,16}$=11.790, p<0.003).

Red Fox

Foxes clearly took greatest benefit from road underpasses as they used them on average 50% more often than expected, were not sensitive to trespassing traffic, and seemed overall little affected by location and landscape parameters. However they preferred smaller passages (R^2=0.161, $F_{1,23}$=4.402, p<0.0469).

Hares

In hares, sample size was very limited (N=10). Nevertheless, the best variable subset contained openness, traffic and the proportion of deciduous forest cover in the surrounding landscape (table 5; R^2=0.763, $F_{3,6}$=6.433, p<0.022). Hares seemed to avoid underpasses that were frequently used by foxes (R^2=0.312, $F_{1,8}$=5.093, p<0.054), and when underpass use by fox was included as independent variable in the multiple regression analyses, subsets containing fox, traffic and agriculture ranked second best according to their AIC.

Regression Coefficients						Model	
MOOSE	Coeff. (B)	S.E	S.E. of B	t-Value	P-Value	DF	F
Intercept	0.122	0.118	0.122	1.036	0.312	3,22	4.40
OPENESS	0.216	0.069	0.536	3.153	0.005	adj. R2	P
TRAFFIC	- 0.053	0.028	- 0.317	- 1.866	0.075	0.29	0.014
FOREST_DIST	- 0.006	0.005	- 0.205	- 1.216	0.237		
ROEDEER	Coeff. (B)	S.E	S.E. of B	t-Value	P-Value	DF	F
Intercept	0.377	0.067	0.377	5.627	0.000	3,47	4.76
TRAFFIC	- 0.054	0.021	- 0.339	- 2.599	0.013	adj. R2	P
OPENESS	0.094	0.044	0.282	2.167	0.035	0.184	0.006
FOREST_DIST	0.001	0.001	0.179	1.370	0.177		
BADGER	Coeff. (B)	S.E	S.E. of B	t-Value	P-Value	DF	F
Intercept	0.611	0.206	0.611	2.958	0.010	2,15	5.38
TRAFFIC	- 0.173	0.060	- 0.579	- 2.901	0.011	adj. R2	P
FOREST_RATIO	0.388	0.375	0.206	1.033	0.318	0.340	0.017
FOX	Coeff. (B)	S.E	S.E. of B	t-Value	P-Value	DF	F
Intercept	1.008	0.067	1.008	15.139	0.000	1,23	4.42
OPENESS	- 0.089	0.043	- 0.401	- 2.102	0.047	adj. R2	P
						0.125	0.047
HARE	Coeff. (B)	S.E	S.E. of B	t-Value	P-Value	DF	F
Intercept			1.229	3.182	0.019	3,6	7.03
DECIDUOUS	- 0.657	0.193	- 0.077	- 3.399	0.015	adj. R2	P
OPENESS	0.613	0.201	0.326	3.054	0.022	0.668	0.022
TRAFFIC	0.431	0.200	0.103	2.158	0.074		

Table 5. Results of selected multiple linear regression models for underpass usage by five game species. For more information about model selection see text.

Limits	Moose	Roe deer	Badger	Fox	Hares
openness	2.3 (**)	1.4 (**)	NA	NA	1.2 (°)
width	11m (**)	7m (**)	ns	ns	ns
length	22m (°)	23m (*)	ns	ns	ns
height	ns	4.5m (*)	ns	ns	ns

Table 6. Recommended dimensions for wildlife adjustments of road underpasses based on multiple regressions (compare table 4). The models include additional predictor variables: TRAFFIC (=0.5 v/h), FOREST_DIST (=15m) and in hares: DECIDUOUS (=15%). Underpass use by badgers and foxes was not limited by passage dimensions within the observed range. Significance levels: NA not applicable, ns p>0.1, ° p<0.1, * p<0.05, ** p<0.01.

Limit Values

Based on the coefficients of the above multiple regression models, the set of conditions can be predicted under which track frequencies in an underpass are likely equal or exceed those expected from controls, i.e., when the underpass can be considered being effective (table 6). In an average situation, that is, when only a few vehicles pass through the underpass (Traffic < 0.5 /h), and forest cover is nearby (< 15m from structure), the underpass should have an openness index larger than 2.3 in order to provide an effective passage for moose, or 1.4 for roe deer, respectively. In hares, given the same conditions as above plus a proportion of deciduous forest cover of 15% within 500m of the location, an openness of 1.2 may probably suffice. These limits for underpass openness include, however, that the width is not smaller than 11 m in moose or 7 m in roe deer, respectively. Already somewhat narrower passages, more traffic, or greater distance to forest cover will start to discourage these animals from using the underpass, whilst not entirely preventing its usage by these species.

In figure 4, we used univariate regressions between openness and relative use by moose and roe deer, to illustrate how usage changes with openness. These regressions are highly significant (Moose R^2=0.639, $F_{1,25}$=44.24, p<0.0001; Roe deer R^2=0.645, $F_{1,50}$= 90.68, p<0.0001), as we excluded the intercept (roe deer: 0.336, moose: 0.072) assuming that an openness of null would not allow any animals to use to passage. However, confidence limits for these predictions are large. In moose, for example, the threshold openness may range from 1.7 to 5.2 (mean 2.4). Note also that these univariate predictions deviate from the limit values proposed in table 6.

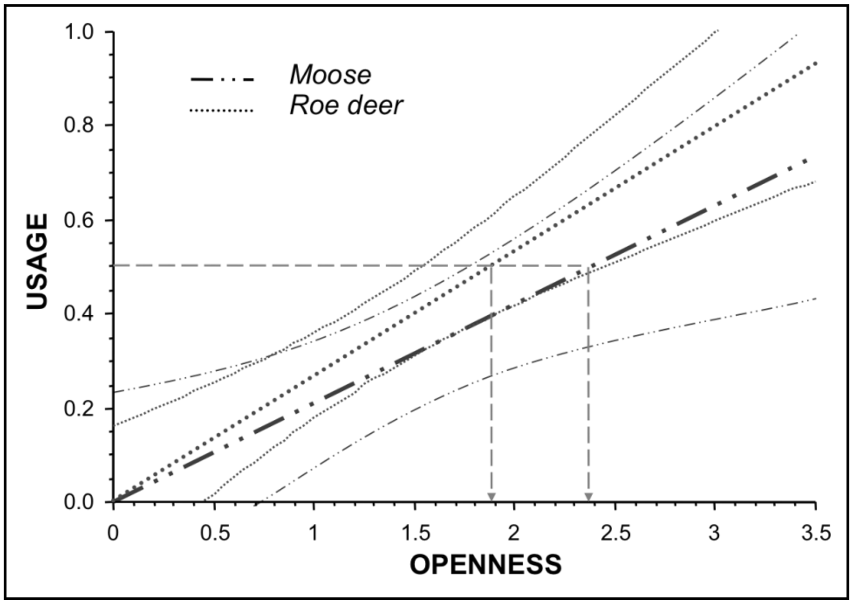

Figure 4. Predicted effect (mean with 95% C.I.) of altered openness on underpass use by moose and roe deer. Predictions were based on univariate regression models with excluded intercepts.

Discussion

Underpass width, and especially openness, appeared to be strong a predictor of the relative use of underpasses by wildlife. Surprisingly, openness was generally more effective than width, height or length taken individually or together. This supports the use of openness as a general criterion in the design of wildlife passages (e.g., Iuell et al. 2003).

Differences between Species Groups

As expected, there were significant differences between the species in how much they preferred or avoided a passage or responded to differences in openness. Moose, as the largest species, was generally more reluctant than roe deer and the smaller species to cross through underpasses and was more sensitive to passage openness and width. Roe deer also preferred wider passages and refrained from using more trafficked underpasses. This is in line with earlier studies suggesting that large mammals, and large ungulates in particular, such as moose (Clevenger et al. 2002), elk (i.e. red deer; *Cervus elaphus*) (Olbrich 1984, Clevenger and Waltho 2005), mule deer (*Odocoileus hemionus*) (Ward 1982, Ng et al. 2004), fallow deer (*Dama dama*) and roe deer (*Capreolus capreolus*) (Olbrich 1984), generally prefer passages that are considerably wider, taller and shorter and less disturbed on average, than the structures that facilitate movements of small and medium sized mammals such as lagomorphs (hares (*Lepus granatensis*) and rabbit (*Orictolagus cuniculus*)), badger, genet (*Genetta genetta*) or red fox (Rodriguez et al. 1996, Rosell et al. 1997, Ascensão and Mira 2007). This may simply be due to their greater body size, but also be related to their biology as prey species. In northern Sweden, Seiler et al. (2003) observed that migratory moose preferred to cross road fences and highway rather than using the (narrow) road underpasses that have been built to reconnect their migration routes. Kusak et al (2008) showed that the ratio of large mammals crossing the highway in Gorski Kotar (Croatia) on wide overpasses was several times larger than compared to narrow underpasses. Iuell et al (2003) recommend therefore building overpasses or viaducts instead of more narrow underpasses as crossing structures for ungulates and other larger mammals.

We observed that foxes did not seem to bother the occasional presence of humans or vehicles near or in the underpass nor its structural features. In fact, foxes were significantly less selective for larger underpasses, while still using them more often than expected by chance. As can be expected from their ground-dwelling activities, foxes and badgers may be more comfortable with smaller passages (Ascensão and Mira 2007), although this pattern might change in smaller passages (Grilo et al. 2008). In general, medium-sized carnivores are frequently reported using drainage culverts or pipes under highways and railway lines (Rodriguez et al 1996, 1997, Rosell et al. 1997, Ascensão and Mira 2007). Similar applies to hares and presumably various other medium-sized to small mammals. Studies suggest that for smaller mammals, the physical dimensions and design of an underpass are generally less important than its placement and surrounding habitat (Rodriquez 1996, Clevenger et al. 2001, Ascensão and Mira 2007, Grilo et al. 2008). Thus, with respect to these species, the typical road underpasses built in Sweden for local access forestry or agriculture roads, do not need any further adjustment to be an effective crossing facility. However this does not imply that their number and distribution suffice to mitigate the barrier or mortality effect of roads and railroads on populations of these species. The problem here may not be that roads impose dispersal barriers but instead kill a significant proportion of the population (e.g., Clarke et al. 1998, Seiler & Helldin 2006).

Evaluating Effectiveness

These general pattern are not astonishing, but must be translated into thresholds and limit values if practical guidance is to be derived for road engineers and planners. Olbrich (1984) concluded from his extensive inventories of 788 crossing structures in Germany, that structures with a relative openness of 0.75 were suitable for roe deer, while red deer and fallow deer were more likely to use passages wider than 1.5. According to the European handbook on Wildlife and Traffic (Iuell et al. 2003), an underpass for large and medium-sized animals should exceed a minimum width of 15 m, height of 3-4 m, and a relative openness of 1.5. Joint usage by wildlife and humans (pedestrians, local traffic) should only be allowed in passages wider than >10m. These recommendations are based on the experience that animals readily use passages with these dimensions, however, without specifying whether the use is lesser or greater than expected from animal abundance or activity nor whether it is sufficient to achieve the management or conservation goal. As stated before, a frequent underpass use by a species does not automatically imply effectiveness, as it could merely reflect the commonness of the species while still being less than expected from its abundance. In order to evaluate effectiveness, performance indices must be established that relate observed to expected frequencies of use (e.g., Yanes 1995, Clevenger and Waltho 2005).

We calculated the relative use of an underpass as the ratio in the number of tracks found in underpass (observed) to averaged control beds (expected) and developed regression models with this index as dependent variable. This allows for estimating the set of parameter values that will produce a certain index level. To illustrate the use of these models and get an idea of the status-quo of road underpasses in reality, we used data on existing road underpasses build for forestry or agriculture (N=113), pedestrians or local access roads (N=68) and cattle (N=4) under motorways in the administrative region of Mälardalen in south-central Sweden (data from Swedish Road Administration). According to the database, the mean dimensions (± 95% C.I.) of these passages were: width = 6.5 ± 0.42 m, height = 4 ± 0.27m, length = 20 ± 1.58m, and mean openness = 1.84 ± 0.63). Applying the limits values proposed in table 6 to these underpasses, suggests that in total only 11 structures out of 185 (6.1%) may be effective for moose, while 55 (30.4%) may be potentially effective for roe deer. Moose and roe deer will probably use more underpasses than these, but likely to a much lesser degree than expected by chance. The question is, however, whether this should be considered as sufficient, acceptable or alarming.

Clearly, the answer depends entirely on the objective for a possible mitigation action and the perspective from which effectiveness is judged. To efficiently prevent genetic or demographic divergence of two adjacent, but separated populations, it may require highly effective passages on many locations (Corlatti et al 2009). For maintaining viable populations of common species while accepting a certain impact on gene flow and population densities, these requirements can probably be eased (Van der Grift 2005). Providing a minimum connectivity across infrastructure barriers for otherwise common species will allow for even fewer and less effective measures. Counteracting deer-vehicle collisions or reducing wildlife road kill by providing safe passages, on the other hand, may require more effective measures again. Thus, in order to develop and implement barrier mitigation plans and invest in new or improved wildlife crossing structures, the objectives for these actions should be clearly stated. Broad environmental quality objectives, as existing in Sweden (Swedish Government 2000), have only little relevance to landscape and infrastructure (Nilsson & Sjölund 2003) and are often not sufficiently detailed to provide guidance for the development of adequate performance targets (Seiler & Sjölund 2005).

Practical Implementation

What is reasonable from a practical planning point of view? We propose using a relative measure of animal movement to evaluate the proximate effectiveness of a crossing facility, i.e. without relating to the ultimate population objective. Such evaluation should comprise an integrated part of the planning of new crossing structures and can also easily be done at existing passages, as in our study. We further propose the level of random use (use as expected by chance or from reference controls, neither avoidance nor preference) as quantifiable performance target for non-wildlife road crossing structures that allow for a use by wild animals. Obviously, this does not apply to crossing facilities where no animals are desired or allowed due to traffic safety reasons. Also, if passages are primarily designed for wildlife, the performance target must be higher (for example 50% more than expected by chance) unless the target is already given by management or conservation objectives (e.g., support winter migration, maintain viable local population).

However, a single crossing structure will not suffice in maintaining habitat connectivity across the landscape. Additional performance targets must therefore be defined with respect to the barrier effect, or better, permeability of the road section or infrastructure network. Several effective passages may need to be distributed at distances that match the mobility of the species in focus. Bissonette and Adair (2008) proposed isometrically scaled distances between adjacent crossing structures, where distances equal the square root of a species' home range ($H^{0.5}$). This measure represents a linear metric for the daily movements of animals and relates also to known dispersal distances of many species ($7*H^{0.5}$) (Bowman et al. 2002). Thus, combining the two performance targets (random use of crossing structures distributed at isometrically scaled distances) in the evaluation of habitat fragmentation due to transport infrastructure may help to define whether and where mitigation efforts are needed to re-create (or maintain) a minimum of landscape permeability and reduce road kill in wildlife.

In southern Sweden, moose home range sizes average about 12-15 km^2 (Olsson et al. 2008), while roe deer home ranges approximate 1 km^2 (Liberg and Cederlund 1995, Kjellander et al. 2004). Applying the $H^{0.5}$ criterion for the distance between crossing structures on these data produces a scaled metric of 3.9 km in moose and 1 km in roe deer. In our data, the mean distance to alternative crossing structures (bridges, tunnels, fence ends) was 800 m, thus well below these limits. However, since only 6-30% of the existing passages under motorways (in Mälardalen, see above) probably meet the performance target for effectiveness, there will likely be several sections along the motorways where adequate crossing facilities are too rare or too distant to provide sufficient permeability.

Whether mitigation actions will finally result in isometrically dispersed adaptations of non-wildlife passages, the building of strategically placed wildlife over- or underpasses (Woess et al. 2002, Herrmann et al. 2007), openings in exclusion fences (with automated warning systems, Huijser et al. 2007), temporally and locally reduced speed limits (compare Seiler 2005), or a re-routing of traffic flow to calm certain rural areas (Jaarsma and Willems 2002), will depend on practical, economic and political constraints. Also, it is still uncertain to what degree extended fences may funnel animals towards a suitable passage, or noise or light shields may increase the attractiveness of existing conventional road underpasses for larger wildlife and thereby provide more cost-efficient mitigation than the enlargement of the construction itself (see Kastdalen 1999). Obviously, more applied research is needed in order to establish a well integrated and effective de-fragmentation approach in transport and landscape planning.

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Biographical Sketches

Mattias Olsson received his Ph.D. from Karlstad University in 2007, with a thesis named "The use of highway crossings to maintain landscape connectivity for moose and roe deer". He has worked as a wildlife biologist since that time, primarily conducting science in the field of road ecology. Currently he is combining his work as a scientist at Karlstad University with a consultant job focusing on ecological adaptations of both present and new road projects.

Andreas Seiler has his PhD in wildlife biology from the Swedish University of agricultural Sciences in 2003 and has worked on animal-vehicle collisions, barrier effects of roads on wildlife, traffic noise disturbance in birds, and landscape fragmentation issues. He has been involved in a number of follow-up studies and monitoring projects of new roads and railroads and worked closely together with the Swedish Road and Rail Administrations on ecological issues. Andreas has recently worked with a research program on sustainable transport and is active in the Infra Eco Network Europe (IENE).

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ARE WE THERE YET? A CASE FOR SPATIALLY EXPLICIT LINKAGE MODELING FOR INTEGRATIVE CONSERVATION PLANNING

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Abstract

While a number of states have completed statewide connectivity mapping to identify landscape-scale linkages, the level of detail involved in such mapping varies greatly from state to state. A few states, such as Arizona, have conducted detailed modeling process from the outset of their linkage assessment processes. More typical is the example of states like Colorado, where broad linkage arrows representing connections across the landscape were identified, but without defined spatial extents, or that of New Mexico and Utah, where stretches of highway with pronounced wildlife conflicts were identified, but without consideration for the broader landscape linkage. These connectivity assessments are an important first step; however, without refined linkage modeling, these broad-scale assessments are not sufficiently detailed for integration into project-level transportation planning, county zoning, or public lands management.

We sought to fill this gap in Colorado by conducting in-depth linkage modeling to give defined spatial extents to wildlife linkages identified in the statewide connectivity assessment. We adapted the Corridor Design methodology - a freeware geographic information system (GIS) tool developed by researchers at Northern Arizona University - - for this purpose. The ArcGIS tool encompasses a series of spatial analyses that walk the user through steps to define suitable habitat for target species, identify core areas, map the optimal corridors between core areas. Our team made several adjustments to the standard Corridor Design methodology to better address our needs and concerns. These adaptations include mapping key habitat rather than protected lands to define core habitat; reconsidering linkage width as a gradation of 'costs' for animals moving across the landscape rather than delimiting a 'biologically best corridor'; and instead of assuming that all portions of the linkage are equally important for all species considered in the linkage area by merging single-species linkages to create a single multi-species linkage at a given location, we encourage planners to review linkages both individually as well as overlaid with one another. The resulting models allow consideration of connectivity needs on a species-by-species basis, while also evaluating how mitigation can be designed for the greatest benefit to multiple species.

This modeling effort resulted in spatially-explicit wildlife linkage data for seven species of greatest conservation need and other species of management concern to the Colorado Division of Wildlife. These data have numerous applications in protecting and restoring habitat connections for wildlife, particularly as wildlife seek to adapt to climate changes and ecosystem shifts. Current applications for the linkage models include, targeting wildlife concerns in transportation project planning and design, including the Interstate 70 highway reconstruction project; county-level zoning and transportation planning; and identifying areas of concern for the Western Governors' Association's Wildlife Corridors Initiative and the Western Renewable Energy Zones Initiative.

Background

In 2005, every state in the nation was required to complete a State Wildlife Action Plan, intended to guide the conservation of species of greatest conservation need and the habitat they depend upon. White et al (2007) notes that every state's plan identifies transportation infrastructure and associated traffic as a threat to key and at-risk species in their state. The disjunction between state wildlife plans, connectivity assessments, and transportation planning highlights the need for detailed linkage models to bring greater specificity and timeliness to both wildlife conservation planning as well transportation planning, and to foster greater integration among these planning efforts, related implementation measures and project designs.

Statewide connectivity planning has proven to be an important first step in identifying and prioritizing broad-scale wildlife movement for conservation purposes (Feinberg 2007). These processes vary greatly from state to state and the resulting maps and products reflect this variation. For example, assessments in New Mexico (http://wildlife.state.nm.us/conservation/criticalmass/index.htm) and Utah (West 2007) focused on identifying stretches of highway that may act as a barrier to wildlife movement, largely based on animal-vehicle collision rates. California, one of the original states to begin mapping connections for wildlife at the landscape scale, hosted a series of expert meetings to identify focal species and map linkages for these species (Penrod et al 2001). In Colorado, conservationists built upon this process, incorporating both spatial analysis and expert meetings to map landscape linkages, resulting in the identification of linkage arrows representing broad connections across the landscape for a defined set of focal species (Southern Rockies Ecosystem Project 2005). While each has its limitations, each of these connectivity assessments notably provide a first-iteration look at wildlife movement corridors in their respective states, setting the foundation for corridor conservation, highway mitigation, and adaptation to climate change.

The state of Arizona is a notable exception. The statewide connectivity assessment in Arizona incorporated detailed linkage modeling from the outset (Beier et al 2007). Researchers at Northern Arizona University developed a 'corridor design' tool in a geographic information system framework (GIS) in collaboration with the Arizona Game and Fish Department, to identify, model and map wildlife linkages. This GIS tool walks the user through steps to define suitable habitat for target species, identify core areas, map the optimal corridors between core areas. The resulting linkage designs offer conservation planners a strategy for protecting, mitigating and restoring habitat connectivity for wildlife between defined blocks of protected habitat.

Although transportation priorities are set well in advance of construction, most land and wildlife agencies are not notified in the early stages of project planning and design and, therefore, comment only during the permit review and environmental assessment stages, when transportation projects are well into the development process (Cramer and Bissonette 2007). At this point, changes to the project design typically result in significant delays, increased costs, and offer little environmental benefit. The need to coordinate between natural resource managers and transportation planners much earlier in the project planning process was identified as a specific need in a number of the State Wildlife Action Plans (White et al 2007) to ensure that appropriate avoidance and mitigation measures are implemented and located appropriately. Yet comprehensive data sets at much a more refined scale - appropriate for project-level planning - are still lacking in many instances and the processes for ensuring early consideration of these data are not in place in most states.

In Colorado, the Southern Rockies Ecosystem Project, in collaboration with the Colorado Division of Wildlife, the Colorado Department of Transportation and Defenders of Wildlife, we sought to adapt this linkage modeling process to give further definition to the broad-scale wildlife linkages identified in the statewide connectivity assessment. Rather than simply flagging important linkage areas for further consideration as in the statewide connectivity assessment, spatially-explicit mapped linkages could be directly integrated into transportation planning and project design, thereby facilitating early consideration of wildlife movement needs. Although the impetus and funding for this project derived from a recognized need for detailed datasets of important wildlife linkages in the arena a transportation planning, the potential applications of these data extend to land conservation, public lands planning, county zoning, and energy development.

Discussion

Linkage Modeling: Applying the Corridor Design Tool

Researchers at Northern Arizona University developed Corridor Design, a freeware geographic information system (GIS) tool to assist with the linkage design process (http://corridordesign.org). This tool was developed to aid in the design of landscape-scale corridors in a heterogeneous environment. The ArcGIS tool encompasses a series of spatial analyses that walk the user through defining suitable habitat for target species, identifying core areas, finally, mapping the optimal corridors between core areas. We applied this tool to give greater definition to identified wildlife linkages in Colorado. Several adaptations were made in the linkage modeling process to fit the needs, concerns and budget of the linkage modeling project in Colorado.

The first step in linkage modeling involves identification of the analysis area, a process that requires being able to define what you are trying to connect. As Colorado already has a completed statewide connectivity assessment, Linking Colorado's Landscapes (Southern Rockies Ecosystem Project 2005), this served as the basis for identifying analysis areas for further definition using the Corridor Design tool.

We then selected 14 target species to capture the range of ecological and topographic conditions present in the state, with the intention of creating a linkage design that would ensure their long-term viability. Target species met one or more of the following conditions: species identified as Tier 1 or Tier 2 species in the Colorado State Wildlife Action Plan, species that are frequently involved in animal-vehicle collisions, and/or species of special management concern to CDOW, such as at-risk species and game species.

Notably, there are several species that were identified as target species at the outset of the project, but were later removed from the list of target species being modeled using this process. For example, meadow jumping mouse (*Zapus hudsonius preblei*) is a riparian species restricted to the Front Range of Colorado. Given its habitat is naturally linear and restricted to the riparian zone, linkages for this species cannot be mapped in the same manner as for other species. Similarly, species with small-scale movements, such as herpetofauna and some small mammals, might operate at too fine of a scale to have their movement patterns adequately captured using this modeling process. In these cases, suitable habitat may be a better determinant of where avoidance or mitigation measures are needed to adequately protect the species' ability to move through its habitat. Attempts were made to model linkages for gray wolf and mountain lion, however, it was determined that the parameters for these species were too general and broad-scale to delineate core habitat and linkages using these methods. To adequately model linkages for these species, other factors, such as prey availability, may be better suited for representing these species use of the landscape.

Once the target species have been identified, there are four primary factors that are evaluated for each target species: land cover, elevation, topography, and distance from roads. Each of these criteria are weighted (0-100%), depending on the degree to which they influence a given target species' habitat use. Each factor is given a percentage of its importance to the species so that the factors add up to 100%. The factors are then combined spatially to create the final Habitat Suitability Model (HSM) where every pixel has a value of the habitat importance to the species. Then, for each factor with a weight greater than zero the weighted geometric mean was calculated by raising each factor by its weight, and multiplying the factors. Other parameters that must be defined for each target species include minimum core patch size and daily dispersal distance. These parameters were defined in close collaboration with biologists at the Division of Wildlife and other species experts, with reference to the relevant literature.

If a particular target species' habitat use cannot be adequately captured by these four factors, then the team may want to consider adding a new factor for that species (e.g., aspect, soil type). However, the makers of the corridor design tool argue, and we concur, that the use of few factors and few categorical metrics within each factor is better than many factors or numerous categories within a factor - complex models become increasingly abstract and are likely to be poor representations of what is actually occurring on the ground.

The corridor design analysis is performed creating a cost surface based on the HSM. This is similar to a least-cost path analysis, but also incorporates suitable habitat patch sizes (i.e., small, stepping-stone patches that are too small to be core habitat patches, but may still be important as animals move between core habitat patches) and the species' daily dispersal distance threshold. The resulting movement surface is a gradation that demonstrates the difficulty (i.e., cost) of moving between the two identified endpoints.

In Arizona, the design team defined the termini between which a least-cost linkage would be defined as existing blocks of protected wildlands (Beier et al 2007). This definition of start and end points for corridor design assumes an objective of connecting existing blocks of protected habitat. For the Colorado analysis we determined that suitable habitat should be used to define movement corridors regardless of the current protection status of the land. When available, we used breeding habitat or occupied habitat to represent known population cores and the start and end points for linkage modeling. In the case of species for which these data were not available, we derived potential core habitat patches from the habitat suitability model to serve as termini in the linkage analysis model. We opted to use this approach because by basing the linkage models on known or modeled habitat cores increases the relevance of the linkage modeling between those core areas to that particular species, regardless of habitat protections that may or may not be in place.

Once the HSM is created - essentially a gradated movement surface representing shifting costs or resistance for an animal moving across that landscape - the next step in the process is to define the width of the linkage. This width is essentially a cut-off that defines the linkage area. The corridor design tool recommends creating slices of the lowest cost 0.1 to 10 percent of the total analysis area. In Arizona the objective was to define a minimum or 'biologically best corridor' between protected lands in order to protect species movement in the face of immediate or impending development. In Colorado, we decided instead to depict a broader linkage area as a gradation representing the range of 'costs' for an animal moving across the landscape between two core habitat patches. Thus, instead of a narrowly defined corridor, the Colorado linkages encompass the concept that some portions of a broader linkage area are more suitable (low cost, or resistance) than others (higher cost, or resistance), retaining in the linkage mapping elements of the original HSM cost surface. This meant that linkage width was not as strictly limited as recommended in the corridor design methodology, and that all portions of the linkage do not have equal value to all of the target species that use the linkage.

The corridor design tool also provides the ability to combine individual species linkages into multi-species linkages. In many cases, linkages for two or more species may overlap in a given area, highlighting the importance of specific portions of the linkage area for more than one modeled species. A multispecies approach is recommended for indicating where land conservation or mitigation measures can benefit multiple species to promote the efficient use of limited conservation dollars. As such, in Arizona, overlapping linkages for different species were unioned together to create multi-species linkages that act as "a collective umbrella for native species and ecological processes" (Beier et al 2008). Once unioned, redundant strands of the linkage may be trimmed off to minimize the overall area and edge of the linkage.

In Colorado, we declined to include this step. While the importance of considering the needs of multiple species in a given area cannot be overstated, we felt that the individual and combined needs of the diversity of species present are better addressed when agencies, conservationists and stakeholders are required to review the species linkages both individually and as an overlay. While this technique does not result in a neat linkage map that is easier for public consumption, we believe that this option allows planning teams to better comprehend and assess the individual components of the linkage area on a species-by-species basis instead of assuming that all portions of the linkage are equally important for all species considered in the analysis area (Fig. 1,2,3). Effective conservation decision-making is supported by process which requires both individual and combined review of the species linkages. This process should consider both areas that capture maximum value for the greatest number of species as well as irreplaceable bottlenecks for a single target species.

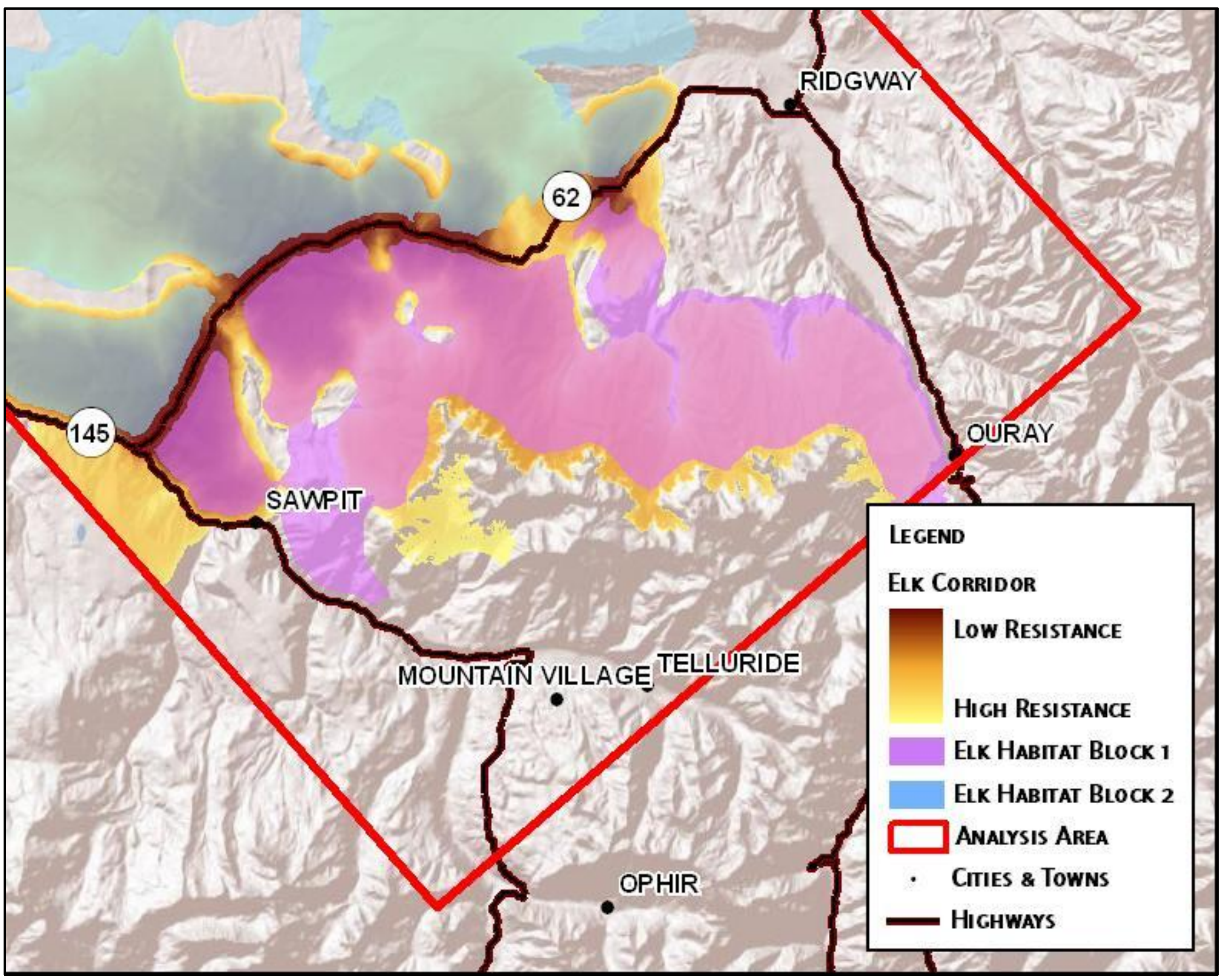

Figure 1. Elk linkage at Dallas Divide in southwestern Colorado crossing over Highway 62. Dark brown represents areas of low resistance (low cost of movement) between the two core habitat areas.

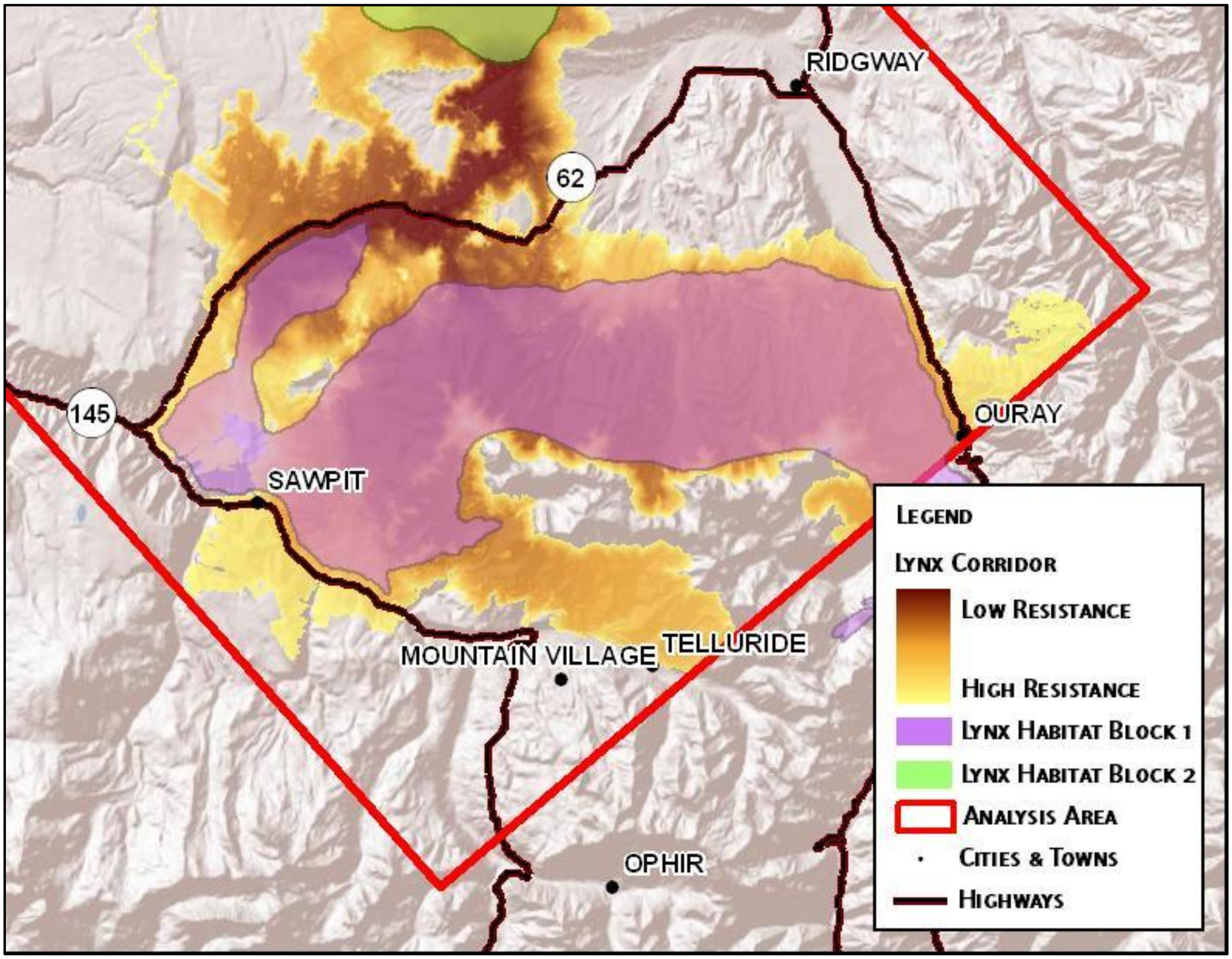

Figure 2. Lynx linkage crossing the same stretch of Highway 62. Note how the low cost (low resistance) portions of the linkage are significantly more restricted for lynx than they are for elk.

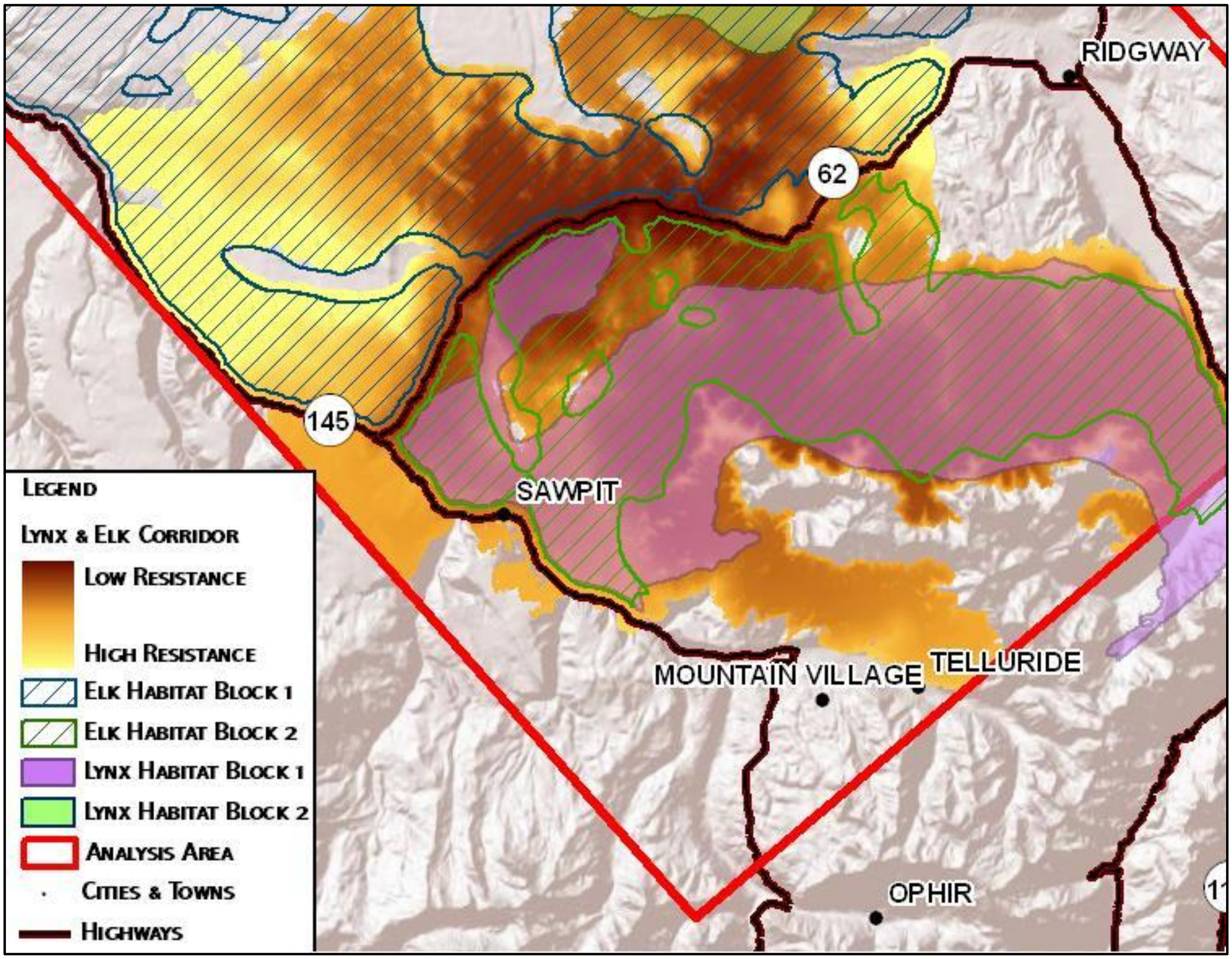

Figure 3. When unioned together, the details of the individual species linkages may be lost. We therefore recommend reviewing the individual species linkages both separately and combined for a given location for a more complete understanding of the conservation and mitigation needs of the multiple species.

Upon completion of the linkage modeling we returned to the species experts for additional review of the linkage models and the parameters used to create them. This final review is useful in ensuring that the linkages properly represent the species movement needs as accurately as possible and to determine whether any adjustments are needed to the model inputs.

Integrative Conservation Planning: Applications of Linkage Modeling in Transportation Planning and Other Conservation Efforts

The easiest and most obvious next step in aligning connectivity conservation with transportation planning is to create overlays with upcoming transportation projects in the Statewide Transportation Improvement Plan (STIP), which outlines near-term (typically 3-5 years) project priorities and funding. As the STIP is subject to change regularly, the state department of transportation should have direct access to wildlife linkage data to conduct these overlays and identify potential conflict areas with upcoming projects. A routine process for identifying potential conflict areas and mitigation or avoidance opportunities is essential in ensuring that wildlife needs are conveyed to the appropriate agency personnel at the outset of project development.

We collaborated with biologists and planners at the Colorado Department of Transportation to determine where early consideration of these linkage data would be most effective and appropriate. During these discussions, members of the team expressed concern about potential misinterpretation of the wildlife linkage data by non-biologists. In response, it was agreed that that within the DOT, the regional biologists would be the keepers of these data, and would be responsible for overlaying the linkage data with the STIP to highlight areas of overlap between planned transportation projects and wildlife movement zones. The biologists, in turn, would report areas with potential wildlife conflicts to planners, engineers and other participants involved in project design. The biologists would also use these data to focus their in-the-field assessments to identify specific mitigation measures.

Prior to this project, wildlife connectivity needs were considered on an ad-hoc basis, depending on the awareness level of the individual CDOT biologist conducting the review, and their knowledge of wildlife movement areas for the array of species. Detailed linkage mapping removes the burden for each biologist to possess exhaustive knowledge of wildlife movement areas across the state, instead providing a comprehensive database of this information to complement their knowledge and expertise. These data cannot take the place of on-the-ground field surveys in the identification and placement of specific mitigation measures, but the linkage models will help to focus and guide these efforts, ultimately streamlining the process to improve landscape permeability for wildlife.

Currently these linkage data are currently being used in support of efforts to identify wildlife concerns and potential barriers to movement along Interstate 70 between Denver and Glenwood Springs as a part of the highway reconstruction project. The mapped wildlife linkages have assisted field researchers in targeting areas along this 130-mile stretch of roadway for further in-depth assessment and, ultimately, the development of recommendations for avoiding and mitigating impacts to habitat connectivity for wildlife, as well as opportunities for restoring lost connections.

The utility of landscape linkage modeling does not end with state transportation planning. Indeed, the potential applications of such data extends to all landscape planning and management efforts, including county-level zoning and transportation planning, conservation acquisitions, public land and recreation management and energy development.

Conclusions

The corridor design tool offers a useful framework and guidelines for linkage modeling, in a manner that is accessible to a wide variety of users, relatively inexpensive, and scientifically defensible. While we made several adjustments to the standard methodology to better address our needs and concerns, we found that adaptations could be readily incorporated, and that the tool greatly supported the evolving process of refining and updating the statewide connectivity assessment for greater application and integration in the State Wildlife Action Plan as well as in transportation planning.

Spatially explicit data can provide much-needed support for transportation planning to ensure that mitigation and avoidance measures are included in plans, designs and budgets from project initiation through construction. While we must be willing to adjust our conservation paradigm as our knowledge of species preferences and movements grows, particularly with regards to adaptations to climate change, linkage models are easily updated and can greatly empower connectivity considerations in non-traditional forums.

Acknowledgements

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Biographical Sketches

This project was conducted while both authors were at the Southern Rockies Ecosystem Project (SREP).

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MONITORING WILDLIFE OVERPASS USE BY AMPHIBIANS: DO ARTIFICIALLY MAINTAINED HUMID CONDITIONS ENHANCE CROSSING RATES?

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Abstract

In the Netherlands wildlife overpass “Groene Woud” is one of the first that aims to provide habitat connectivity for amphibians. In both the design and management of the overpass much attention has been given to create optimal humid conditions for amphibians, including a chain of small pools across the overpass and its access ramps. The question we addressed is if the measures significantly improve the use of the overpass by amphibians. We monitored amphibians 1-2 times a week at the overpass and in the direct surroundings for three years (2006-2008). We analyzed the impact of the overpass adaptations on amphibian use by comparing amphibian numbers in the wetland zone on the overpass with amphibian numbers in the dry zone on the overpass. We found that, depending on general weather conditions, the adaptations to maintain a humid environment on the overpass and its ramps significantly improve overpass use by amphibians. As a result wildlife overpasses with special adaptations as implemented at the Groene Woud overpass may become an alternative, and less costly, measure than elevating roads to restore habitat connectivity for semi-aquatic species in wetland areas.

Introduction

In the Netherlands wildlife overpass “Groene Woud” is one of the first that aims to provide habitat connectivity for amphibians. The overpass, opened in 2005, is situated in the heart of National Landscape Groene Woud and connects wetland areas that are bisected by motorway A2. The wildlife overpass is 50m wide and about 65m long (Figure 1). It crosses the motorway 7m above ground level. The access ramps are 110m (west) and 85m (east) long and have a gradient ratio of 1:14 and 1:10 respectively. The overpass is covered by a layer of 0.5m topsoil. On the access ramps the topsoil depth is 1m. The topsoil layer on overpass and access ramps consists of soil that originates from the immediate vicinity of the overpass. The topsoil is put in place in such a way that the original sequence of soil layers is maintained. Along the edges of the overpass 2.5m high embankments have been constructed to reduce disturbance from light and noise emitted by passing traffic. The overpass is closed for public.

In both the design and management of the overpass much attention has been given to create optimal conditions for amphibians. Besides a controllable groundwater level on top of the overpass, across the whole length of the overpass and its access ramps a wetland zone has been constructed existing of a chain of small pools (Figure 2). Water is pumped up to the top of the overpass and slowly released through the cascade of small pools towards bigger pools at the feet of the access ramps (Schellekens et al. 2005). The philosophy of these special adaptations is to maintain sufficient humid conditions to improve amphibian use throughout the dry season. The question we addressed is if those expectations are correct, i.e. whether the use of the overpass by amphibians is significantly improved in contrast with the situation that the humid conditions on the overpass are not artificially maintained.

Figure 1. Wildlife overpass Groene Woud across motorway A2 in The Netherlands (Photo courtesy of Rijkswaterstaat).

Figure 2. Wetland zone on wildlife overpass Groene Woud immediately after construction, consisting of a series of small ponds on loamy soils supplied by water that is pumped up to the top of the overpass (Photo courtesy of Rijkswaterstaat).

Methods

We monitored amphibians 1-2 times a week at the overpass and in the direct surroundings for three years (2006-2008). The surveys on the overpass took place along four about 180m long transects across overpass and access ramps (Figure 3). The ponds at the feet of the access ramps were start- and endpoint of the four transects. Transect 1 and 2 were located in the wetland zone of the overpass with the series of small ponds in between the two transects. Transect 3 and 4 were located in the dry zone of the overpass, bordering a wall of tree stumps. Along each transect 20 wooden plates (60x60x2 cm) were spread out (Figure 4). During surveys all transects - up to 3m on both sides of each transect - have been actively searched for amphibians. Furthermore, all amphibians that were found underneath the wooden plates were counted. We analysed the impact of the overpass adaptations on amphibian use by comparing amphibian numbers in the wetland zone on the overpass with amphibian numbers in the dry zone on the overpass.

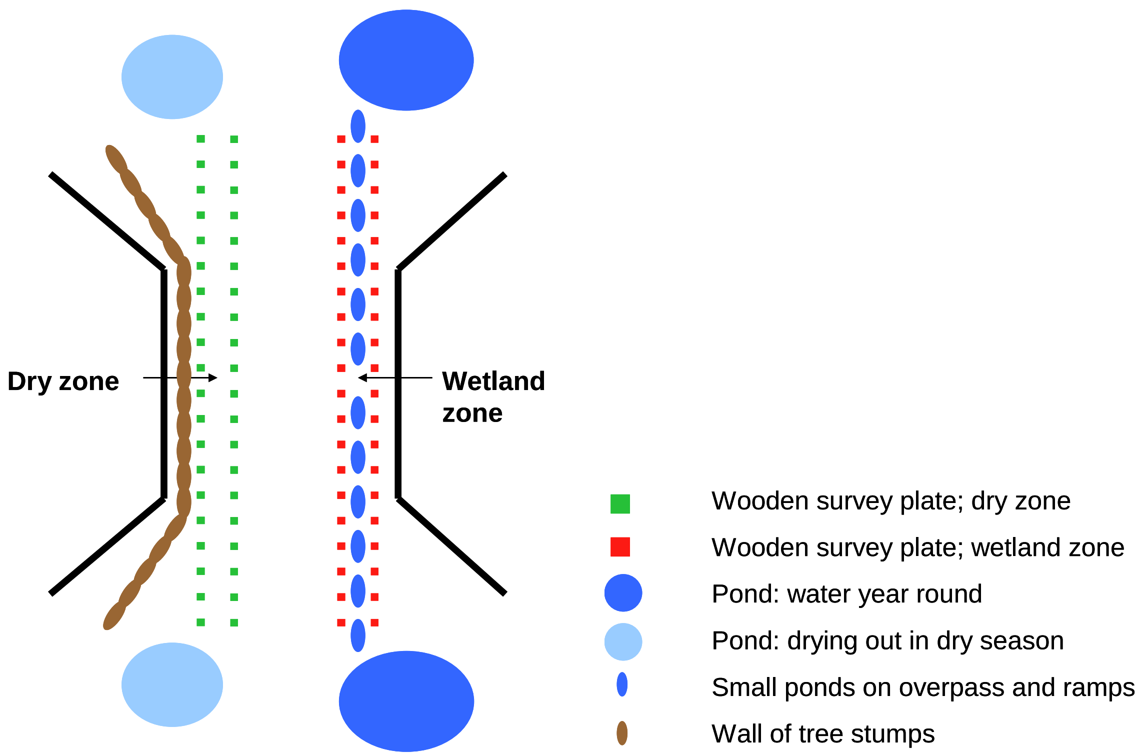

Figure 3. Study design with two transects in the wetland zone and two in the dry zone.

Figure 4. Wooden plates that were systematically spread out along the four transects functioned as artificial shelters which eased and standardised the counting of amphibians on the overpass. In the front the wetland zone with one transect on each side. In the back the dry zone with two transects as well, bordering the wall of tree stumps (Photo courtesy of E. van der Grift).

Results

On the overpass six amphibian species have been found: common toad (*Bufo bufo*), common frog (*Rana temporaria*), marsh frog (*Rana ridibunda*), edible frog (*Rana klepton esculenta*), smooth newt (*Triturus vulgaris*) and great crested newt (*Triturus cristatus*) (Figure 5). In total 2706 observations of amphibians have been recorded on the wildlife overpass (Table 1). Most observations concerned the common frog (78%), followed by common toad (15%), species that belong to the green frog complex (*Rana esculenta synklepton*; 5%), great crested newt (1.5%) and smooth newt (<1%). Based on these numbers about 5000 observations of amphibians can be expected yearly if the overpass was surveyed daily (Table 1).

Species	2006		2007		2008		2006-2008	
	n	N	n	N	n	N	N	G_w
Common toad	31	263	177	818	193	992	2073	691
Common frog	455	3862	1003	4634	642	3300	11797	3932
Green frog-complex								
- species not determined	5	42	98	453	36	185	680	227
- Marsh frog	0	0	0	0	1	5	5	2
- Edible frog	1	8	1	5	1	5	18	6
Great crested newt	17	144	5	23	22	113	281	94
Smooth newt	6	51	7	32	5	26	109	36
Total	515	4372	1291	5965	900	4500	14963	4988

Table 1. The number of observations of amphibians for each species during the field surveys (n), the expected number of observations if the overpass is surveyed daily (N), and the average number of observations in one year calculated over all research years (G_w).

Figure 5. The counting of amphibians underneath one of the wooden plates. Over the whole research period 15,440 plate checks have been carried out. During 1,190 (~8%) of these checks amphibians were found. In about 80% of the cases that amphibians were present underneath a wooden plate it concerned one individual. In the remaining 20% more than one animal was found underneath the plates with a maximum of seven animals underneath one plate (Photo courtesy of B. Vervoort).

The first amphibians were observed on the overpass in February and March, although still in low numbers (Figure 6). In April and May the number of observed adults and subadults increased considerably. In summer (July-August) and early fall (September-October) the highest numbers of amphibians were found on the overpass. In these periods most observations concern juveniles. In November the number of observations of amphibians on the overpass drops quickly. The animals retreat to their wintering habitat in this period, which resulted in only a few observations of amphibians on top of the overpass, especially underneath the wooden plates where some animals seem to intend to winter. Larvae – of common frog and common toad – were only incidentally found in the small ponds on the overpass. Eggs have not been recorded on the overpass.

We found that, depending on general weather conditions, the adaptations to maintain a humid environment on the overpass and its ramps significantly improve overpass use by amphibians. The number of observations of amphibians in the wetland zone on the overpass is at least 1.5 times higher than the number of observations in the dry zone. On average 12.5 amphibians were observed within the wetland zone each survey versus 6.5 amphibians in the dry zone. Due to technical problems the water pump was not operational year round, which caused the wetland zone to dry out temporarily at several occasions. In these periods on average 5.6 amphibians were observed within the wetland zone each survey versus 6.8 amphibians in the dry zone.

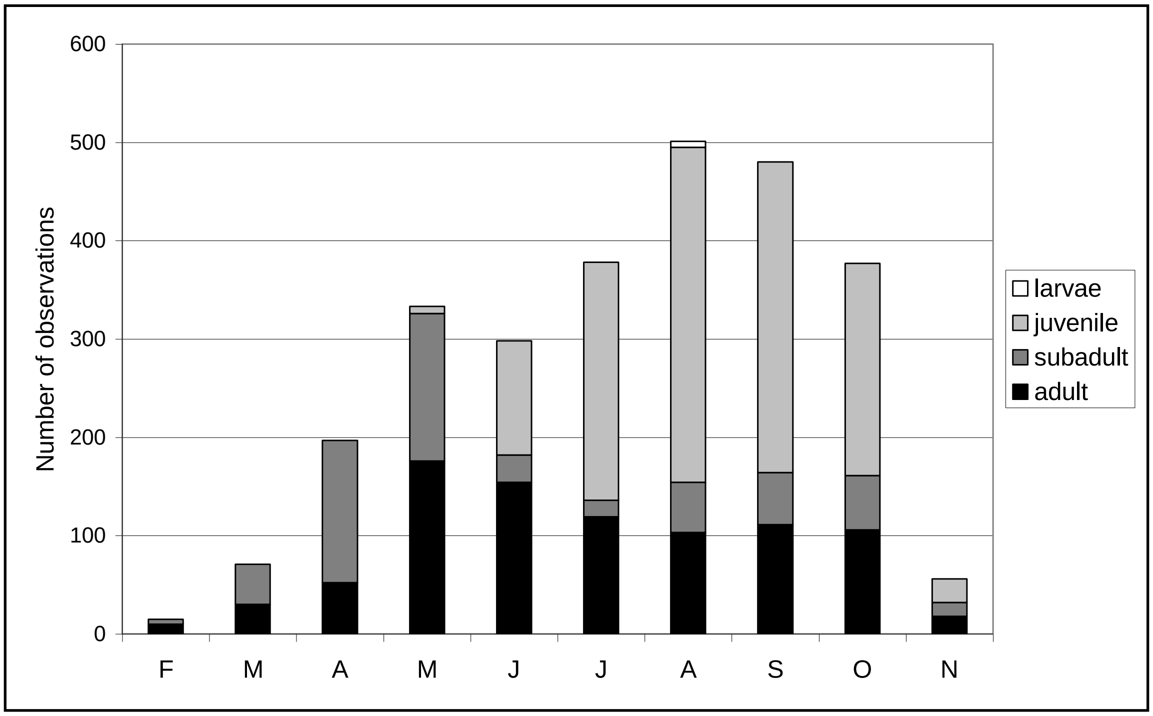

Figure 6. The number of observations of amphibians per month and per age group on wildlife overpass Groene Woud over 2006-2008. In the months January and December no surveys have been carried out.

Conclusions

Although the special measures to create humid conditions on top of the overpass did not work properly year round due to technical problems it can be concluded that de creation of a wetland zone improves use of the overpass by amphibians. This conclusion can be seen as an argument to consider special measures to maintain humid conditions on wildlife overpasses more often, especially when amphibians are seen as target species for the defragmentation measure. As a result wildlife overpasses with special adaptations as implemented at wildlife overpass Groene Woud may become an alternative, and less costly, measure than elevating roads to restore habitat connectivity for semi-aquatic species in wetland areas. A second conclusion is that at moments the wetland zone had dried out due to failure of the water pump, the dry zone hosts significantly more amphibians. This seems to be caused by the more humid conditions and better shelter possibilities for amphibians in the high vegetation in the dry zone at those moments compared to the relative less vegetated wetland zone. The presence of the wall of tree stumps in the dry zone, providing amphibians with shelter, may have further contributed to the difference in number of amphibians between wetland and dry zone in periods that the water pump did not work, as the higher number of amphibians in the dry zone also occurred in periods when the vegetation in this zone had hardly been developed yet. The creation of sufficient cover, such as a wall of tree stumps, low embankment of boulders or a row of branches, and the development of sufficient vegetation cover, can therefore be recommended to improve the use of wildlife overpasses by amphibians. Further research should focus in more detail on individual movements of animals to better quantify overpass use and qualify the role of the linkage in maintaining amphibian life cycles and population persistence.

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The research has been carried out in close cooperation with Brabants Landschap, which manages the overpass and surrounding nature reserves, and the regional department of the Dutch Ministry of Transport. Our special thanks in this respect go to Erik van Ingen and Hubert van Beusekom who not only secured finances for the study but also provided us with valuable suggestions and practical support throughout the research period. The field work was done together with volunteers of Natuurwerkgroep Liempde and IVN Best. We would especially like to thank Jeanne Soetens, Marijke Abrahams, Bert Vervoort and Marco Renes who enthusiastically spend many hours on top of the overpass. Thanks also to Gerard Traa, Mark Kapteijns and Karel Voets of Brabants Landschap for their practical help in setting up and carrying out the field research.

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Edgar van der Grift works as a senior research scientist at Alterra, Wageningen University and Research Center, Wageningen, The Netherlands. His work focuses on the assessment of the impacts of habitat fragmentation on wildlife populations and the effectiveness of measures that aim to reduce such fragmentation and increase habitat connectivity, e.g. the establishment of landscape linkages, ecological corridors and wildlife crossing structures at roads and railroads. Besides his scientific research he acts as a consultant for policy makers, road planners and conservation groups during the preparation and implementation phase of projects that aim for the establishment of effective ecological networks and road mitigation measures.

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New Concepts in Wildlife Habitat Linkage Assessments to Focus Mitigation Measures and Reduce Wildlife Crossing Costs

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Abstract

One of the greatest concerns State Departments of Transportation (DOT's) have is that wildlife mitigation costs will exceed available funds, or that mitigation costs will outweigh the benefits to wildlife and cannot be justified to the public or DOT Commissions. The process the authors describe has been used successfully in Utah and Idaho as part of wildlife habitat linkage assessment and has the potential to substantially reduce wildlife mitigation costs while providing recommendations for effective wildlife crossing structures. It has also been used to "negotiate" solutions to wildlife mitigation on highways where State DOT's, resource agencies and/or citizen groups disagree on appropriate mitigation measures. As with the wildlife habitat linkage process, the prioritization of the linkages is an interagency and interdisciplinary decision process. Both processes rely on DOT engineers and resource agency professionals as well as "hands-on" employees such as highway maintenance personnel. The processes also rely on state-of-the-art GIS data to facilitate decision-making, including road-kill, vegetation, terrain, wildlife habitat and other data. Results in Utah and Idaho suggest that a relatively small proportion of highways rank "high priority" where the highest dollar investments for wildlife mitigation are warranted. Preliminary use of the wildlife habitat prioritization process suggest that a majority of highway mileage will rate out as "no priority" which suggests that transportation and resource agencies agree minimal mitigation measures are appropriate. The entire wildlife habitat linkage assessment and prioritization process took one day per DOT Region in Idaho (approximately 1,200 to 1,700 miles of highway per Region per day). Recommendations for size, type and number of wildlife crossings were made on an interagency and interdisciplinary basis in a matter of days or weeks for US 6 and I-70 in Utah.

Introduction

There would be far more wildlife crossings throughout the United States and Canada if it were not for two factors. First, wildlife habitat linkage assessment has not been completed, or is bogged down with various bureaucratic factors in most states and has not completed in any Canadian Provinces. Not completing state and provincial wildlife connectivity plans results in lost wildlife mitigation opportunities, inconsistent wildlife mitigation, money potentially spent in low priority situations, more time and money spent on process and less likelihood that wildlife crossings and other effective terrestrial and aquatic mitigation will occur. There are also indications that there is a higher likelihood that proposed wildlife crossings and other mitigation will be more costly. In summary, these results occur because wildlife habitat linkage assessment is fundamental to good highway and wildlife habitat connectivity planning.

The second reason that more wildlife crossings have not been built is simply the high cost. Wildlife crossings, even the least expensive options, are expensive. Add in a need for redundant structures, different sizes for various target species, fencing, monitoring and follow-up corrective measures and maintenance and State Departments of Transportation (DOTs) are rightly concerned about trying to facilitate new and evolving ecological principles with their primary duty of providing safe and cost-effective highways for the public.

Since the authors original description of using existing GIS data and expert-based wildlife habitat linkage assessments (Ruediger and Lloyd 2003) – then called a "Rapid Assessment Process" - many State Departments of Transportation and resource agencies have used the process and new insights and processes are being implemented. This paper is a summary of some of the improvements in the wildlife habitat linkage assessment process and associated new ways that this information can be used to expedite highway projects, improve mitigation measures, facilitate interagency dialog and implement wildlife habitat connectivity on the landscape.

Discussion

Update on the Use of the GIS/Expert Based Wildlife Habitat Linkage Assessment Process

Since the wildlife habitat linkage assessment process was developed for Highway 93 in Montana (Ruediger et al 2004 and Ruediger and Lloyd 2003), several applications have been made of the process in Alaska, Montana, Idaho, Utah and elsewhere. From these experiences, there have been some lessons learned and many improvements made. The first lesson learned, on Sterling Highway in Alaska was that the GIS data needs to be state-of-the art and facilitation of the digital GIS data during the interagency wildlife habitat linkage workshops must be provided by GIS personnel with adequate computer skills. GIS data continues to be improved and with this, digital file sizes can be extremely large and complex. When several large digital files are superimposed on each other, only the most updated computer hardware and software will handle the information without long delays.

Several statewide habitat connectivity assessments have used paper map files and the linkages physically drawn on hard copy maps, but this negates the speed, rapid overlaying of data and on-the-spot documentation of using a computer assisted process. Hard copy maps were used in the initial state-wide habitat connectivity assessments in New Mexico, Arizona, Oregon and Utah (West 2006). In this wildlife habitat linkage assessment process, groups of people (experts) familiar with how wildlife use the landscape collaborate to develop known areas where wildlife habitat connectivity is either known to occur, or deemed necessary. Some of the benefits of this method is that it uses collaborative processes, requires minimal computer assessment and GIS skills and can be accomplished with meetings that last only one or two days. The State DOTs are involved in the process and can provide their expertise and values to the process, along with appropriate resource agencies (state wildlife agencies, U.S. Fish and Wildlife Service, U.S. Forest Service, Bureau of Land Management, National Park Service and other government and non-government entities). This process provides very good wildlife habitat linkages based on agency knowledge and science and because it is developed collaboratively usually provides decisions that hold all agencies accountable to help implement the end product.

The GIS/Expert based wildlife habitat linkage process utilizes a number of layers of resource data that are used in conjunction with experts or knowledgeable local people. This process combines computerized GIS data with both local expertise and interagency involvement of resource people (fish and wildlife biologists, botanists, etc), engineers and often decision-makers. The process involves open discussions about the validity and/or rationale for wildlife habitat linkages, the target species, terrain factors, species occurrence, vegetation arrangement and type, wildlife range information, existing wildlife habitat linkage maps or computerized (least-cost analysis and others) models and any other data available. Human developments such as houses, commercial properties and other data are usually mapped and digitized. It also uses DOT information including animal-vehicle collision data, usually displayed by highway milepost or fractions thereof. This type of process was used initially for Highway 93 in Montana and later for the Idaho Statewide Wildlife Linkage Assessment (http://www.socialtext.net/idahohighwaywildlifelinkage/index.cgi) and for Highway 6 (Ruediger et al 2008) and I-70 (Ruediger et al 2007b) in Utah.

Once the GIS data is assembled, the process usually starts by prioritizing the highways that need wildlife habitat linkage decisions during the workshop. This ensures that the most important highways within the analysis area are dealt with first. NOTE: This step is not a prioritization of wildlife habitat linkages. The process starts with the highest priority highway, usually at the lowest milepost. GIS mapped data is projected onto a screen and any workshop participant can suggest wildlife habitat linkages based on their knowledge of the highway, wildlife occurrence, animal-collision data – or they ask for specific GIS data to be displayed or superimposed. Groups quickly learn the process and move forward with decisions about wildlife habitat linkage suitability. The wildlife habitat linkages are documented as a specific location, such as a stream crossing, or as a length of highway from one milepost to another. The linkage area is accurately drawn in with a computer boundary line or point, given a specific number or code and information about what the issues are is documented on a form (see Appendix 3 for an example). The entire process for a wildlife habitat linkage usually takes less than 15 minutes, including the documentation. After all highways within the analysis area have been assessed, then the entire group of wildlife habitat linkages is prioritized based on predetermined criteria. This process usually takes an hour or so (see the section on Prioritization of Wildlife Habitat Linkages).

Productivity of the GIS/Expert process is amazing. In Idaho, interagency and interdisciplinary groups were able to assess entire DOT Districts in one day. This was with groups of engineers, maintenance personnel, biologists and planners from a variety of agencies and NGO's that often numbered 40 to 80 participants. Approximately 1,000 to 1,700 miles of highway per day were assessed. In several other situations (Utah and Montana), an entire highway was assessed in one day (120-230 miles).

One of the interesting aspects of the GIS/Expert process, using projected GIS data, is that it focuses the attention of the group on the projected GIS maps and problem-solving, verses agency or personal differences. All participants have equal status to ask questions, illicit discussions and propose or modify wildlife habitat linkages. This includes professional people (biologists, engineers and decision-makers), technical staff (highway maintenance personnel), NGO staff and interested citizens. Natural resource personnel tend to focus on ecological issues. DOT personnel tend to focus on highway safety. Not surprisingly, these two objects are often located within the same geographic areas.

Photo 1. Kim Just, Idaho Transportation, Sandy Jacobson, US Forest Service and others discuss Highway 21 just after the Boise, Idaho Wildlife Habitat Connectivity meeting (2007). Highway 21 near Boise is a High Priority linkage due to habitat fragmentation of a major mule deer winter range and an extremely high deer-vehicle collision rate. Photo by Ruediger.

The GIS/Expert wildlife habitat linkage assessment process is a decision-making tool that is supplemented by state-of-the-art GIS data. It is the GIS data and knowledge of profession people that provide the scientific credibility to the process. GIS/Expert wildlife habitat linkage assessment is certainly not a "pure science" approach. Agency, professional and various community, regional or personal values and knowledge supplement the scientific information provided. The process is definitely a "collaboration" of agency missions and policies as well as professional values and concerns. Once linkage and other highway decisions are made and documented, history suggests they remain solid for several years. This is especially important to DOT's since highway projects take many years to plan and implement and a reoccurring situation is having the issues evolve and cause delays in critical highway projects.

Use of Existing GIS Data to Assess Wildlife Habitat Linkages – Is this Enough?

Over the last decade there have been discussions among agencies, academia and biologists as to whether or not existing information is adequate to accurately develop wildlife habitat linkages and/or site specific wildlife crossings. Part of the answer lies in the biases and background of the observer. If the process is viewed primarily as a "management decision", then just enough data and information is provided to make a decision. Time, funding, personnel and other factors must compete with collecting existing or new information. Action agencies must make decisions within confined time lines and often the choices can be to use available data, or potentially forgo wildlife crossings and other mitigation measures.

If determining the locations of wildlife habitat linkages and wildlife crossings is considered a research project or a monitoring project, then collecting new data or information may take on a different perspective.

The authors began to search for ways to quickly determine wildlife linkages – and later specific locations for wildlife crossings. When this effort began in the 1990's, most highway projects went forward without wildlife habitat linkage assessments or wildlife crossings. Even when the ecological issues involving highways and wildlife began to be known, delaying important highway projects was not an option. And, where delays did occur (like Seward Highway in Alaska), the result was often strife and conflicts between highway and resource agencies. This resulted in conflicting policies and objectives, with State DOT's needing to get certain highway projects underway within defined timelines and resource agencies taking stands that the upgraded highways were detrimental to wildlife conservation. This battle has gone on throughout the United States and Canada as anyone working in the road ecology field can attest.

In the late 1990's and early 2000's, there was a need to increase traffic capacity of Highway 93 in Montana. This highway had a history of serious vehicle accidents, but also fragmented prime wildlife and fish habitat. Many years were spent haggling about whether or not an upgraded highway was necessary. Part of the issue involved the Flathead Indian Reservation and other issues involved the Bitterroot Valley south of Missoula. The primary author (Ruediger) was asked by the County Commissioners, highway departments and resource agencies to see if there was a way to quickly define wildlife habitat linkages on the non-Reservation portions of Highway 93. The results and process were documented in Ruediger and Lloyd, 2003 and Ruediger, et al, 2004.

Ruediger's experience included 35 years working for the U.S. Forest Service as a wildlife biologist. Part of this experience included funding many wildlife and fish surveys and studies and helping to develop and collect wildlife data used in threatened, endangered and sensitive species recovery plans and other wildlife management plans. Ken and Robin Wall are owners and operators of a GIS technical business (Geo-Data, Inc) that specializes in collecting existing GIS data on wildlife, wildlife habitat and other related natural resource data, geologic and geographic data, highway data and human use data. Before collecting new biological data, for Highway 93, the authors decided to assemble existing data and work with a knowledgeable team of local resource and highway personnel to define wildlife habitat linkages.

Based on other situations in Utah, Idaho, Alaska and Montana, using and refining the process previously defined, the authors determined that there usually is enough existing data and knowledge to define wildlife habitat linkages. One situation where there were problems with defining wildlife linkages was on the Sterling Highway in Alaska. The issue there was not having the available wildlife and other digital GIS data available for the workshop (Note: Geodata Services was not part of this project). The situation was compounded by polarized highway and resource agency positions and relationships. The Seward Highway experience provided a lesson on what resource information needs to be digitized and ready-to-go before the wildlife habitat linkage workshop begins. Based on the experiences from several wildlife habitat linkage workshops, the following measures are required:

1. All available GIS data layers must be compiled and ready to be used when needed during the workshop. An example of specific GIS layers needed are included in Appendix 2 (used in the US 6, Utah wildlife habitat linkage assessment), but will vary depending on the geographic area. This information is generally available, but exists in many different agency and non-agency sources, so the person compiling the GIS data must have knowledge, experience and access to where and how to obtain it. Knowing how to access all available GIS data is a skill necessary to assess wildlife habitat linkages and may not be readily available within resource or highway agencies.

2. The GIS information must be rapidly accessed and over-laid during the wildlife habitat linkage workshop. This involves state-of-the-art computer and GIS skills that may not be available within many highway or resource agencies. The GIS data operator is critical.

3. The workshop facilitator must understand the GIS data layers and how to synthesize the data during the meetings so that problem-solving evolves smoothly and quickly. In many situations, productivity requirements require hundreds of miles of highways be assessed, wildlife habitat linkages defined and all aspects of the decision documented within relatively short time-frames. Becoming immersed in irresolvable problems can result in failure or not meeting all of the wildlife habitat linkage assessment needs. The facilitator is critical.

4. Documentation of the specific rational and boundaries for each wildlife habitat linkage area is required, including maps, species present, target species, wildlife attractants, existing or future human uses, land ownership patterns, existence of migratory or season habitat uses and much more. This requires that both the GIS operator and the process facilitator quickly document each wildlife habitat linkage. Decisions as well as the supporting details must be documented, reviewed and finalized while the participants and the facilitators have a fresh memory of details.

Once the appropriate GIS data and experts are assembled and the workshops properly facilitated, .the quality of the decision, while subjective, is usually excellent. This result is due to the general availability of wildlife and other data and the knowledge of professionals as to where wildlife interfaces with highways. Also, the options for where wildlife habitat linkages are feasible are usually limited by existing human developments.

One of the best human (non-data) sources of wildlife use near highways is highway maintenance personnel. These people spend their entire careers on limited highway sections and intimately understand where most species of wildlife cross highways. Other important sources include land owners, postal workers as well as biologists and engineers familiar with specific highways.

With the exception noted (Seward Highway), all of the highways assessed for wildlife habitat linkages had adequate existing data to define where habitat or population connectivity is necessary. In the case of the Seward Highway in Alaska, the quality and adequacy of the existing data was unknown, since it was not available in digital form, as required, before the wildlife linkage workshop took place. Based on the experiences on US 6 and I-70 in Utah, the Idaho Statewide Habitat Connectivity Plan and US 93 in Montana, existing information was adequate to define wildlife habitat linkages and to define specific locations for most wildlife crossings.

Prioritization of Wildlife Habitat Linkages – How this Can Guide Wildlife Crossing Structure Selection and Minimize Mitigation Costs

One important factor evolved as various highways or highway projects were assessed. Prioritization of highway linkages is important to making subsequence decisions on the type and number of wildlife crossings eventually implemented.

There are many perspectives on what an appropriate wildlife crossing structure should be. Biologists from resource agencies may recommend expensive wildlife crossings because they are unsure of what size and type of structure will be adequate. Resource agencies often recommend several structures and more expensive designs such as bridges or overpasses so they are comfortable that the crossings will work. Since resource agencies do not pay for the design and construction of wildlife crossings, there is less pressure to constrain costs. Transportation agencies pay for the structures and want to limit the cost to the least amount necessary to satisfy regulatory and other resource agency needs. They also are concerned that the structures function well for wildlife.

There are four critical questions pertaining to all wildlife crossing decisions:

1. How many wildlife crossing structures are needed?
2. Where should they be located?
3. What type of structure is appropriate?
4. What size?

By prioritizing wildlife habitat linkages, the decisions on the number, type and size can be made easier and, often, less costly. In Utah, on Highway 6 is where agencies first began to discuss and use prioritization of wildlife habitat linkages and the rationale for setting priorities. Prioritization continued on Interstate 70 in Utah and was included as part of the Statewide Wildlife Habitat Connectivity process in Idaho. Prioritization of wildlife habitat linkages should only occur after all wildlife linkages on a highway, or region, have been identified. This allows the decision agencies a fully view of all proposed wildlife habitat linkages where comparison can be made.

The most recent criteria for prioritizing wildlife habitat linkages were based on the following factors:

HIGH PRIORITY LINKAGES:

1. Existence of threatened, endangered or agency listed sensitive species that could be adversely impacted by the proposed highway.
2. High collision rates with big game animals causing a significant highway safety issue.
3. Migratory big game herds of significant population size.
4. The presence of significant ecological-landscape level linkages involving multiple species.

MODERATE PRIORITY LINKAGES:

1. Collision rates with big game that are significant to highway safety (average to above average), but not of the highest concern level.
2. The presence of regionally important big game requiring population or habitat connectivity. These are often associated with attractants such as water, agricultural field and other human food sources (bears).
3. Severe impacts to local populations of wildlife that is not threatened, endangered or sensitive. Examples might be turtles needing to cross highways for breeding or habitat use, marmots on high elevation highways, salamander migration corridors, etc.

Photo 2. Monte Aldrich (front) and Randall Taylor, UDOT Engineers, look at a road-killed bull elk on I-70. Approximately 100 elk are killed on I-70 each year. This location, near milepost 6 is considered a high priority linkage due to traffic safety and high mortality to elk/deer and other wildlife. Photo by Bill Ruediger.

LOW PRIORITY LINKAGES: Any wildlife habitat linkage that is identified, but does not meet the criteria for high or moderate priority.

HIGHWAY SEGMENTS WITH NO PRIORITY: Once wildlife habitat linkages are determined and prioritized, some highway segments will not have important wildlife habitat connectivity issues, wildlife-vehicle collisions, or other significant wildlife or aquatic organism concerns. Minimum standards may still be necessary, including providing bridges that allow passage over stream channels, or minimal wildlife crossing structures connecting urban or rural open spaces.

Applying or using priority ratings when considering wildlife crossing is simple and straight forward. Consider using the higher cost structures, such as overpasses and bridges, primarily in high priority wildlife linkages and only when lower cost structures will not meet the management objectives. In general, moderate priority wildlife habitat linkages should use lower cost structures such as arches and box culverts. This will almost always save money, reduce wildlife-vehicle collisions and provide for habitat connectivity across highways. Lower cost structures often function well, even when applied to high priority highway segments. Both resource and transportation agencies should strive to use the lowest cost structures that provide passage for targets species. Risk is associated with all actions and decisions. With increasing knowledge of wildlife use of various types and sizes of structures, based on research and monitoring, even the least cost structures will often meet management objectives. An exception may be when providing plant and multiple-species habitat connectivity and ecological-landscape linkages. This situation may require large bridges, multi-span structures and/or ecopassess.

Application of wildlife habitat linkage prioritization in Utah suggests that only small portions of highways will qualify as "high priority". Based on US 6 and I-70 results, most highway mileage will have no priority (Figure 1). Both US 6 and I-70 traverse extensive public lands of high wildlife habitat value and both have exceptionally high wildlife-vehicle collision rates, suggesting that other highways may have significantly lower proportions of high and moderate rated sections.

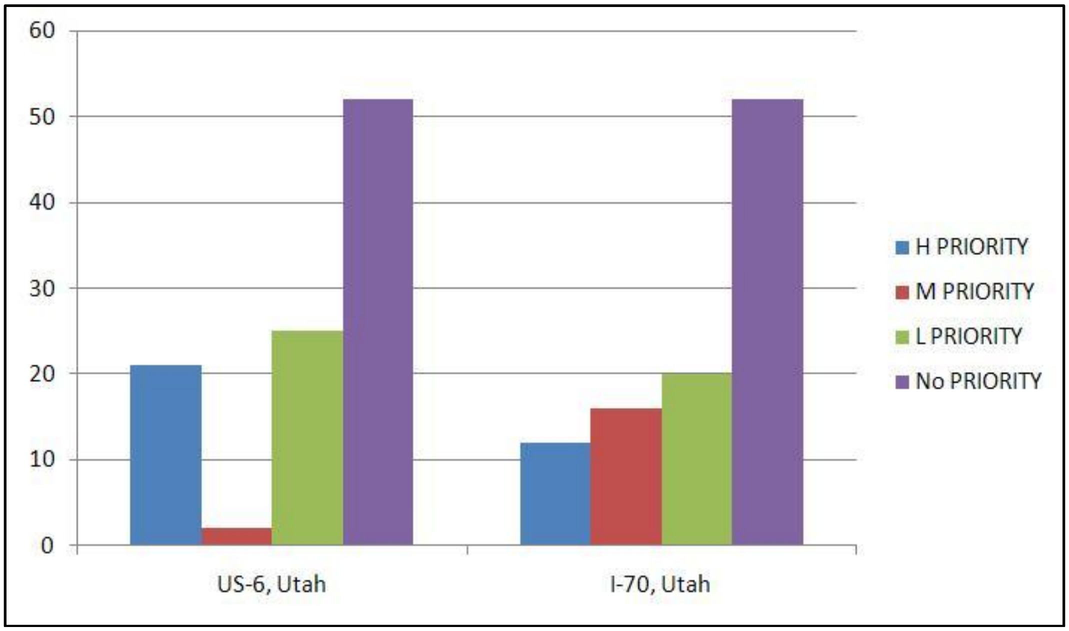

Figure 1. US 6 and I-70, Utah. Percentage of miles by priority category.

The size of structures provided should also consider the priority rating of the highway. Decisions on appropriate sized wildlife crossings involve interagency and interdisciplinary discussions and decisions on site limitations, safety, cost constraints, habitat requirements and target species. The recommended minimum crossing structures sizes are described in Safe Passage: A User's Guide to Developing Effective Highway Crossings for Carnivores and Other Wildlife (Ruediger and DiGiorgio 2007).

The determination for how many crossing structures are necessary is often uncomplicated. Suitable locations for wildlife crossing are often the limiting factor in how many crossings are feasible. In some instances, such as in very difficult terrain and where highway construction requires steep cuts walls, few or no opportunities may exist. In most situations the number of feasible locations limit crossings to a few sites and these solve the "how many and where" questions. In the rare situations where multiple sites are available, agencies must come together and select the best site or sites.

Interagency and Interdisciplinary Selection of Wildlife Crossing Locations and Structure Types and Sizes

Often decisions must be made immediately on where wildlife crossings will be constructed and what type and size they will be. This immediacy results from several situations which are common throughout the United States and Canada, and probably elsewhere. Most states have not undertaken Statewide Habitat Connectivity Plans. This omission results in highway departments going ahead with highway improvement plans and projects without the basic guidance of where habitat connectivity, wildlife mortality and traffic safety are important issues. This problem was identified during the first ICOET Meeting in Orlando, Florida (1996) and continues to exist.

As is often the case, necessity is the mother of invention. On US 6, Utah, the wildlife habitat linkage assessment was reviewed and reassessed and 35 wildlife crossings were identified as to location and type (see Figure 2). Utah already had a statewide habitat connectivity plan. The entire process took about 6 months to accomplish, plus some time to finalize the report. The cooperating agencies involved in the effort included Utah Department of Transportation, Utah Division of Wildlife Resources, Manti-la Sal National Forest, Uinta National Forest, Bureau of Land Management, US Fish and Wildlife Service and Utah Cooperative Wildlife Unit from Utah State University. Coordination, GIS and report editing were provided by HDR, Inc from Salt Lake City, Utah. The process facilitator (William Ruediger) was from Wildlife Consulting Resources. Twenty seven people were involved in the wildlife habitat linkage assessment and wildlife crossing decisions.

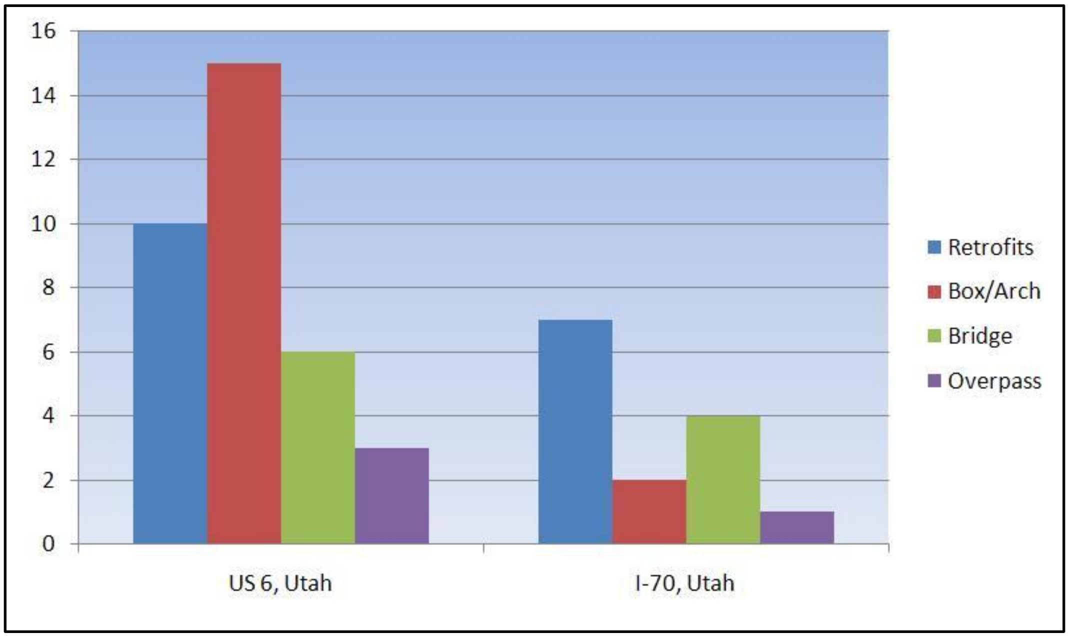

Figure 2. Number and type of recommended wildlife crossing structures selected for US 6 and I-70, Utah

On Interstate 70 near Richfield, Utah a similar group was established to review the wildlife habitat linkages and make wildlife crossing recommendations. On I-70, Utah Department of Transportation made a bold decision to invite several "experts" to review potential wildlife crossings and provide recommendations. In addition, UDOT made the wildlife habitat linkage session and the wildlife crossing recommendation process into a workshop so that other transportation and resource agencies could receive training. GIS data and facilitation was provided by HDR, Inc in Salt Lake City and the session was coordinated by Wildlife Consulting Resources. The expert panel consisted of the following individuals:

1) William (Bill) Ruediger, Wildlife Biologist, Wildlife Consulting Resources (retired US Forest Service), Missoula, Montana. Organized the I-70 Wildlife Crossing Workshop. Primary author of the report.
2) Pat Bastings, Missoula District Biologist, Montana Transportation Department, Missoula, Montana.
3) Dr. John A. Bissonette, Leader, USGS Utah Cooperative Fish and Wildlife Unit, College of Natural Resources, Utah State University, Logan, Utah
4) Norris Dodd, Research Wildlife Biologist, Arizona Game and Fish Department, Pinetop, Arizona.
5) Paul West, Wildlife Ecologist, UDOT, Salt Lake City, Utah;
6) Bruce Bonebrake, Habitat Program Manager, UDWR, Cedar City, Utah
7) Monte Aldridge, Region 4 Project Manager, UDOT, Richfield, Utah.
8) Randall Taylor, Region 4 Environmental Engineer, UDOT, Richfield, Utah.

Dr. Paul Garrett, Ecologist from Federal; Highway Administration's Headquarters Office planned to attend but was in a serious accident just before the workshop.

The flowing describes the situation on I-70: "Collisions with elk and mule deer are common on some sections of I-70. Utah Department of Transportation maintenance personnel estimate that two, or more, dead elk are observed or removed per week in the I-70 corridor from Salina to Fremont Junction, resulting in 100 or more elk being killed per year in this section – plus many more mule deer. Additionally, almost one elk per week is killed in the section of I-70 from the I-15 interchange to the summit near Mile Post 8 (there are approximately 40 elk-vehicle collisions in this section per year, plus numerous collisions with deer)" (Ruediger, et al 2007c).

The expert panel, assisted by 45 workshop participants, provided recommendations on 15 wildlife crossings on I-70 (see Figure 3), plus fencing projects. Recommendations were based on existing information, aided by knowledge from engineers, highway maintenance and resource professional from the local area. While final decisions on recommendations were the responsibility of the expert panel, workshop participants provide numerous ideas and comments. Partial funding was approved by UDOT for design and construction of the highest priority wildlife crossing and fencing. This section, from milepost 0 to milepost 8 has one of the highest elk–vehicle collision occurrences in

Utah. In addition, I-70 fragments important mule deer habitat and both deer mortality and deer-vehicle collisions are common.

The US 6 and I-70 processes illustrate that wildlife crossings can often be made with existing information and within narrow timeframes when required. The decisions required accurate knowledge of road kill information, topographic maps, information on target species habitat and use and migration corridors. Data was augmented by local technical and professional expertise.

Surprising Abundance of Retrofit Opportunities

One of the insights that were observed on both US 6 and I-70 that all agencies can learn and benefit from was that there are more opportunities to retrofit existing highway bridges, box culverts, arches and culverts into effective wildlife crossings than previously imagined. Some of the retrofits were fully adequate for wildlife crossings, some exceeded what would have likely been built for wildlife purposes only, and some were of dubious or marginal value, but still provides some use. Since these structures are already in place, the cost of providing wildlife habitat connectivity, reducing wildlife mortality and animal-vehicle collisions would be a fraction of the funding needed for stand-alone structures.

Almost all highway crossing structures provides potential passage some species, even small 18" cross-ditch culverts. The number of existing structures on US 6 and I-70 in Utah that were potentially suitable for elk, deer, moose, black bear and mountain lion was surprising.

On US 6 (Utah), 10 of 37 originally recommended structures were retrofits (27% of the recommended wildlife crossings – see Figure 2). This included several large bridges that were very suitable for wildlife crossings of multiple species including elk, deer, antelope, black bear mountain lion as well as smaller animals. Most of the bridges were crossings of the Price or the White River, but other retrofits included railroad bridge crossings of US 6 and a large existing bridge crossing at Grassy Trail Creek (see Photo 3).

Photo 3. Large bridge across Grassy Trail Creek, US 6, Utah. This existing bridge is larger than would likely be built for a wildlife crossing. It is suitable for antelope, mule deer, desert carnivores and other small animals. It is also in a stream channel that wildlife often use for travel and dispersal. Photo by Ruediger.

I-70 (Utah) had even more retrofit opportunities as a percentage of recommended wildlife crossings. In this case 7 of 15 recommended wildlife crossings were retrofit opportunities (47% - Figure 2). Several of these appeared to be very functional for wildlife crossings if relatively simple modifications were made like modifying existing right-of-way or cattle fencing, removing cattle guards and installation of wildlife fencing. Improvements on several locations are already planned or underway.

The most common retrofit opportunities on US 6 and I-70 existed in three areas:

1. Existing stream or river crossings.
2. Existing railroad crossings
3. Existing low volume county or forest road crossings.

All bridge and culvert crossings should be inspected for retrofit opportunities on highways where wildlife connectivity, reducing wildlife mortality and/or traffic safety are issues. If the situation is similar to US 6 or I-70 in Utah, approximately 1/3 to 1/2 of the potential wildlife crossings may already exist in either fully functional or partially functional bridges or culverts (box, arch or round). The cost of assessing and improving these retrofits will be a fraction of the cost of installing stand alone structures. This is an opportunity that is not being taken advantage of on most highways. Improvements might include installation of wildlife fencing, modifying or replacing existing fencing, installation of foot paths, removal of cattle guards or other low cost measures. Many of these improvements can be made without major funding. Most of the opportunities reviewed were on National Forest or BLM lands, suggesting that habitat improvement projects funded by those agencies could make significant improvements in local wildlife habitat connectivity.

One problem that appeared repeatedly was existing livestock or highway right-of-way fencing that hampered or precluded wildlife from using otherwise suitable existing crossings. Highway right-of-way fencing often includes a bottom section of hog or page wire that precluded use by small animals, including fawns and calves. Livestock fencing problems include 4, 5, 6 and 7 strand barb wire fencing that also makes passage by young animals impossible. Many of the livestock fences were such that even large adult animals would likely go around the crossings and over the highway surface. Welded page wire panels were observed in several locations which was an absolute barrier to all wildlife larger than cottontail rabbits (Photo 4). Livestock fencing adjacent to potential retrofit wildlife crossings should be modified into more wildlife friendly designs such as 3-wire fences with smooth bottom wires (better, use smooth wire for all 3 strands in a limited area around the crossing) with bottom wires 18” from the ground to allow fawns and calves (elk/moose) access. Highway right-of-way fencing should be tied into the retrofit structure so that animals can access it without having to cross the fence. Appropriate wildlife fencing may be required to prevent deer and elk from jumping the right-of-way fence and crossing the highway.

Figure 4. Example of welded livestock panel blocking two large box culverts on Icelander Creek, US 6, Utah. These culverts would be used by large and small wildlife if livestock fencing were modified and wildlife wing fences installed. Photo by Ruediger.

Acknowledgements

Many people and agencies helped fund, organize, edit and attend the wildlife habitat linkage and wildlife crossing meetings in Idaho and Utah. Many also helped provide comments and ideas to improve the processes presented in the paper. These include: Utah Dot – Monte Aldrich, Randall Taylor, John Higgins, Daryl Friant, Shane Marshall, Paul West and Rocky Williams. Idaho Transportation Department – Kim Just. HDR, Inc. – Vince Izzo, Heidi Spoor and Shawn Frye. Idaho Fish and Game, Greg Burak and Gregg Servheen. Utah Division of Wildlife – Bruce Bonebrake, Rudy Drubnick, Leroy Mead, Doug Sakaguchi. US Forest Service – Jeff Jewkes, Pam Jewkes, Mary Erickson, Chris Colt and Steve Rodriguez. BLM – David Waller. USGS, Utah Coop. Unit – Dr. John Bissonette and Dr. Patty Cramer. Federal Highway Administration – Brent Ingrham. Arizona Game and Fish – Norris Dodd. Montana Transportation Department – Pat Bastings.

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Appendix 1. Wildlife Genus and Species Used in the Text

1. Black bear *Ursus americanus*
2. Mountain lion *Felis concolor*
3. Mule deer *Odocoileus hemionus*
4. Rocky Mountain elk *Cervus elaphus*
5. Rocky Mountain bighorn sheep *Ovis canadensis*
6. Moose *Alces alces*
7. Pronghorn antelope *Antilocarpra Americana*

Appendix 2. GIS Layers Used to Assess US 6 in Utah

1. Strike data 2001 to 2005 – Collision data on vehicle/wildlife crashes – UDOT
2. Mileposts – UDOT
3. Utah Natural Heritage Exact Points – UNHP
4. Streams_Utah – AGRC (Utah's automated geographic reference center)
5. Contours 500 – AGRC
6. Washes – From US 6 EIS
7. SGID500 Watershed – AGRC
8. ut_landcover (vegetation) – Utah GAP (USU)
9. Black Bear Habitat – DWR (Division of Wildlife Resources)
10. Moose Habitat – DWR
11. Mule Deer Habitat – DWR
12. Pronghorn Habitat – DWR
13. Rocky Mountain Bighorn Sheep Habitat – DWR
14. Elk Habitat – DWR
15. Sage Grouse Brooding Habitat – DWR
16. Sage Grouse Wintering Habitat – DWR
17. Threatened and Endangered Species – DWR
18. Wetlands (formally delineated) – US 6 EIS
19. Municipalities (Boundary) – AGRC
20. Land Ownership – AGRC
21. Aerial Photos 2003 and 2004 Images – US 6 EIS and AGRC

Appendix 3. Wildlife Linkage Work Sheet Used to Document I-70 Wildlife Habitat Linkages in Utah:

Wildlife Linkage Worksheet – Interstate 70, Utah Date: May 1, 2007 Page _____

1. Linkage Area Number________ 2. Linkage Name ____

3. Mile Post: From _______ to __________

4. General Description (Including biome, habitat and terrain):

5. Species:

☐ Mule Deer ☐ Moose ☐ Black Bear ☐ Antelope

☐ Elk ☐ Cougar ☐ WT Prairie Dog

Other Mammals ____

Reptiles ____

Amphibian's ____

Fish ____

T&E or Sensitive? ☐ Yes ☐ No Species ____

____

7. Significance of Linkage Area

☐ Local ____

☐ Regional ____

☐ Ecosystem ____

8. Migratory Herds

☐ Yes Species and Numbers ____

____

9. Local Animals Mostly ☐ Yes Species and situation ____

10. Is there a significant number of highway kills? ☐ Yes ☐ No Species ____________________________

____

11. Attractants: ☐ Water ☐ Ag Fields ☐ Cover ☐ Garbage/Human

Explain ____

12. Land Ownership/Management ☐ BLM ☐ Forest Service

☐ State ___________ ☐ Industrial ☐ Private ________________________________

Are easements or purchases recommended? ____

____

13. What agencies need to be involved in Hwy Project Planning?

☐ BLM ☐ Forest Service ☐ State DWR ☐ Fish & WL Ser

14. Who?

Name:	Office:	Phone:
____________________	____________________	____________________
____________________	____________________	____________________
____________________	____________________	____________________
____________________	____________________	____________________
____________________	____________________	____________________

15. Are there other people who should be contacted? Private, conservation, University, etc.

____________________	____________________	____________________
____________________	____________________	____________________
____________________	____________________	____________________

16. Is research or monitoring recommended? ☐ Yes ☐ No Species ________________________

____

17. What agency is primarily concerned about the wildlife linkage area?

____

18. Priority Rating: High ___ Moderate ___ Low __

Rationale:

____

____

____

WASHINGTON'S HABITAT CONNECTIVITY HIGHWAY RETROFIT INITIATIVE

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Abstract

At the Washington Department of Transportation, an Executive Order – "Protections and Connections for High Quality Natural Habitats," is influential in directing resources toward investments in habitat connectivity improvements. A habitat connectivity retrofit program is in its early phases of development, with cost estimates completed for nine proposed projects. Deer and elk carcass removal data and outputs from rare forest carnivore least cost distance models were the primary sources of information used to select these project locations. Each one employs, primarily, highway right-of-way fencing, jump-out escape ramps, double-cattle guards at intersecting side roads, and under-crossings to reduce wildlife-vehicle collisions and provide wildlife with safe access to habitat on either side of the highway. Staff resources have also been directed toward a statewide habitat connectivity assessment. WSDOT co-leads the multi-organization working group that is producing the assessment. The group has completed a study plan, selected sixteen focal species, and assembled draft geographic information system models that utilize least cost distance and circuit theory modeling methods to provide insights to landscape characteristics conducive to wildlife movements. The outputs from these models will be used to support the development of priorities for future habitat connectivity retrofit projects.

Background

Since July 23, 2007, the Washington Department of Transportation (WSDOT) has worked under an Executive Order, "Protections and Connections for High Quality Natural Habitats", which directs the agency, in partnership with other agencies, organizations, and the public, to assure that road and highway programs recognize, together with other needs, the importance of protecting ecosystem health, the viability of aquatic and terrestrial wildlife species, and the preservation of biodiversity. This Order establishes a number of approaches to achieving this goal including identification of affected habitats early in planning processes and investments in habitat protection as part of project delivery. It directs the agency to identify specific opportunities to restore habitat connectivity where it has been damaged by transportation corridors and to use both capital projects and maintenance activities to effect restoration. The Order urges development of a statewide habitat connectivity plan and lends support to efforts to protect and enhance habitat along highways and promoting the traveling public's enjoyment of wildlife in Washington State.

Washington State has a well-established highway improvement program that includes projects that benefit the environment. Currently funded projects remove barriers to fish passage and correct problems associated with chronic scour. This program has been expanded to include habitat connectivity retrofit projects. Conceptual plans for nine habitat connectivity projects have been fully developed.

Identifying Habitat Connectivity Project Locations

Habitat connectivity retrofit project locations were identified through the use of two primary data sources. One was WSDOT's deer and elk carcass removal database and the analysis of these data by the Washington Department of Fish and Wildlife (Myers et al. 2008). The other came from a WSDOT-sponsored rare forest carnivore least cost distance modeling project (Singleton et al 2002).

Locations identified in these two data summaries were used as the basis for the initial reconnaissance to determine if safe passage improvements could reasonably be accomplished. Identified highway segments were assessed through field visits and review of GIS layers for occurrences of rare, threatened, and endangered species, priority habitats and land ownership patterns. In some instances, efficiencies were identified where removal of fish passage barriers or correction of hydrologic/erosion problems could occur as part of a wildlife habitat connectivity retrofit. Figure 1 shows an area in the Okanogan River Valley where a deer-vehicle collision problem area corresponded with a modeled least cost distance corridor for Grizzly Bear. A total of nine such projects have been fully described and assigned design, permitting, and construction cost estimates (table 1; figure 2). One project, which coincides with a fish blockage, is currently funded for the design phase and will likely be constructed in the near future.

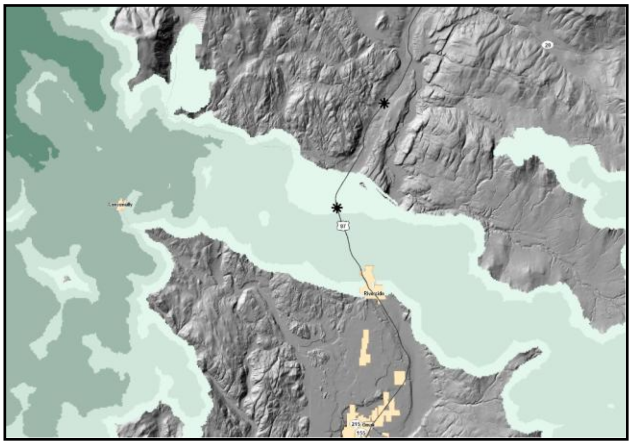

Figure 1. Grizzly Bear Least Cost corridor (shaded) and location of proposed wildlife underpasses (asterisks on highway).

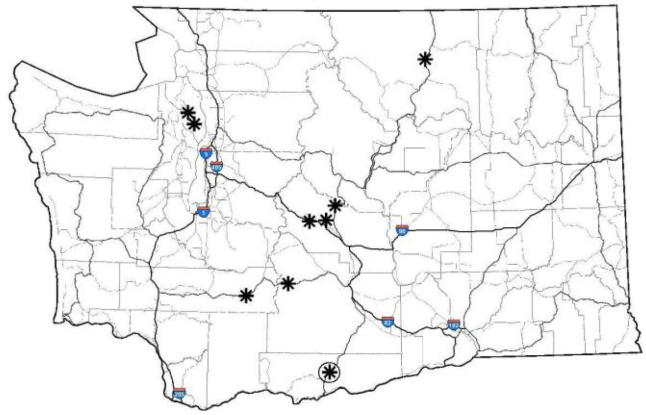

Figure 2. Locations of nine proposed habitat connectivity retrofit projects. Circled location represents project going to design phase

Name	State Route	Mile Post	Estimated Cost ($)	Description[1]
1) Packwood-Randle	12	117-131	3,355,799	1 Culvert, 13 mi of fence
Elk-vehicle collision problem area; Fish passage barrier				
2) Goldendale North	97	15-23	4,018,850	4 Culverts, 13 mi of fence
Deer-vehicle collision problem area; Fish passage barrier				
3) Upper Rimrock Lake	12	157-159	1,281,357	1 Culvert, 5 mi of fence
Elk-vehicle collision problem area; Wide-ranging carnivore habitat concentrations				
4) Riverside	97	300-310.5	5,615,800	2 Culverts, 14 mi of fence
Deer-vehicle collision problem area; Wide-ranging Carnivore Linkage				
5) Swauk Creek	97	158-159	2,893,020	1 Culvert, 5 mi of fence
Elk-vehicle collision problem area; Fish passage barrier; Wide-ranging Carnivore Linkage				
6) Teanaway	970	3-8	3,768,266	2 Culverts, 3.5 mi of fence
Elk-vehicle collision problem area; Wide-ranging Carnivore Linkage				
7) Bullfrog	90	79-82	1,554,467	6 mi of fence
Elk-vehicle collision problem area; Wide-ranging Carnivore Linkage				
8) Whidbey South	525	15-17	5,909,001	1 Bridge, 5 mi of fence
Deer-vehicle collision problem area				
9) Whidbey North	525	25	7,726,633	1 Culvert
Deer-vehicle collision problem area				

[1] Culverts, in this context, are large bottomless multi-plate arch culverts.

Table 1. Elements of nine Habitat Connectivity retrofit projects in Washington.

In the future, WSDOT's habitat connectivity retrofit program will benefit from a more comprehensive effort to identify locations of importance to wildlife and ecological processes. The agency is co-leading a habitat connectivity assessment covering the entirety of Washington State with extensions into adjacent British Columbia, Idaho, and Oregon. This multi-year project involves selection of focal species and the use of least cost distance and circuit theory models to identify areas of value to wildlife moving between large blocks of high quality habitat. The results of this assessment will inform a process for prioritizing investments intended to improve safe passage for wildlife that cross our highways.

Best Practices for Providing Safe Passage

Fencing the highway right-of-way and providing safe passage crossing structures was considered the most desirable option because of proven effectiveness and low maintenance (Huijser et al 2007). Therefore, highway segments were assessed for their suitability for right-of-way fencing and the locations and spacing of sites deemed suitable for installing crossing structures. Locations where the road was built on deep fill were especially desirable because of the economies of a “cut and cover” approach to installing large multi-plate arch culverts to provide animal passage under the highway. Final project designs included regularly spaced jump-out escape ramps and double-cattle guards or gates at intersecting side roads. Eight foot tall woven wire fencing and large multi-plate arch culverts or single span bridges were included in most projects and, in two instances, will serve to provide both terrestrial wildlife passage and improved fish passage. Existing bridges were exploited, whenever possible, to provide safe passage for wildlife. Bridges sometimes needed substrate improvements or increased vertical clearance to make them attractive.

Discussion

The nine projects proposed for the first phase of habitat connectivity highway retrofit projects provide multiple benefits including improved motorist safety, preventing the property damage that results from collisions, and reducing wildlife mortalities. It is anticipated that these projects, by reducing human injuries and damage to vehicles, will pay for themselves well before their design life has expired. A variety of wildlife, other than deer and elk, are expected to benefit from the measures taken to prevent them from entering the highway right-of-way while providing safe crossing opportunities.

Acknowledgements

Suggestions for content and review of an earlier draft were provided by Marion Carey, Fish and Wildlife Program manager at WSDOT.

Biographical Sketch

Kelly McAllister is the Habitat Connectivity Biologist for the Washington Department of Transportation, a position he has held since February, 2007. Prior to joining WSDOT, he worked in various capacities as a wildlife biologist with the Washington Department of Fish and Wildlife, mainly involved with endangered species listing and recovery but including nine years doing both game and endangered species work as a District Wildlife Biologist. Kelly has a Bachelor of Science degree from the University of Washington.

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IDAHO STATEWIDE WILDLIFE / TRANSPORTATION DATABASE

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Abstract

Idaho recently completed a statewide inventory of wildlife linkage areas in relation to the state highway system. The inventory presents first order information identifying important wildlife crossings and public safety concerns on Idaho's roads. Issues requiring additional study during transportation project planning as well as actions necessary to protect wildlife migration corridors and critical habitat linkage areas and address highway safety issues were identified for each linkage area. The resulting information is presented in a GIS database available to transportation planners, resource agencies, and the public at large.

The project was initiated to benefit streamlining of project environmental review as well as increase transportation planning efficiencies in road corridor planning and transportation project development. The project, funded by FHWA, was phased expansion over four years to map wildlife linkages on roads and highways for the entire state. Idaho Fish and Game partnered with the Idaho Transportation Department and FHWA and acted as project manager as well as a primary source of habitat and wildlife information. A rapid assessment technique described by Ruediger and Lloyd (2004) was utilized to gather wildlife and highway information at workshops held around the state. Wildlife-vehicle collision data compiled from agency records, first-hand knowledge of field staff from the Idaho Fish and Game Department, Idaho Transportation Department, land managers, and other available wildlife, habitat, and human development information was used to identify and model linkage areas. After synthesis and modeling was completed, the information was made available on an interactive website: http://fishandgame.idaho.gov/cms/wildlife/manage_issues/collision/. The website allows for ongoing input and comment by users so new information can be amended into the database, providing continuous improvement over time.

A web-application was also developed by Idaho Fish and Game to allow the collection and compilation of wildlife traffic mortality data. That web application is accessible and useable by agency personnel via the internet and provides a consistent protocol and terminology for roadkill reporting across the state to increase QA/QC of data. The information is held in a centralized repository for use at the project and program level. Efforts to deploy and use these improved technologies in terms of efficiencies, coordination, and benefits to the resources are discussed.

Introduction

Idaho has a transportation system that includes an integrated network of more than 60,000 miles of roads, approximately 4,000 bridges, 1,887 miles of rail lines, 30 airfields, and a seaport. The Idaho Transportation Department (ITD) has jurisdictional responsibilities for nearly 5,000 miles of highway (12,000+ lane-miles) and more than 1,700 bridges.

This transportation system provides the primary network for commerce and the daily lives of Idaho's citizens. When wildlife, especially larger ungulates like elk, deer, and moose, interact with the highway interface; public safety and wildlife conservation converge. Huijser et al. (2007) found that the total cost of wildlife/vehicle collisions, which includes vehicle repair, consumptive and non-consumptive recreational loss of the animal, removal of the carcass, police investigation, human injury or fatality, to be $8,000 for deer, $17,500 for elk, and $28,600 for moose. At a national level, there are between 700,000 to 1,500,000 collisions between deer (mule deer and white tail) and vehicles each year in the United States (Conover et al. 1995). In one 20-mile stretch of State Highway 21 north of Boise, it is estimated over 220 mule deer a year are being killed. For six miles of US-30 in southeastern Idaho, it was found that over 300 mule deer were killed on the roadway from the years 2000-2006, equating to roughly 50 mule deer killed per year. While these numbers are from roads with a high profile for this problem, the estimates do not take into account the number of animals that may be struck on the road and are able to travel far enough away from the road prior to dying and remain uncounted. Data of this type reflects that wildlife-vehicle collisions on Idaho's roads represent an ever increasing human-caused mortality on Idaho's wildlife.

This is important not only from a public safety and wildlife conservation perspective but from an economic one. According to 2001 wildlife-based recreation expenditure economic data, hunters and anglers in Idaho spent $319 and $396 million respectively on hunting and fishing related retail sales (USDI 2002). Non-consumptive recreationists spent $228 million on wildlife viewing in Idaho in 2001. Maintaining Idaho's wildlife is a business and economy issue as well as a conservation issue. And as Idaho's human population continues to rapidly increase, making Idaho the third fastest growing state in the nation (US Census Bureau, 2007), balancing wildlife and transportation management is an ever increasing necessity from a safety, economic, and conservation perspective.

As a result, the Idaho Transportation Department's mission "to provide cost-effective transportation systems that are safe, reliable and responsive to the economical and efficient movement of people and products" must increasingly find solutions to fish and wildlife and endangered species concerns where they intersect transportation. Doing so in an economic and efficient manner that reduces costs and streamlines implementation is good business for transportation and resource agencies.

This project was initiated to streamline environmental review of projects as well as to benefit wildlife. Transportation planning efficiencies resulting from information produced by this project and provided in the early stages of highway corridor planning make for more efficient as well as more wildlife friendly transportation projects. Our identification and documentation of areas along highways that are important for maintaining or restoring wildlife connectivity among fragmented habitats provides planning level assessment information that might otherwise be too cost or time prohibitive to gather at the project or field level prior to implementation.

The objectives of this project were:

- Define wildlife linkage areas using rapid assessment workshops (Ruediger and Lloyd 2004) and describe in a seamless GIS format for the state of Idaho.
- Model wildlife habitat connectivity and habitat fragmentation related to human development (Servheen et al., 2003).
- Develop and implement a wildlife mortality data collection system for consistent collection and use of wildlife-vehicle collision data.
- Communicate knowledge and information related to wildlife linkage in Idaho and update and maintain linkage and mortality systems as needed.

Methods

Ruediger et al. (1999) suggest that the current practice of assessing highway projects in individual segments is inappropriate for mid- to large-sized carnivores and is neither cost-effective nor suitable for determining high priority wildlife areas. A more appropriate scale for planning effects of these linear developments on wildlife is at a landscape level.

Out of this need, Ruediger and Lloyd (2003) and Ruediger et al. (2004) developed a "Rapid Assessment" procedure." Rapid Assessment is a process for quickly and efficiently locating critical fish and wildlife linkage areas along roads and highways. The process involves obtaining input from local experts to populate GIS-based maps with occurrence data of fish and wildlife species of interest. Other map layers typically include land cover, wildlife distribution, elevation, hydrologic features, land ownership, and roadkill data. The workshop approach is a mix of qualitative data (local expertise) and quantitative data (GIS-based). The final step in identifying linkage areas is to ground-truth the sites identified by the "team" of experts to determine the level of connectivity that exists, and to assess the kinds of mitigation necessary to promote safe movement of fish or wildlife across the highway. The value of the Rapid Assessment process is that it can provide cost-effective broad-scale information useful to a variety of agencies.

An initial effort to map wildlife linkages relative to Idaho's highways was undertaken in June 2004 using the Rapid Assessment procedure described by Ruediger and Lloyd (2003) and focused on all state highways north of Interstate 90 in Idaho. However, because it was done earlier and separate from the larger statewide effort we discuss here, the information was updated and made consistent with our more recent mapping workshops.

Our first wildlife linkage assessment module was undertaken in May 2005 on mountainous highways of eastern and central Idaho. Initially four highway corridors were targeted for study using the Rapid Assessment process. The four study areas were selected to provide an opportunity for this analytical method to be applied to a range of highway facilities, including an interstate, a busy two-lane highway, and low-volume rural state highways. The project included an approximate total of 450 miles of highways including high valleys, mountainous areas with three mountain passes over 7,000 feet elevation, and low elevation desert areas. Average daily traffic counts ranged from approximately 450 to 4,000 on these four roads.

The project areas were identified because they were expected to encompass areas for federally listed threatened and endangered species including bull trout, Chinook and sockeye salmon, steelhead trout, and terrestrial species such as grizzly bear, gray wolf, Canada lynx, and the bald eagle. Using the Rapid Assessment method proved to be an effective and economical methodology at the scale it was conducted and the study of the four corridors was completed under budget. The project was then expanded to include completing a Rapid Assessment for all highways (990 centerline miles) in eastern Idaho (ITD District 6).

The effort to complete Rapid Assessments of the entire state highway system was accomplished in a phased manner over the next two years. Idaho Fish and Game partnered with the Idaho Transportation Department and FHWA and acted as project manager as well as a primary source of habitat information. The Rapid Assessment technique was utilized to gather information using a workshop format at locations across the state. Use of the same information and process made the data seamless and consistent at a statewide level.

One-day expert workshops in each of the Idaho Transportation Department's six geographical districts were organized, coordinated, and facilitated to develop area of interest maps for the highways within each of the districts, and provide the content for the wildlife linkage assessment. It was crucial to the success of the project to have wildlife biologists, transportation department and highway maintenance staff, and members of non-governmental organizations attend and provide expert local knowledge in these interactive workshops. At the workshops, data was compiled from agency records; first-hand knowledge of the workshop participants, and other available wildlife information was recorded and used to model habitat and linkage areas.

There were two primary GIS processing tasks required prior to conducting the workshops. These tasks included developing the base layers for reference in the meetings and for data summarization in post workshop processing, and creating the wildlife linkage mapping model for reference during the workshops. The base layers are normally derived from a subset of the digital data from a larger regional or national data layer for vector-based layers and re-projected as needed to make them suitable for display and analysis. The image base (orthoimagery and satellite imagery) necessary for use in the workshops required a large amount of the processing time. A draft wildlife linkage model was developed and then reviewed by workshop participants. A moderate amount of GIS grid-based processing was necessary to prepare the final model.

At each workshop, highway segments were collectively analyzed mile by mile by the group with guidance provided by the facilitator. As linkage areas were identified, the GIS mapping operator would digitize an area of interest (AOI) polygon that encompassed the linkage area. While the digital mapping was being carried out, the facilitator would provide guidance to the group in identifying the linkage specific attributes, such as the species that utilized the linkage area, seasons of use (primarily migratory versus local populations), and the type of wildlife attractants that were the driving factor of wildlife use. While this information was being identified, recorders wrote down the information on linkage data forms. All data and notes provided the metadata for each linkage area (see example in Appendix).

The second GIS processing task included Idaho Transportation Department districts in northern and eastern Idaho. In these areas, a wildlife linkage model developed by Meitz (1994) and Servheen et al. (2003) was utilized to predict broad areas of highest linkage potential between habitat units for various carnivores. This model combined four input data layers into a new layer displaying the combined impact of each of these factors on habitat quality. The four input data layers were road density, human developed sites, vegetation hiding cover, and riparian areas. The results of the final layer were divided into one of four categories based on objective evaluation: minimal, low, moderate, and high. Servheen et al. (2003) provides a detailed account of the methodology for the linkage model.

Due to the large amount of time compiling the input data layers, specifically identifying human site developments, for the linkage model, the extent of where it was applied was limited. Because the model was primarily developed for grizzly bears, a large, wide ranging carnivore species that requires large amounts of unfragmented habitat, the most cost-effective application was in Idaho Transportation Department districts in northern, central, and eastern Idaho. This area has been identified by many as necessary to wildlife connectivity between the Yellowstone ecosystem, Central Idaho Wilderness areas, and the forested ecosystems of northern Idaho, northwest Montana, and Canada.
The resulting information is presented online at the Idaho Highway Wildlife linkage wiki in a GIS database available to transportation planners, resource agency personnel, and the public at large. The database presents first order information

that identifies areas of special concern and hot spots for fish/wildlife/ transportation issues that require additional study during project planning and development of projects to protect wildlife migration corridors and critical habitat linkage areas and address highway safety issues. The wildlife linkage website is interactive and allows for ongoing input and comment by users, so new information can be amended into the database to allow continuous addition and refinement of the information over time. The website is: http://fishandgame.idaho.gov/cms/wildlife/manage_issues/collision/.

The project also included a statewide effort to initiate a standardized system for collecting and summarizing wildlife road mortality information. Past and current efforts to collect this information have been largely inconsistent and unavailable and so did not add value to efforts to streamline environmental reviews or aid in transportation system designs that might also aid in reducing wildlife-vehicle collisions.

A web application was developed to allow field personnel from the Idaho Transportation and Fish and Game Departments to directly enter data on wildlife road mortality into an Access database using the Web as the interface. Standard information including wildlife species, highway numbers, mileposts, and wildlife road mortality descriptions (species, condition, sex, decomposition) were incorporated into the data input menu. Users are required to register prior to entering data, which allows follow up during QA/QC of data and data summaries.

Results and Management Applications

Eleven one-day workshops identified a total of 315 wildlife linkage areas associated with roads and highways. A total of 158 participants attended actual workshops while additional wildlife crossing information was provided through individual contacts with knowledgeable experts who were unable to attend workshops, and through the online linkage wiki.

Of those 315 wildlife linkage areas, a total of 37 were identified as high priority. Prioritization was done two different ways. For those defined in workshops in Districts 1 through 5 linkage areas were classified into one of three priority classes: low, moderate, and high. For those in Districts 6 (east and east-central Idaho), linkage prioritization was done after workshops were completed using key individuals from various agencies within those individual districts. Linkage prioritization was collectively completed using the following considerations: 1–Highway safety, 2–Reductions of big game or habitat fragmentation on key game ranges, 3–Highway segments through key wildlife producing areas, including state wildlife management areas, wetlands or other limited and high value wildlife areas, 4–Linkages with Federally-listed Threatened and Endangered species issues, 5–Areas where mortality of state or federal species of concern or sensitive species, and 6–Linkages associated with imminent highway construction plans where wildlife and human safety are concerns.

A map of each wildlife linkage and the metadata associated with that linkage is available via the web and an interactive wildlife linkage wiki that allows updates to each linkage area (an example is presented in Figure 1, with data table in the Appendix).

In Idaho Transportation Department districts in northern, central, and eastern Idaho, the wildlife linkage model developed by Meitz (1994) and Servheen et al. (2003) was utilized to predict broad areas of highest linkage potential between habitat units for various carnivore using input data layers of road density, sites of human development, vegetation hiding cover, and riparian areas. The results of the final layer were divided into one of four categories based on objective evaluation: minimal, low, moderate, and high and shaded green, blue, pink, and red, respectively (Figure 2). The model provides a landscape perspective on areas of greatest wildlife linkage risk and opportunity; especially as it coincides with the boundary along the Idaho-Montana border and its potential to provide north and south connectivity among public lands, wide ranging species such as the grizzly bear and wolverine, and designated management areas including Yellowstone National Park, The Frank Church River of No Return Wilderness, and proposed and existing wilderness and roadless areas. The model highlights those areas of greatest concern to maintaining this connectivity. Areas of greatest threat to connectivity include those directly west of Yellowstone Park and in association with US Highway 20 and Interstate 15 and then moving north; US Highways 93 and 12, Interstate 90, State Highway 200, US Highways 95 and 2 and State Highway 1 in northern Idaho and on the Idaho-Montana border.

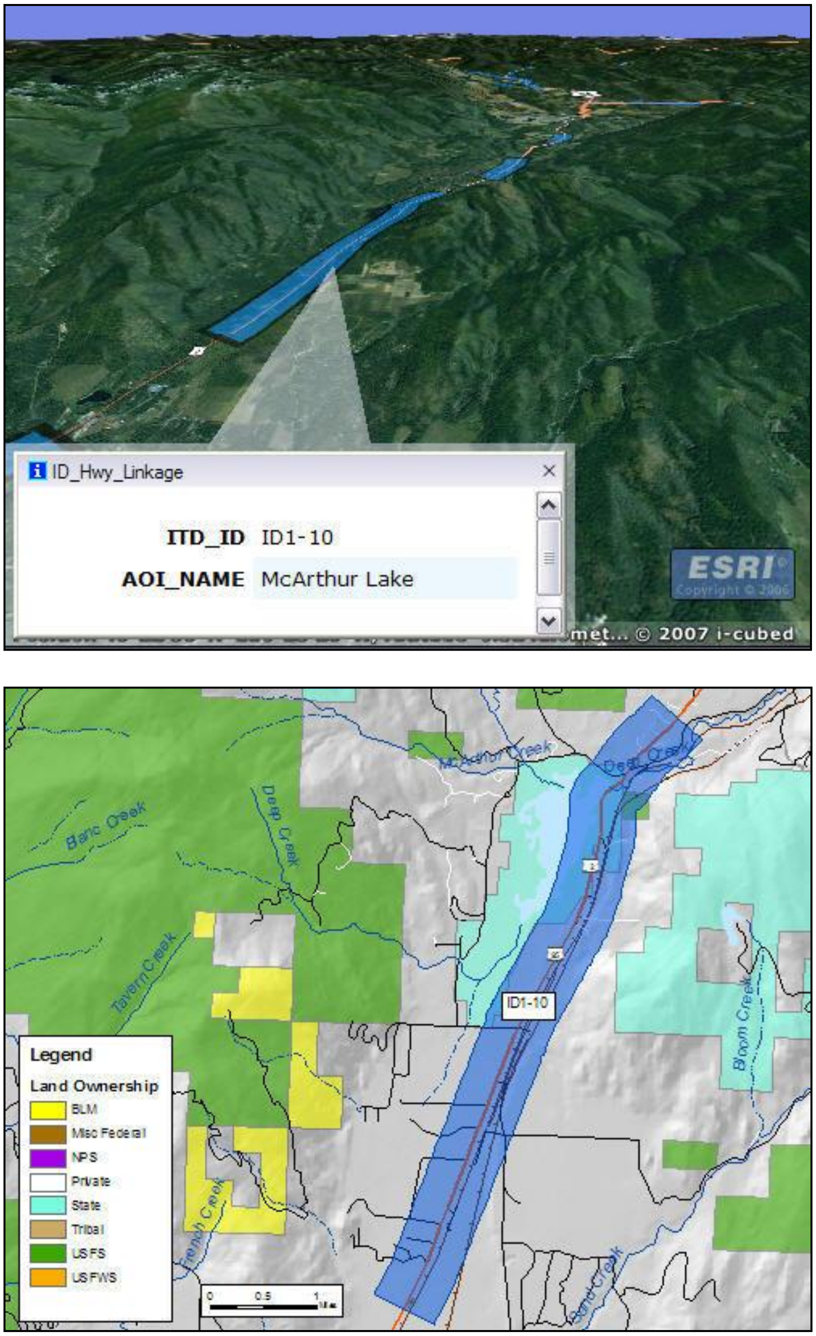

Figure 1. Example displays of Idaho wildlife linkage area in Google Earth and landownership map representations on Idaho Wildlife linkage wiki. Metadata for this same identified wildlife linkage is presented in the Appendix.

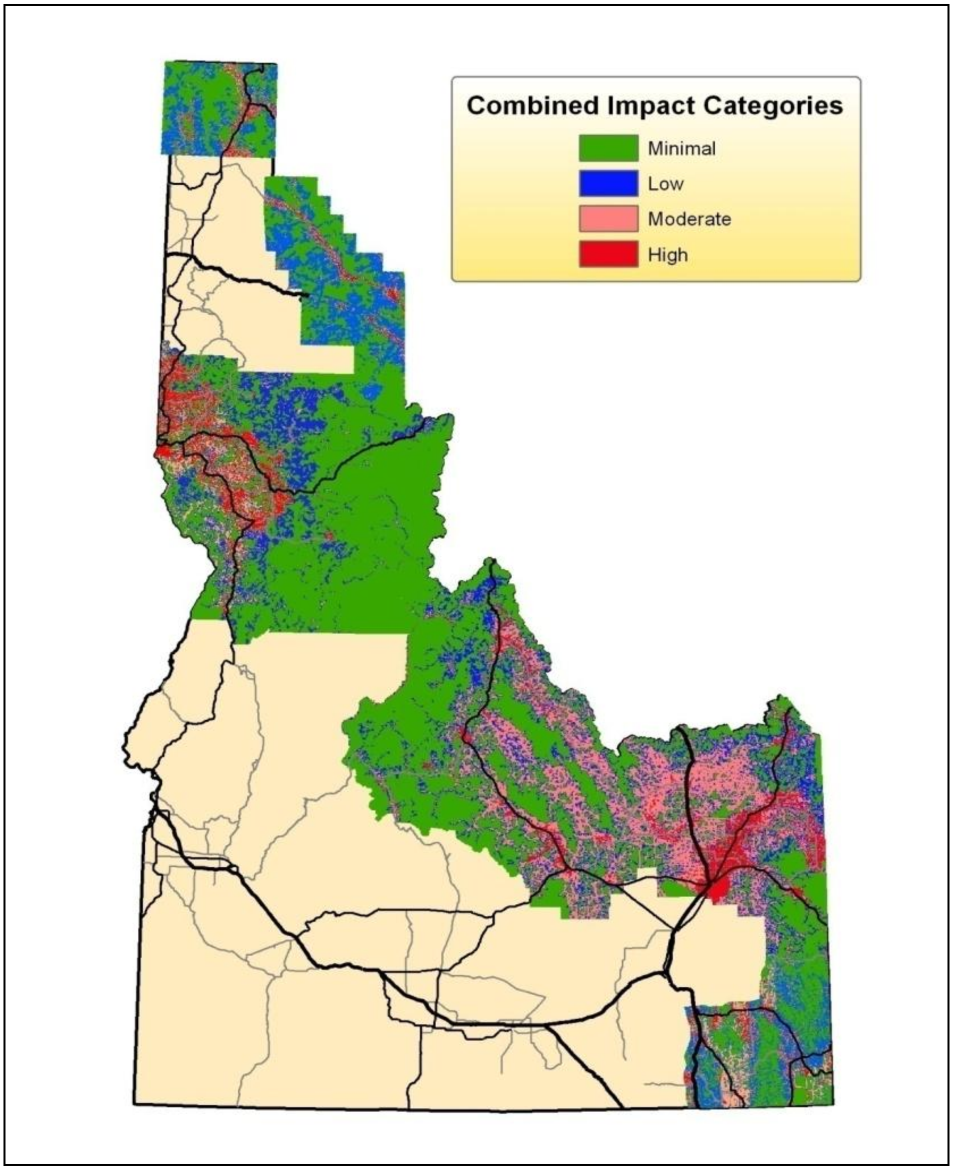

Figure 2. Results of wildlife linkage modeling based on human development, road density, riparian areas, and vegetation variables and expressed in terms wildlife connectivity impact categories.

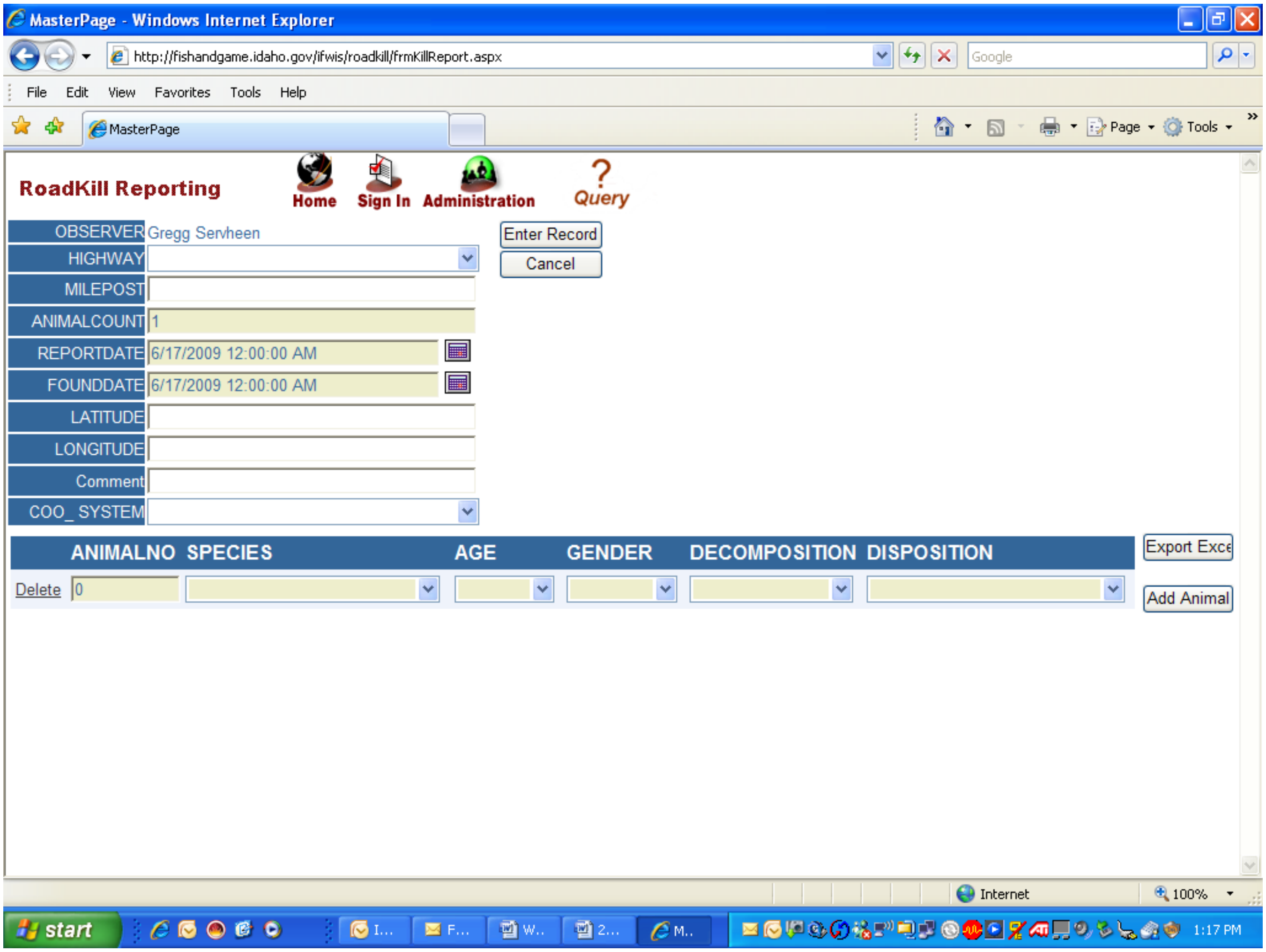

Figure 3. Menu page for wildlife mortality data input application.

The web application for input of wildlife road mortality data is deployed on the Idaho Department of Fish and Game and Idaho Department of Transportation web sites. (http://fishandgame.idaho.gov/ifwis/roadkill/). The application requires a user to register upon their initial entry and then to use a password to enter the application for subsequent input of road mortality data. Simple pick lists of the most basic roadkill information are provided to the data entry user to reduce difficulty of use and to enhance data quality (Figure 3). For example, the lists differentiate between white tail and mule deer and does and bucks and help reduce loss and misinterpretation of data that might be entered in different ways or with different terms by users. Similarly, an entire list of state highways within the state is provided and locations can be provided either by mile post or latitude and longitude or both. The resulting data can be queried at any level of a field and exported and downloaded as needed.

To date a total of over 8,300 records have been collected and consolidated into the database. The greatest numbers of records are for mule deer, which has more than four times as many records as the next most common species, white-tailed deer. More than 42 species/genera of wildlife have been recorded, including wolverine, grizzly bear, lynx, mountain lion, mountain goat, wolf, sage grouse, and bald eagle.

Efforts continue to increase the number of regular Idaho Transportation and Fish and Game Department employee users and to gather and input data collected prior to the availability of the application. The application has more than 150 registered users.

Discussion

This project permitted the transportation and resource agencies to gain experience applying the Rapid Assessment Process. It was found to be a useful and effective means for translating brain trust information into a format that is applicable to management decision making. Most important to the workshop assessment approach is insuring attendance of people who have the greatest field knowledge and understanding of the roads throughout the year.

A statewide information layer on wildlife linkage has now been created in relation to the state highway system that was collected in a consistent and credible way. Although many of the identified linkage areas were not substantiated by roadkill data, the workshop format helped validate individual and collective knowledge in lieu of real data. And mapped locations of linkages are now available for validation of roadkill numbers, timing, and location that can be more focused and project driven than might have been done before.

The benefits of having now completed a statewide wildlife linkage inventory include:

- This work provides a basis for maximizing the effectiveness of future measures to address these concerns, such as locations for potential wildlife crossing facilities, and locations where future studies of wildlife activity may be warranted or not warranted.
- Early initial efforts expedite consultations with resource agencies by assisting in understanding wildlife-highway interactions for a number of threatened and endangered species as well as other wildlife, fish and plants.
- Streamlining is promoted through preemptive identification of issues and areas that relate to fish and wildlife. Project decisions can then be made at an early, appropriate time on the basis of this information. “Hotspot” locations which are problematic or in need of further study, can be identified and addressed early in project development.
- Safety enhancement through reduction of wildlife-vehicle collisions can be incorporated into road projects and budgets to eliminate the hazards of collisions with big game animals or other wildlife.

Recently, several high priority linkage areas throughout the state have received funding through federal stimulus and other sources to address present wildlife and safety concerns. For example, State Highway 21 near Boise has received $500,000 in federal stimulus funds to construct a wildlife underpass and fencing in an area that passes through a major mule deer migration area. This project is the first stand-alone wildlife crossing to be funded in the state of Idaho and recognition that identification of wildlife linkage areas not only helps environmental streamlining but can also represent projects themselves. Other projects addressing wildlife linkage issues and road mortality have been funded and initiated on major roadways in central, southeast, and northern Idaho.

Efforts to implement and facilitate statewide collection of highway mortality of wildlife have had mixed results to date. The development of the application was relatively simple and easy, but this has caused some problems because the simplicity of the application did not fulfill the expectations of some users or because application function problems put off some users. In addition, it takes time and effort to get Fish and Game and Transportation Department field employees to accept and use a new and technological solution that may be viewed as only indirectly benefitting them and their responsibilities. A strong outreach and training effort is important in finding acceptance and use of the application. Such outreach and training should also be coupled with direction from higher organizational levels that use of the tool would be both useful and beneficial to agencies and their employees. To the greatest extent possible, future versions of the application or similar efforts should make it relatively easy and satisfying to sum, count, and visually display the results of the data across roads and highways. Such capabilities would put field line staff capabilities in line with information that would help them take direct action or advocate for a change to benefit both public safety and wildlife conservation in relation to roads and highways.

Development and use of these two database tools has improved communication and mutual understanding between wildlife and transportation agencies in Idaho and has raised the profile of an issue that to this point was just accepted in terms of its public safety risk and wildlife impacts. We hope this will further prove to be of mutual benefit to these agencies in their roles of managing Idaho's wildlife resources and roadway safety.

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Biographical Sketches

Brent Inghram, with the Federal Highway Administration, Boise, Idaho, holds degrees in Environmental Planning and Management from the University of California, Davis, and Geological Engineering from the University of Nevada, Reno. He is a registered professional engineer in six western states. During his career he has performed engineering design for water and wastewater treatment plants, rock slopes, solid waste landfills, airfields, highways, and numerous other project types. He has conducted extensive seismicity, earthquake hazard mitigation, and environmental studies, and is also an experienced NEPA practitioner. Mr. Inghram has worked for consulting firms, as a university instructor, for a state DOT, and has been with the FHWA Idaho Division office since 2000, where he serves as the Environmental Program Manager.

Gregg Servheen, Wildlife Program Coordinator with the Idaho Department of Fish and Game, has a B.S. and M.S. in wildlife management from the University of Massachusetts and Texas A&M, respectively. He has worked for the Idaho Department of Fish and Game for more than 20 years in wildlife research, threatened and endangered species, big game management, habitat protection and conservation, strategic planning, technical assistance, mitigation, and policy development. Gregg is a past president of the Idaho Chapter of the Wildlife Society.

Greg Burak, Regional Wildlife Biologist with the Idaho Department of Fish and Game, received his B.S. in environmental resource management from Penn State University and M.S. in biology from Boise State University, and has been employed with the Idaho Department of Fish and Game since 2001. Greg was the lead coordinator for the statewide wildlife and transportation database project from February 2007 through April 2008. Past work experiences include upland habitat management, wildlife management and research, and fisheries research. He is presently working on technical assistance and highway/wildlife projects in southwest Idaho.

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Appendix

Example of Linkage Metadata for Idaho Priority Wildlife Corridor

AOI_NAME: McArthur Lake

PRIORITY: High

SPECIES: Mule deer, white tail deer, elk, moose, black bear, grizzly bear, wolf, lynx, wolverine, otter

MIG_POP:

LOC_POP:

SCALE: Ecosystem

HWY_MORT: White-tail deer

SEASON: Year-round

ATTRACT: Garbage containers, pigs, chickens, roadkill for scavengers, alfalfa fields, and aquatic habitat

ADDITIONAL COMMENTS:

Scale: The McArthur Lake Wildlife Corridor is important for different species or populations on both local and ecosystem scales. It is an important winter range for white-tailed deer and moose. As a linkage area, it's important for grizzly bear, lynx, wolf, all ungulates, and even woodland caribou (at least one has used it in the early 90s). A vehicle-killed wolverine has been found there. Connection between the Selkirk Mountains and Cabinet Mountains

Existing Crossing Structures: The concentration area of the McArthur Lake Wildlife Corridor extends about 11 miles and includes three of the named sites here. A Transportation Enhancement was funded for an underpass, but the funding was lost due to various reasons. The culvert replacement with a bridge at the McArthur Lake Dam-Deep Cr is being used as an opportunity to provide passage. My data indicate that at least two others are needed in this 11-mile stretch. South of the Deep Creek culvert, the topography is difficult for any crossing structures and the water table is quite high, but moose and other ungulates cross there frequently. Fencing along the entire 11-mile stretch is complicated by the many access roads. Sandra Jacobson, former District Wildlife Biologist, Bonners Ferry Ranger District, Bonners Ferry ID. (USFS).

Important Seasons: Spring - transition to summer range, natal areas for several ungulates, general moving around for everything. Summer – Less important for mortality of ungulates, but probably more important for connectivity for grizzly bears and some other dispersing large mammals. Fall - transition to winter range, resident ungulates. Winter - Winter range for several ungulates; will eventually be important for wolves if not currently; lynx potentially could cross from Selkirk's to Cabinets here.

Permanent Human Presence: Residential homes, Recreation site. Snowmobile runs. Commercial buildings or industrial facilities, Recreation site.

Wildlife Attractants: Garbage containers, pigs, chickens, etc., roadkill for scavengers (i.e. bald eagles especially).

Average daily traffic volume: 6,600.

Most common species killed by vehicles: White-tailed deer is most recorded and most obvious. I have recorded turtles, otter, moose, elk, several species of birds, turkeys. Bald eagle (threatened when I was in Idaho); wolverine. Moose and elk (5-20 collective total per year).

Wildlife deaths resulting from collisions with trains: All ungulates in area, bear, probably others. The harsh snow winter of 96-97 was a huge killer on the tracks (two railroads) that parallel US 95.

Research or monitoring studies: I have data on locations of roadkilled individuals, plus anecdotal info from 13 years of driving US 95. Nothing published. McArthur Lake Wildlife Corridor mortality data has been used in many of my presentations and training courses, however.

Species that currently do not exist in this linkage zone but might use this area in the future if population or recovery objectives are met: Woodland caribou, lynx, wolf, grizzly bear, wolverine, fisher. More.

Effective functioning of linkage area: Poorly. As ADT increases, and the train traffic volume increases, it will be worse. Currently at night most of the volume is low but large trucks traveling on US 97 from Canada to California keep the traffic higher than most rural roads. Topography, access roads, and multiple landowners contribute to a challenging mitigation environment, especially combined with local attitudes towards potential government interference. The safety issue of animal/vehicle collisions is well-understood, however, and that's where people can probably collaborate.

Existing conservation easements, land exchanges, etc.: A group was formed in the mid-90's to work on the combined transportation infrastructure (highway plus railroads) contributing to mortality, and the intermixed land use and ownership contributing to difficult connectivity issues. This group has changed over the years but the germ is still there. Conservation easements were difficult to consider given local feelings towards the government and NGOs.

Impediments or current threats to the linkage area: Increasing traffic volume, especially 24-hour truck traffic, development, increasing train rails and volume. US 97 is a Border Corridor highway and is slated for increased capacity improvements. Highway and railroad.

Opportunities to improve the effectiveness of the linkage area: Tons of opportunities especially if the local group can gain traction with the local communities. There is currently a sign, "McArthur Lake Wildlife Corridor Area" at MP 486.

McArthur Lake area. State wildlife / waterfowl management area. The Wyman Land Trust (conservation easement) with no development just north of McArthur. There is a new highway bridge planned over the outlet of McArthur Lake and the highway parallels the railroad tracks. North end of this segment may have more development than the south end. There are numerous moose in the area.

ITD Conceptual plan straightening hwy curve

Elk, deer, and moose movements across highway, but not much opportunity for a structure.

More elk and moose in addition to deer.

MP 490-491.5. Numerous moose sightings and activity moving across the highway with elk sightings also. Flat area, not much potential for structures.

JUDD ROAD CONNECTOR: LESSONS LEARNED IN ECOLOGICAL MITIGATION – WILDLIFE CROSSINGS, HABITAT PRESERVATION, WETLANDS AND MORE

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Abstract

The Judd Road connector project began as regional planning vision in the early 70s and gained support in the mid-90s. The project is a new four lane highway alignment with associated features extending approximately four miles. The project went from a draft EIS to a final EIS in less than two years. The project was progressed in a timely manner based on several factors including innovative environmental consideration and proactive agency collaboration. Also unique to this large of a project was that the design, environmental studies, and writing of the EIS were almost exclusively done by a team of staff at NYSDOT. No other project of his magnitude has ever been completed by NYSDOT without the aid of more outside sources. This close project familiarity by NYSDOT from scoping through completion provides a classroom of lessons learned that can serve as examples for future projects.

Some primary issues that were identified by environmental studies and agency coordination were a need to address wetland, stream and the habitat issues. Items such as wildlife crossings and means to which reduce future conflicts with the new highway construction. Many factors determine feasible mitigation including information gathered from previous research on this topic. Some studies would lead you to believe we were wasting our time including small culverts as wildlife crossings due to factors of crossing distance and lack of ambient light. Professional judgment determined to move forward and use small culverts at key locations regardless of some of the studies' findings due to other factors such as installation costs during and after construction. In addition innovative use of surplus soil from the project was used to create landscaped berms that direct wildlife to the crossing structures. This also alleviated some waste disposal needs that can have secondary impacts offsite. These crossing structures have proven to be extremely effective and the monitoring information will be shared. Other habitat connectivity applications such as habitat buffer area acquisition and stream treatments will be touched on.

The single most important issue that influenced the project alignment and profile throughout the corridor study area were wetlands, including avoidance of one of the largest wetland complexes in the county. The alignment today reflects these considerations. Many innovative considerations went into wetland mitigation that will be shared including profile considerations that minimized wetland impacts, but unknown later limited wildlife crossing opportunities. In addition a permeable flow through embankment was built to maintain hydrology to a large wetland system intersected by the project that may be a first of its kind.

Overall this project has significant value as a model to future project planning, design, studies, and agency considerations. The project has left many clues that are obvious such a nationally recognized recreation trail to less obvious clues such as over a million dollars in project cost savings that were made due to environmental science expertise contributing to the engineering analysis. This project will spotlight how future projects can be delivered with balanced environmental considerations.

Introduction

The Judd Road Connector Project is a unique project for many reasons including it is primarily a new 3.9 mile highway construction project on new alignment, the environmental and engineering studies/designs were done primarily within the Agency, it was the first EIS of this magnitude to be completed by New York State Department of Transportation (NYSDOT) staff, it involved a wide range of environmental considerations, and it established many new and innovative environmental mitigation measures for NYSDOT. Many projects have untold stories, and the establishment of a record and sharing of these project experiences are beneficial beyond the Region and State.

New highway construction on new alignment is a very small portion of NYSDOT's program versus some State DOT's that experience a greater new construction needs in part due to larger population growth. Some of these State's through permitting necessity have moved to more innovative approaches of environmental mitigation. Permitting was a consideration for mitigation efforts in this project, but much of the effort was supported by an increased environmental ethic at NYSDOT to try and go beyond the minimal standards.

The project is located in Central New York in the Village of New York Mills and the Towns of New Hartford and Whitestown in Oneida County. The area has experienced some of the greatest growth in the County over recent decades including commercial and residential growth. The area is a major commercial and business district with the largest shopping mall in the region. As a result, roadway demand and traffic congestion had increased significantly, which led to a decline in levels of service and an increase in safety issues and accidents. The purpose of the project was to address congestion and safety issues. The Judd Road Connector project was proposed to improve the overall transportation system of the study area.

The project was built from the existing State Routes 5/8/12 interchange westward to the existing Judd Road / Halsey Road intersection, a distance of almost 3.9 miles. The new 4 lane highway was constructed partially as a freeway and partially as a rural arterial. The eastern portion of the project is very developed and as it progresses to the west the surrounding development is rural in character. From the east the project followed an old abandoned railroad grade to a point where two alignment alternatives were considered, a north and south alignment segment, and then a final section to the terminus at existing Judd Road. The south alignment section was chosen because it resulted in less wetland impact, provided the largest upland buffer areas to the large wetland, and fragmented less overall habitat.

The Judd Road Connector project was the first project of this size and magnitude to be developed primarily within NYSDOT. When the primary project development really started being progressed into a project around 1995 there were some budget constraints limiting the use of consultants for the studies and development of the EIS. A decision was made to assemble the work with a Team from the Region, supplemented with some technical support from other offices in NYSDOT, and some limited consultant support. The result has been a unique opportunity for learning that has had great value.

Project Chronology

- Project Initiation Request: May 1984
- Judd Road Connector Study: 1994
- Notice of Intent Issued: October 1995
- Primary Environmental Studies Begin Summer 1995
- Draft EIS Approved: September 1997
- NEPA Public Hearing: November 1997
- Final EIS Approved: April 1998
- Record of Decision: May 1998
- Primary Construction Begins 2000
- Project Opening 2005
- Oriskany Flats Stream, Wetland Creation/Enhancements 2008 /2009

As part of the Judd Road Connector Project environmental considerations were a major component that shaped the final alignment and design of the project in keeping with the NYSDOT values and the importance that these resources provide to the public. Considerations such as air quality, noise analyses, threatened and endangered species, water quality, wetlands, and archeological resources. In addition to all of the studies, agency coordination throughout all of the project development phase led to a draft Environmental Impact Statement to Final Environmental Impact Statement in less than two years time. Environmental commitments continued with a pre-construction meeting with NYSDOT and Agency staff to re-visit considerations and commitments prior to Construction. An Environmental Liaison during construction was also assigned to the project to take the lead on these issues and report back to the Agencies with a monthly report. The Judd Road Connector project established significant beneficial relations between regulatory Agencies and NYSDOT that continues today as a result.

The project itself has exceeded many of the standards and mitigation requirements placed on a project of this type. Some items included in this project are 14 small wildlife crossings, over 9 acres of wetland creation and enhancements, 62 acres of wetland buffer areas preserved, highway embankment treatments to allow hydrology equalization to adjacent wetlands limiting secondary impacts, development of a recreation trail, and several thousand feet of stream replacement and restoration. These efforts have included educational outreach to local schools, and continue with development of environmental education signage along the recreation trail.

There were many environmental aspects studied, and addressed in this project. Air analysis, noise, hazardous and contaminated materials, asbestos, farmland, stormwater being some of the areas addressed. There were over 4000 shovel test pits for archeological studies and over 30 buildings that required asbestos investigations for demolition as an example of the magnitude. The environmental considerations were the single most influential aspect in the final alignment. Some of which had significant influence on the project including the construction of a noise wall and special handling of thousands of yards of contaminated soil. These items are beyond this paper, but in some cases they influenced the wetland, water, and ecological consideration and are noted were appropriate.

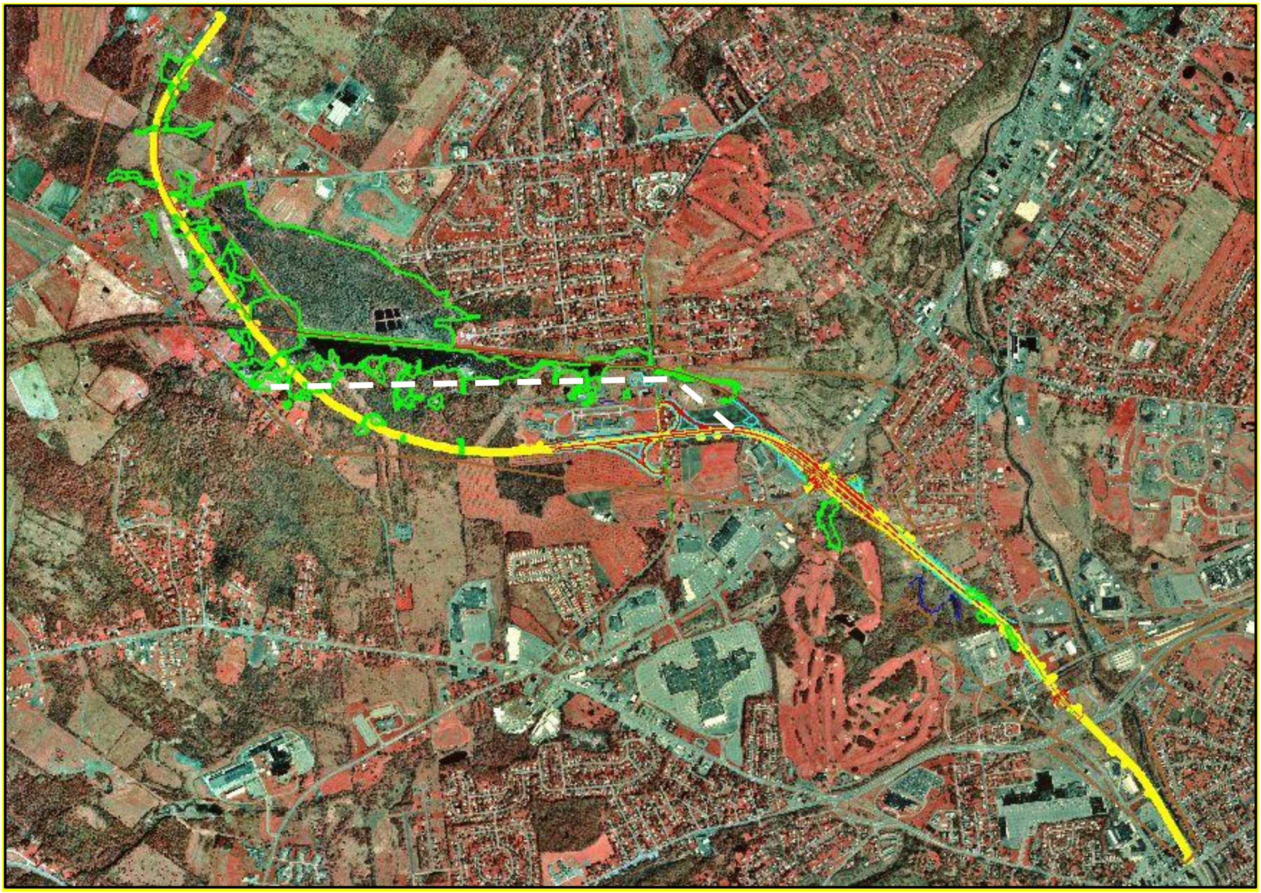

Figure 1. Project Map showing final alignment alternative, green areas are wetlands delineated as part of the studies, the white dashed line was the approximate north alignment alternative.

Some specific mitigation for this project consists of:

1) Trout stream enhancements (boulder placements and Pool digger) at Mud Creek
2) Wetland replacement by creation of 7.4 acres of wetlands
3) Wetland enhancements to 1.26 acres of Reed Canary *(Phalaris arundinacea)* grass dominated wet meadow
4) Stream mitigation by replacement and creation of 3163 feet at two locations.
5) Acquisition of 62.5 acres of land to serve as a buffer between the highway right-of-way and existing wetlands and open water areas
6) 14 small culvert wildlife crossings
7) Installation of approximately 2 miles of Swareflex wildlife warning reflectors
8) Construction of a wetland enhancement berm enhancing 40 plus acres of wetlands

<u>Discussion</u>

Project Evaluation and Development

Coordination and Communication

There is little debate on the importance of communication, but to really effectively consider, incorporate and build a balanced project that includes a wide range of considerations it is the single most important considerations. The project was developed from an initial project development team, then a design squad following the FEIS, and then a hand off to construction staff. The one thing that didn't change was the involvement of the NYSDOT Regional Environmental Unit which has been involved from the studies, writing of the EIS, project design, environmental mitigation development, construction, and continues with monitoring of environmental mitigations.

One of the items that have been instrumental throughout the project development was periodic meetings with all involved NYSDOT groups to continue discussion of considerations and implications to the project. Many times one groups issue can have negative implications on another group's responsibilities. A willingness to listen and understand each group's issues results in whether or not one issue should take precedent over another or a balance can be made between the issues. In most circumstances, the end result of the process leads to the best project development decision that can be made. It is easy for anyone to become convinced that their issues are the most important and lose site of the big picture. Factor in outside stakeholders and agencies and the complications can sometimes seem overwhelming. With careful analysis, and the proper degree of consideration decision are made and were with this project. Safety, cost, feasibility, and balancing the environmental considerations were all part of the decision making process.

To facilitate dialogue with the involved environmental agencies NYSDOT environmental staff (4 staff) had assignments of responsibility for each involved agency. The staff worked together to balance issues, and communicate the issues between agencies. To balance the engineering aspects of the project and create better understanding the involved agencies were invited throughout the project development to office and field meetings on numerous occasions. The involved agencies for the wetland, water and ecological issues met and talked by conference calls on an ongoing basis. This included integrating understandings of the engineering implications required to avoid, minimize and mitigate these issues. It is important that the involved agency staff know the key engineering staff and vice versa. This was facilitated throughout the project development, and even into construction were a meeting was held for the agency and construction staff to meet and talk. In addition monthly reports during construction were given to the involved agencies highlighting items of interest to the agencies.

To foster better understanding of environmental considerations with engineering and other NYSDOT staff the NYSDOT Regional Environmental Unit led office meetings, and of sometimes more importance field meetings to discuss the issues. Often times too many decisions are being made on assumptions made from an office. One can't fully appreciate the difference in say wetland types or a streams until you stand in or next to one. The Close Order Excavation Specification was the result of one of these field meetings, and is discussed later.

Figure 2. A Project Field Meeting led by Regional Environmental Unit with Multi-discipline NYSDOT Team and Involved Agencies

Integration of Expertise

For most DOTS' throughout the country the involvement of environmental expertise in projects was limited or even absent during most of the transportation infrastructure establishment. For most DOT's that is not the case anymore. NYSDOT made a point to hire an increased number of environmental staff over the past 15 years or so. With this increased expertise comes a better opportunity to integrate environmental considerations earlier into project development and anticipate issues and mitigation needs in advance of discussion with involved agencies. This ability provides for better dialogue with the regulatory agencies that have responsibilities for resources such as wetlands and wildlife. For the Judd Road Connector project the appropriate expertise to understand the ecological issues and work with engineers to balance considerations in the project development was present. This is not to say there wasn't a few chuckles in the early meetings when small critter crossings were first mentioned. With time the chuckles changed to engineering suggestions on ways to better design them into the project.

To adequately address environmental issues, engineering needs, and all the other aspects involved in delivering a quality transportation project the integration of all the appropriate expertise cannot overstated. When the expertise is absent or limited the result is a poor quality transportation project and often times ends up costing more money and staff resources in the end.

As an example of the importance of the integration of the appropriate expertise another large project in the Region, the Utica-Rome Expressway, was kept on schedule, saved millions of dollars, and resulted in some innovative wetland mitigation. A portion of the preferred alternative was to take the new expressway under a local road versus over. The result would be a cut below existing grade of more than 15 feet to accomplish this. An adjacent wetland under this proposal would know be higher than the highway, and the highway cut could act like a large ditch potentially draining the adjacent wetland. Understandably, the proposal to cut below the local road was being proposed because to go over the local road it would have required two large bridge structures and an embankment fill versus the alternative to have a smaller local road bridge over the expressway in a cut. The cost difference was in the millions and it was justifiable to progress with the alternative and finds ways to minimize the wetland impacts. To minimize impacts and explore mitigation it was mentioned at a project development meeting that we needed to take a hard look at the highway profile cut and the influence this could have on the hydrology of the adjacent wetland. Additionally, further hydrological study would be required to assess the overall potential influence of the cut on the adjacent wetland. The intent to raise the profile cut issue with many professionals beyond wetland expertise was that maybe someone had an innovative means to reduce the cut, work with new vertical alignments on each road, or some other geotechnical treatment adjacent to the wetland. Additional hydrology studies were completed and our geotechnical group came up with a possible mitigation solution. The mitigation alternative was a trench parallel to the wetland lined with a very impermeable clay material, referred to as a clay slurry wall. The estimated cost would be on the order of two million dollars. The decision was left to Regional Environmental Unit on whether this should be progressed to mitigate wetland impacts. The Regional Environmental Unit coordinated all of the information with the involved agencies and they agreed the building of a clay slurry wall was not justifiable to minimize wetland impacts. Other innovative mitigation was progressed at far less costs. The lesson to be learned is that many transportation projects require a wide degree of expertise and understandings and with the right expertise good decisions can be made. Had no one been involved in the project with any wetlands background early on the question could have come much latter in the project development phase by the regulatory agencies and it could have negatively influenced the schedule or even been a permit requirement to mitigate wetland hydrology without consideration of the extensive costs. Having the appropriate expertise's involved in project development has major benefits in progressing balanced projects. The Close Order Excavation Through Wetlands that follows is an example of how having all the appropriate expertise's can have a positive project benefit, and have project cost savings. Without wetland expertise some engineering assumption may have lead to unnecessary undercuts over large areas of the Judd Road Connector project.

Appropriate Expertise and Level of Expertise

In general, sometimes the considerations in engineering that may have significance environmentally are beyond the degree of need to come to an engineering decision. For example, the design of a water conveyance structure where a transportation system crosses a wetland usually comes down to an engineering evaluation of culvert size. On the other hand, a wetland scientist is looking for what are the other potential influences of this crossing on the wetlands. In the culvert scenario, asking things like what invert elevation will be used and suggesting multiple culverts versus one may be some of the thinking from the wetland scientist's perspective. It can make for some challenging conversations between the two disciplines, but if one can get beyond this there are real opportunities to better design transportation systems into the environment.

One of the difficulties even with increased environmental staff at NYSDOT is the fact the term environment is broad. All of the areas the DOT's need expertise in, air, noise, cultural resources, wetlands, wildlife, fisheries, forestry, hazardous waste, asbestos, etc are fields that may involve at least four years of college, and most candidates have only one or two primary areas of expertise when starting with DOT. The four primary environmental staff on the Judd Road Connector project was no exception and each had a primary background of expertise, but with years of combined project experience there was sufficient understanding of all the topic areas to address these issues or to know when to reach out to other more qualified staff in the state as needed. A common mistake is for someone in one of these positions to assume they fully understand an area they have had no formal training in. This is not to say with some training and project experience one cannot gain expertise to address other areas of expertise, but one needs to know their limits. It is also sometimes easy for a non-environmental staff person to assume everyone in a title with environment can address any issue. This can be misleading and lead to poor attention or decisions related to environmental considerations in developing a project.

As an example, at a statewide meeting a Environmental/Landscape Architect staff person with no expertise in wildlife issues made the comment to a room full of Regional Design staff that it doesn't matter where you build roads, wildlife will be impacted and for the major project he was leading this was the reason no significant considerations were made in the alignment alternative analysis for wildlife. In ways this statement is true, but anyone with the appropriate wildlife expertise could provide alternatives to minimize these impacts and suggest alignment alternatives with less overall impacts to wildlife. The problem with uniformed or poorly worded statements like, "it doesn't matter where you build a road wildlife will be impacted" is that for some engineering decision makers they assume this was an expert in wildlife issues and may now think of the topic as unimportant to future project development. Environmental and Landscape staff must recognize their boundaries, and be careful of assumptions that can be made from statements they make about environmental issues. Having an experienced lead environmental staff person to coordinate other environmental staff in the project development process can help establish the boundaries of staff and when outside resource expertise is needed in the project.

From Project Development to Construction and Future Monitoring

There are many things that can be lost along the way when developing any project, but even more so with a project as large as the Judd Road Connector. Some of the means to maintain these commitments include: primary points of contact for key issues, an understanding that the implementation and avoidance of environmental considerations has to be understandable by a construction contractor that has had no involvement in the project development, project proposals and plans become the primary documents to build the project, and this is the point where all the commitments are implemented. Too often all the detail is focused at studying, designing the project with mitigation, coordinating with the agencies for approvals and once permits are in hand the work is over. Nothing could be further from the truth and follow through into construction has to be part of the commitment. Having key staff points of contact throughout a project is beneficial, but not always possible due to many reasons including time frames of years. For the most part many of the key staff was involved or available during the project, and as mentioned the entire key environmental staff have been involved throughout the project. As part of the project permitting requirements a concern was raised regarding follow through of environmental mitigation measures in construction. Often times there are a lack of understanding of these issues, and limited environmental expertise in the field during construction. To help address this issue a staff person with environmental expertise was identified as the lead for environmental issues during construction. This staff person spent several years with the Regional Environmental Unit during the final project design and had familiarity with the majority of issues. In addition, this individual has a strong commitment to the issues and knew when to call upon additional expertise when needed. This individual played a major role in the success of the environmental mitigation measures that were designed into the project and helped facilitate solutions in the field to unexpected conflicts or issues. Any project with the degree of environmental commitments as the Judd Road Connector should consider having a staff person with an environmental background in the field during construction.

Environmental Considerations and Mitigations

Direct Project Wetland Impact and Context

Within the project area there were over 30 wetlands identified and delineated as part of the studies. The area studied was a corridor approximately 1 mile wide by about 4 miles. Many of the wetlands were associated with some hydrological features such as streams including intermittent ones. Some wetlands were isolated, but their avoidance, minimization and mitigation were considered regardless. There was one large wetland complex, over 200 acres, that was mapped as a State regulated wetland. NYS Regulated wetlands are generally larger than 12.4 acres (5 hectares) in size. The State wetland maps showed this area as regulated wetland UW-8. Federal wetland mapping was preliminary at the time of the study. Both state and federal wetland maps showed less wetland than actually was identified in the studies. State regulated wetland UW-8 was mapped close to the actual core area, but lacked many of the smaller fingers and portions that were along the edges. All of the wetlands identified in the field were coordinated with the involved agencies for concurrence. All wetlands were accepted and considered federally regulated, and for those that were subject to State jurisdiction they were noted in the reports.

To avoid and minimize wetland impacts much effort was taken including aspects like; agency discussions on the general importance of wetland areas, alignment modifications, and steepening embankment slopes. The eastern portion of the project was relatively a developed area and the use of an old railroad alignment provided the least impact to surrounding land and wetlands. At the commercial drive intersection the use of a single point interchange had less impact on commercial property and wetlands. A partial clover leaf option would have had significant impact on a riparian forested wetland complex adjacent to Mud Creek. Further the single point interchange alternative had less overall impact on Mud Creek. Contrary to the name of the stream it is more gravel like and has water quality sufficient to support trout.

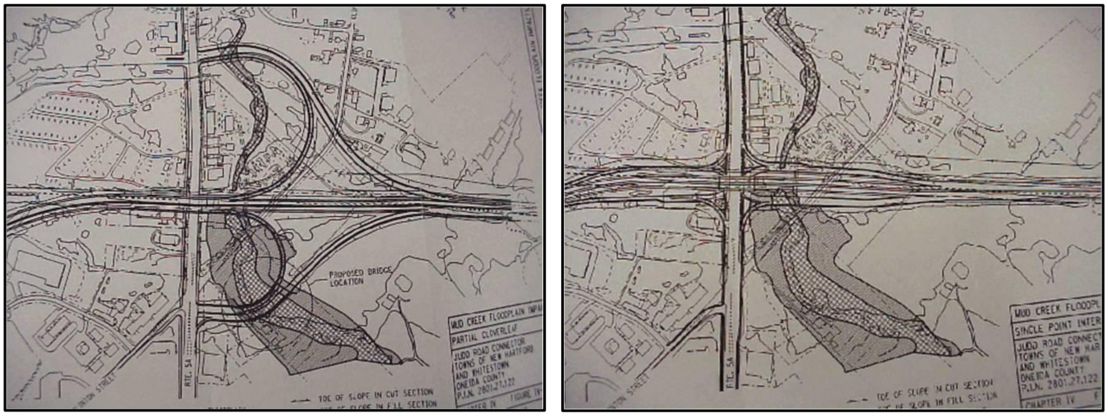

Figure 3. Partial Clover Leaf and Single Point Interchange Alternatives, wetland shaded area

Just west of this area the surrounding land character starts to transition from commercial, to suburban, and then rural. At a point west of the Commercial drive area the alignment separates' from the abandoned railroad grade and a north and south alignment alternative was evaluated. The south alignment resulted in less total wetland impact and was the farthest from the large State wetland complex. The south alignment was the chosen alternative (Figure 1.). The remaining alignment to the west was about a mile and the alignment was shifted as much as possible to avoid wetlands, and still connect with the existing intersection of Judd Road, the project terminus. At this location a small unnamed tributary to another unnamed tributary of Oriskany Creek could not be avoided. This small tributary, 1 to 2 feet wide, was a spring feed seep with associated wet meadow wetlands. The tributary and wetlands were not shown on any existing state or federal wetland mapping. The small stream was noted as having Brook trout (*Salvelinus fontinali*) fry, and assumed to be a spawning tributary. Mitigation to maintain this tributary was built into the project. As a result of the efforts to avoid and minimize wetland impacts the final project alternatives resulted in a total of 5.56 acres of wetland impact which included 1.99 acres of isolated wetland impacts. A total of 2.19 acres of the total were state regulated wetland impacts. The entire project foot print is approximately 50 acres in size including lanes, medians, embankments, and drainage.

Wetland Creation Mitigation

Direct wetland replacement is being mitigated with the creation of 7.4 Acres of wetlands; wetland enhancements to 1.26 acres of Reed canary grass (*Phalaris arundinacea*) grass dominated wet meadow, and a wetland enhancement water control structure/earthen berm. A total of 3 sites were progressed of which two were adjacent to the project and the larger site is located within 5 miles at the state owned Oriskany Flats Wildlife Management Area (WMA). Included in the mitigation is 3163 feet of new stream creation integrated in the wetland creation area designs.

The key considerations progressed with the Agencies was the fact that several locations could be converted to wetlands adjacent to the project, but this would reduce remaining adjacent upland areas to the wetlands. It was agreed to develop two sites adjacent to the project area and do the larger mitigation at the nearby Oriskany Flats WMA.

The first site was adjacent to Mud Creek, and was a commercial property purchased that would no longer have access to any highways. The site was a former small spring water business that no longer used the spring on-site. The conversion to wetland was relatively simple with hydrological connections made to Mud Creek. The site continues to be a successful wetland creation area. The area created was 1.30 acres of new wetland.

The second site is at the terminus with existing Judd Road where the spring fed tributary and wet meadow wetlands could not be avoided. It was determined to be federal wetlands, and agreed that a new stream should be created adjacent to the highway alignment with associated new wetlands. This wetland and stream area of approximately 1.06 acres has been created and has been successful to date.

The off-site location is under construction in 2008 and 2009 and was progressed by a separate contract to utilize expertise through the Soil and Water Conservation District (SWCD) and the wetlands programs they administer. This mitigation is well beyond the project completion, but innovative means to progress the most beneficial wetland and stream mitigation was desired. One of the early discussions with the involved agencies was the fact that wetland construction as part highway construction projects is often costly, and the results often have mixed success. A primary reason is that the contractors don't typically construct wetlands and they are usually a minor component of a transportation project. Initially some effort was progressed with US Fish and Wildlife Service to use their wetland creation and enhancement programs to build the wetlands and new stream creations. The effort would be funded with transportation funds from NYSDOT and FHWA, but many complicating factors created difficulties in finalizing the agreements between the Agencies. The effort continued and an agreement was made with the Oneida County Soil and Water Conservation District (SWCD). As a result of working with the involved agencies to progress this innovative mitigation plan at the Oriskany Flats WMA the outcomes will be greater total wetland creation and enhancements. The wetland creation and enhancements required by permit required a little more than 5 acres. The actual wetland creation and wetland enhancement will result in 40 to 50 total acres, and is more than a 0.25 million dollar cost savings from initial estimates planned for onsite wetland creation mitigation. Approximately 2000 feet of new stream creation is also under construction as part of the mitigation plan at this site.

Wetland creation and enhancements is a science that requires careful consideration, and planning to implement a successful outcome. As mentioned previous, it is not always the most beneficial wetland creation being adjacent to the transportation project or that the prime transportation contractor is the best qualified to construct these features. The emphasis by regulatory agencies to look "on-site" has contributed to some narrow thinking on this topic, but with good analysis and discussions with the Agencies better options can be explored if on-site options are limited. Regardless of the contractor, well thought out plans, specifications, and construction notes are a must. In addition, a get start meeting prior to construction, on-going meetings as necessary, and construction inspectors with wetland creation experience can make a big difference in success. One consideration that is often a failure in many wetland creation sites is the lack of ample information on hydrology during design. Even with several years of hydrological monitoring with gauges, piezometers, and monitoring wells variations in hydro-periods can lead to difficult decisions on grading elevations. One of the benefits of having qualified staff involved during construction is that some field characteristics such as soil features can confirm grading elevations or modifications that are needed. Where most highways' can be designed to precise detail in plans wetlands need to have some flexibility for changes on the ground. This is often a difficult concept for highway designers and contractors, but the norm for folks that restore and build wetlands.

Potential Indirect Wetland Impacts

The focus of discussion when it comes to wetland impacts is on direct impacts. This continues today and for good reasons, but indirect wetland impact from projects including transportation can be far greater then direct impacts in many situations. There is little work and study in this area to help plan for these potential impacts. I will share some general considerations and aspects we considered in this project. The requirement to address this was not the result of any agency requirement, but a growing understanding by the author through observations of adjacent wetlands to transportation corridors. Figure 4 shows the influence from a transportation corridor and has been observed in numerous states along every type of highway system. The example used is for a transportation system built over a100 years ago and helps demonstrate that the influence is not new, and is beyond any direct impacts that resulted from the construction of the railroad. It also demonstrates it is not unique to just highways, but is more the result of embankment and drainage design for transportation infrastructure. In some circumstances it could be that the drainage has been modified by limiting the hydrology to a culvert. It can also be done to compaction of the soils and further impeding hydrology in the wetland system making one side inundated in depth and duration for a longer period. It can also be that the transportation embankment and culvert/bridge locations make an ideal opportunity for Beaver (*Castor canadensis*) to block the drainage where prior it was not feasible. The abandoned railroad grade used for a portion of the Judd Road Connector alignment also crossed a portion of the large state regulated wetland complex. Similarly to Figure 4 showing the influence along this corridor in the Adirondack Park, Figure 5 shows an aerial view of the Judd Road Connector project area and the influence the abandoned railroad has had on this wetland system. This understanding is part of the reason a permeable type embankment was designed and built at the primary wetland crossing in the project. Figure 7 details this embankment.

Figure 4. Remsen- Lake Placid Travel Corridor (Adirondack Railroad) built in 1890, Left side is now emergent wetland and Right side is Spruce-Tamarack Forested Wetland. Pre-railroad would have been all Spruce-Tamarack Forested Wetland, hydrology changed by railroad embankment and drainage design.

Buffer Area Wetland Mitigation

One area of indirect wetland impacts that was discussed and of concern to the involved agencies was adjacent upland area considerations to wetlands. The state wetland law also regulates a 100 foot adjacent area to all state wetlands. Design considerations, including alignment alternatives, were made to minimize impacts to adjacent areas to wetlands. The north alignment alternative maintained the greatest buffer to the large state wetland complex and was a primary consideration in the selection of this design alternative. The benefit of maintaining adjacent areas to wetlands is a complex topic, but in general the larger the area and separation that can be preserved the greater value to the remaining wetlands. This is generally true for wildlife, water quality, species richness, and other related benefits.
The value of adjacent areas to wildlife is one aspect of the issue, and in many areas where development is un-regulated in the adjacent area development extends to the boundaries of wetlands. With this continued development pressure the species diversity will tend to decrease, and invasive species tend to increase. The surrounding areas to the Judd Road Connector project have been under continued development pressure prior to the project and have increased since project completion (Figure 5). Less adjacent areas to many of the wetlands exists since the studies started in 1995. A large housing development has been built, and numerous large commercial shopping centers. Though some of this was anticipated it has had a significant change on the entire area. The project did control access to the highway system, and one measure was included to secure some long term integrity to the remaining wetlands. This was the establishment of 62.5 acres of habitat preservation adjacent to the highway alignment (Figure 5). The area is one of the most significant areas of uplands and smaller wetlands adjacent to the large state wetland complex. It represents the most important buffer areas identified in the project area. Though the project alignment was designed with no access at this location and access was limited by the large wetland along the other portion of the property it was felt that some long term way was needed to secure some preservation of adjacent uplands. A future business park was possibly planned on the south side of the Judd Road Connector and this land is on the North side. If a future highway interchange was ever re-evaluated under the EIS these lands could be in jeopardy of further development pressure. The involved agencies agreed this should be a priority area for preservation, and the project was permitted with the 62.5 acres as part of the final wetland mitigation requirement. Though the permitting credits given for buffer areas is minimal it is by far one of the most important project mitigations, and efforts should be made at DOT's and from within involved agencies to encourage more of this type of mitigation as part of certain projects. Regulatory Agencies should consider more credit for buffer area protection to promote them when warranted.

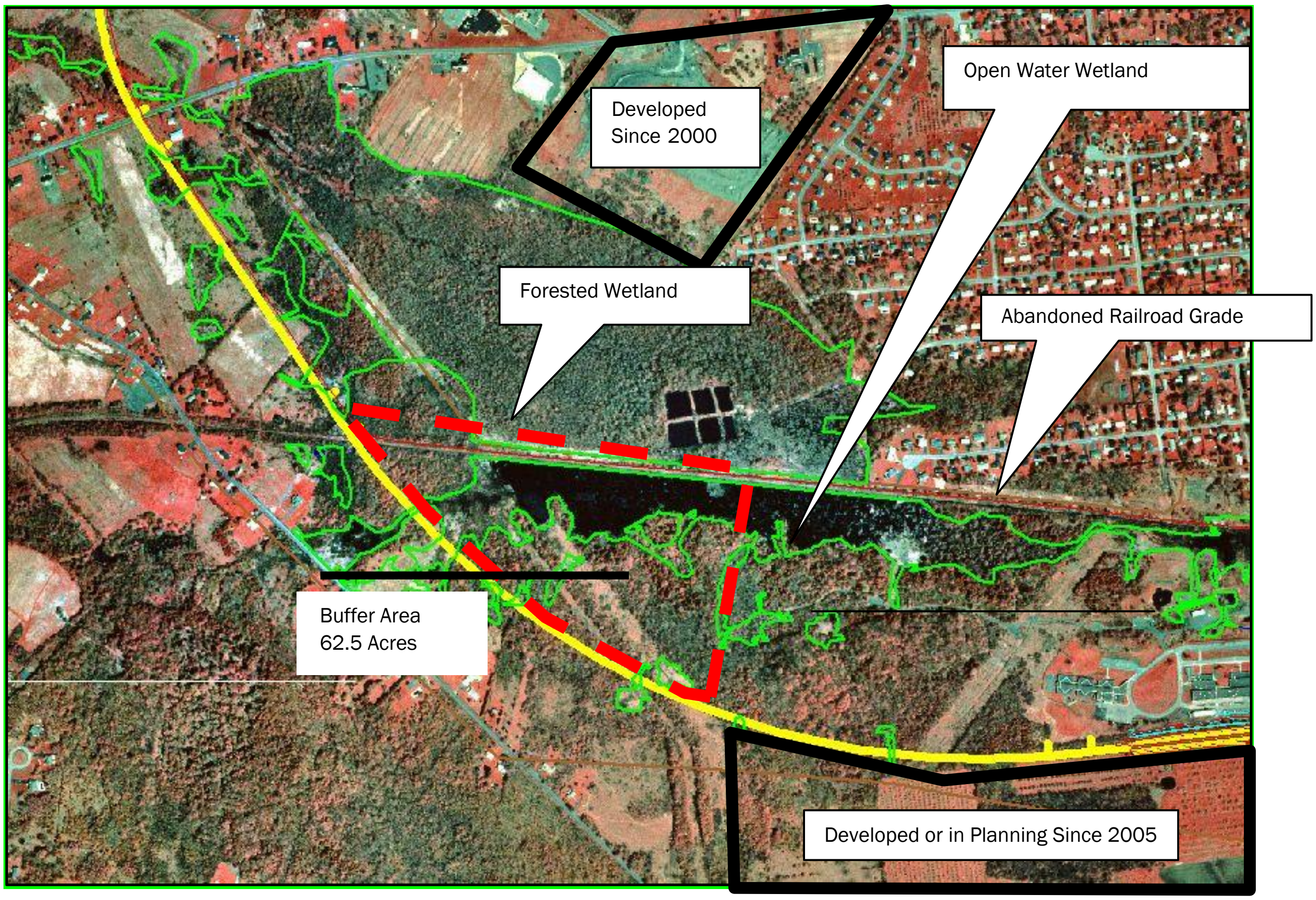

Figure 5. Aerial with Buffer Area, Wetland, Development, note influence of railroad grade on wetland crossed, wetlands outlined in green, north top of photo

Highway Design Consideration for Wetland Mitigation

There are several considerations that can be made when designing transportation projects that can influence wetlands positively or negatively. These considerations are not often a primary consideration due to lack of understanding by the regulatory agencies, most DOT environmental staff and the highway designers themselves. Direct wetland impacts and the avoidance are the most recognized, and the second is most likely run-off impacts to adjacent wetlands. Profile elevation of the highway from existing grade has the most influence on direct wetland impacts besides the actual highway width. The closer the highway is designed to existing grade the less direct impact from the embankment results. Figure 6 illustrates this. What is not shown is the impact from ditching if determined necessary. With a typical design to maintain good drainage within the frost zone, approximately 4 feet, it is assumed a ditch would be designed for any highway built less than 4 feet in elevation from existing grade of a wetland. This is not a given and in many occasions wetlands are ditched even when more than 4 feet below the surface of a highway. Many times it is just a belief that ditches and moving water is best. Often times depending on the wetland system this just results in a ponded area in these ditches, but in some cases it can negatively influence these adjacent wetlands. There needs to be an understanding of the wetland hydrology associated with all wetlands within an adjacent to the project. For example, if a wetland area has a fragipan like layer at 2 feet below the surface and sand below a ditch greater than 2 feet in depth could drain the wetland system. Careful consideration should be given to evaluate the wetland hydrology as it relates to highway design considerations, and is often overlooked.

For the Judd Road Connector project a general comment was made to the preliminary design staff to minimize wetland impacts where possible. Alignments avoided and threaded between wetlands where feasible and the profiles were set as close to existing grade to minimize direct impacts. The profiles do not show up on plan views and initially overlooked by the environmental staff. As mentioned previously this can lead to wetland hydrology impacts from needed ditching. These issues were addressed through detail design, but could have been easily overlooked. What wasn't realized till late in the design was how this decision early on would limit the ability to include small wildlife crossing. A concrete culvert 3 foot in diameter with 1 foot cover including asphalt would require a minimum of a 4 foot embankment profile above existing grade. Many areas were designed within 2 feet of existing grade to minimize wetland impacts. This was not recognized to late in the project design and it limited wildlife crossing placement and size of culverts. This was a major lesson learned and one that should be shared with regulatory agencies. Had some embankments been designed at a greater profile elevation above existing grade more wildlife crossing structures could have been installed, though additional direct wetland impacts would have resulted. Plan view and profiles should always be reviewed when considering potential direct and indirect wetland impacts.

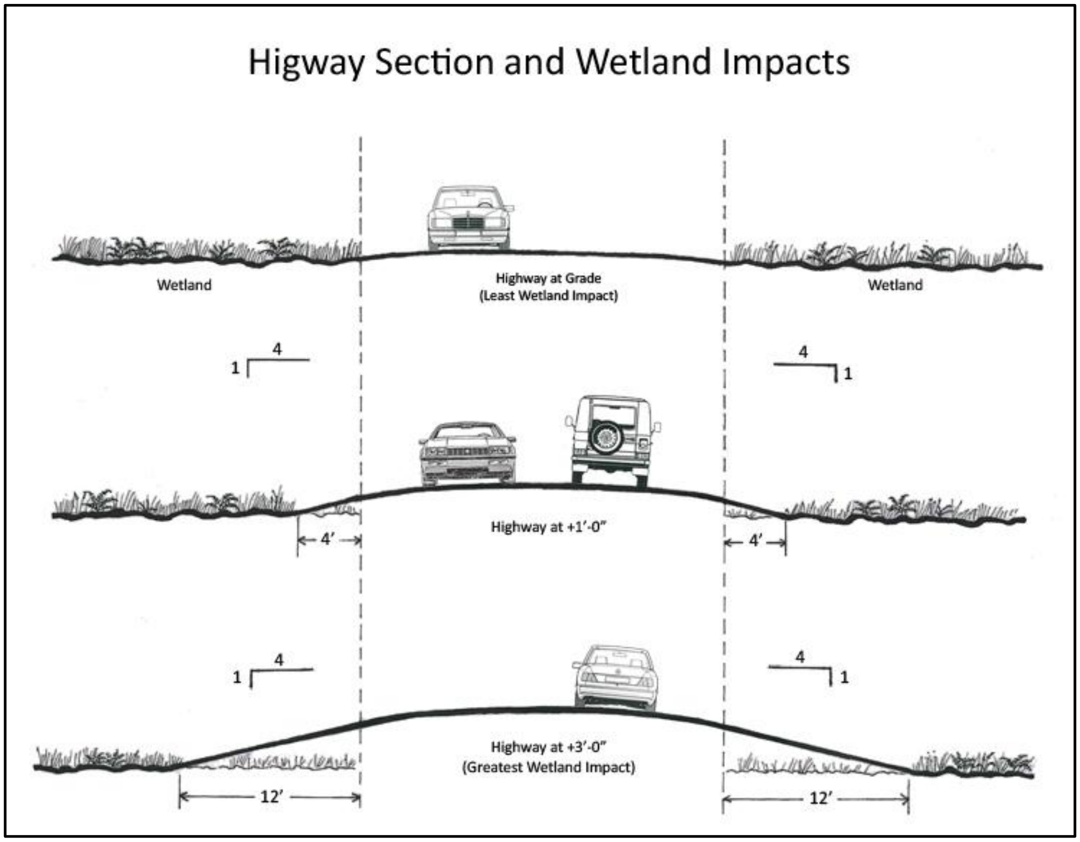

Figure 6. Profile and Wetland Impacts. With increased profile elevation direct wetland impacts can result without steepened slopes or walls. These treatments can add significant project costs and have safety implications.

Close Order Excavation

There were two key aspects of the project that led to the development of what was specified as Close Order Excavation through Wetlands. During the preliminary design soil borings were done along the alignments. Many of the borings showed unsuitable soil conditions and consideration was being given to undercut extensive areas more than a mile in length. When the environmental unit staff looked at the boring locations it was recognized that the problem locations were in areas that were delineated as wetlands. Based on the Regional Environmental Unit input it was recognized that the assumption to undercut large areas was not necessary and the use of wetland locations could help identify the limits of where undercuts were necessary. Undercutting is a technique where to some depth of soil is removed and a stable material is placed for construction of highway embankment. The result is costly and creates spoil from the unsuitable material that needs to be disposed of. By combining expertise problem areas were minimized and millions of dollars in cost savings resulted.

The second aspect is that undercutting can influence hydrology. Groundwater moves through the earth and without giving this consideration you can change the hydrology of an area. Figures 4 and 5 are examples of the influence transportation corridors can have on adjacent wetlands. A larger stone material was placed within the water table area of the wetland crossing which allowed for hydrological movement of water through the embankment. In addition five equalization culverts that could also provide passage for wildlife were added at an elevation near the surface of the wetlands. As a note, soil boring logs can be used to help determine key hydrological aspects of wetlands such as soils, depth to bedrock, fragipan layers, water table depth, and other features. As part of project development the environmental staff should be aware of soil borings and review them with the appropriate geotechnical staff. If warranted, request special borings in wetlands or adjacent to wetlands to help make better decision regarding highway design aspects.

The following is the language used for this item in the contract:

PIN 2230.08
SPECIAL NOTE
CLOSE ORDER EXCAVATION

The contractor's attention is directed to the requirements of Close Order Excavation for all work required for items 203.02 and 203.06 at the following areas: CL 5 + 300 to CL 5 + 500, CL 5 + 650 to CL 5 + 800

The intent of the Close Order Excavation requirement is to limit the contractor's operation to minimize the potential for disturbance to the ground water quality and the adjacent wetland areas.

The contractor shall be governed by the following construction sequencing details:

1. Remove unsuitable materials by a method of excavation approved by the engineer, progressing continuously in one direction full width and parallel to the proposed roadway centerline.

2. The undercut excavation work area shall be backfilled in such a manner as to limit the size of the excavated area. The limit shall be such that the toe of slope of the excavation shall not progress ahead of the backfill toe of slope to a distance greater than 5 meters.

3. Excavate the existing soils to the limits identified in the plans or as ordered by the Engineer. Excavated materials shall be immediately removed from the site and wasted in an approved waste area. Topsoil shall be stripped and stockpiled in an approved area for subsequent wetland restoration and use.

4. If the excavated area contains standing water, place the select layer fill layer to 0.60 meters above the water level. Do not dewater the excavation.

5. Cover the excavated area with a minimum 0.60 meter thick layer of select fill, Item 203.06 M prior to placing the embankment material. Backfill all excavations prior to placing embankment material. Backfill all excavations prior to the conclusion of the day's operation.

All work between these areas must be complete within 30 days of the start including final seeding and mulching.

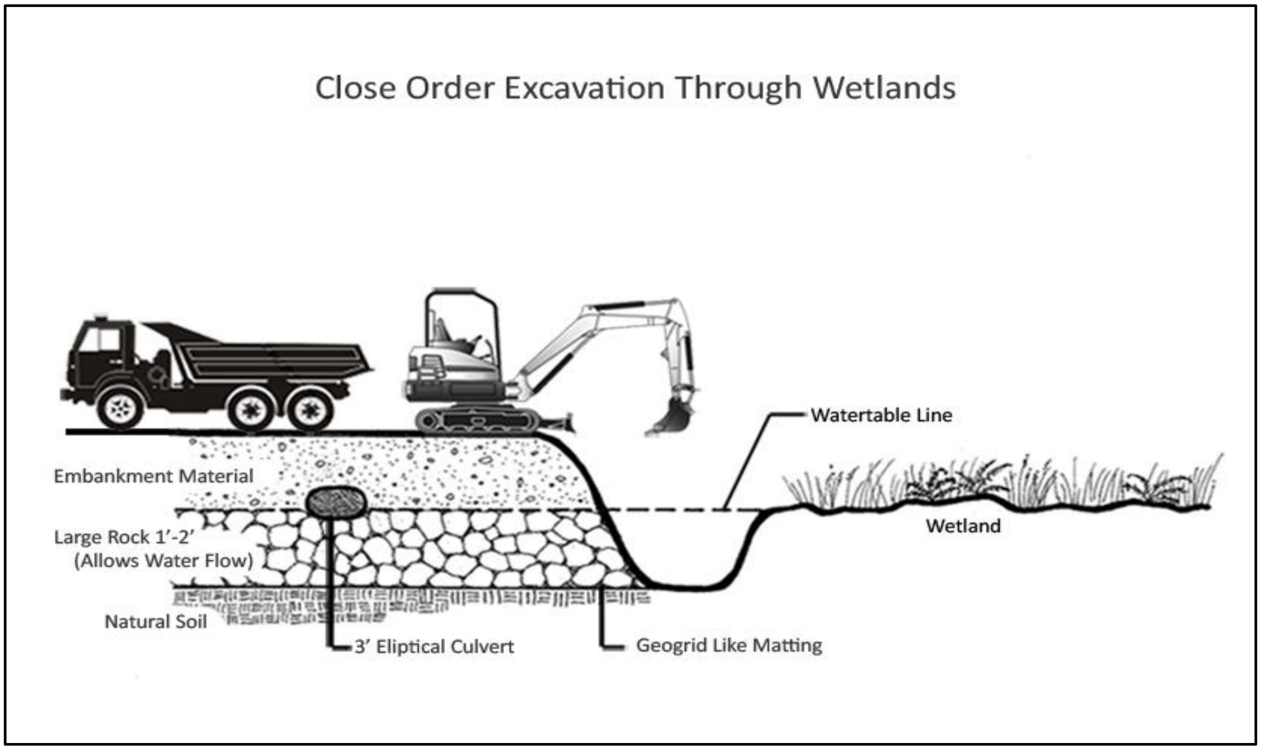

Figure 7. Close Order Excavation sketch, large stone for embankment stability and permeability from wetlands on each side of highway

Fish and Wildlife Considerations

When considering mitigation measures for fish and wildlife it starts with the species present, their importance (which may vary depending on the audience), the risk of impacts, and possibly safety considerations to the traveling public. For this project area the largest species present is White-tailed deer (*Odocoileus virginianus*). Typical medium to small mammals include: raccoon (*Procyon lotor*), Grey fox (*Urocyon cinereoargenteus*), Red fox (*Vulpes vulpes*), Virginia opossum (*Didephis virginінanus*), Mink (*Mustela vison*), Stripped skunk (*Mephitis mephitis*), Beaver (*Castor canadensis*), Muskrat (*Ondatra zibethicus*), Long-tailed weasel (*Mustela franata*), and eastern coyote (*Canis latrans var.*). Typical amphibians and reptiles include: Red backed salamanders (Plethodon cinereus), Garter snakes (*Thamnophis sirtalis*), Snapping turtles (*Chelydra serpentina*), Painted turtles (*Chrysemys picta*), Northern leopard frogs (*Rana pipiens*), and American toads (*Bufo americanus*). No threatened or endangered species were identified within the project area, thus not requiring and specific mitigation needs. Two species of State concern, Northern harrier (*Circus cyaneus*) and Red shouldered hawk (*Buteo lineatus*), were considered and studied based on potential habitat availability though no nesting sites were found. For these species buffer areas adjacent to wetlands would be more appropriate mitigation if warranted.

Throughout the project development we faced many comments including requests that we consider wildlife and fisheries passage, and aspects of habitat connectivity. Very limited recommendations were made from involved agencies, but NYSDOT committed to consider mitigation measures. Some of the comments we heard that may have lead some to not even consider mitigation measures included: small diameter wildlife crossings under a 4 lane highway are to long and will have limited value, the lack of light on long crossing culverts will limit use of many species, the crossing culverts will become feeding locations for predators resulting in another impact, wildlife warning reflectors don't work, and so on.

For this project it was determined that the most effective mitigation would be small culvert underpasses with some unique design considerations, large culvert considerations, stream enhancements, buffer area protection, alignment selection factors, and installation of wildlife warning reflectors. Professional judgment was used to identify the most appropriate locations for small wildlife crossing culverts. Primarily edge effects and certain habitat features were expected to be the best location for placement. Further the highway embankment needed to allow for a minimum of a 24 inch concrete culvert and were possible larger culverts. Elliptical type culverts would be preferred to provide a wider crossing width. Regardless of skepticism that was found in the literature or brought for attention to cost analysis to construct a small culvert crossing at the time of the initial project construction was $5,000 each. Following construction it would cost more than 10 times as much to cut the road, maintain traffic, and install the culverts. A total of 14 locations were determined to be feasible and likely small wildlife crossing locations. The 14 locations selected were prioritized as the best locations based on general wildlife habits and considering constructability, culvert cover. Approximately 80 locations were considered, but lack of culvert cover limited most. The total installation cost of 14 culverts during construction would be about the same as installation cost for 1 following construction. Partially for this reason it was decided it would be more cost-effective to risk installing all the locations then to study potential crossing locations and install locations following construction completion.

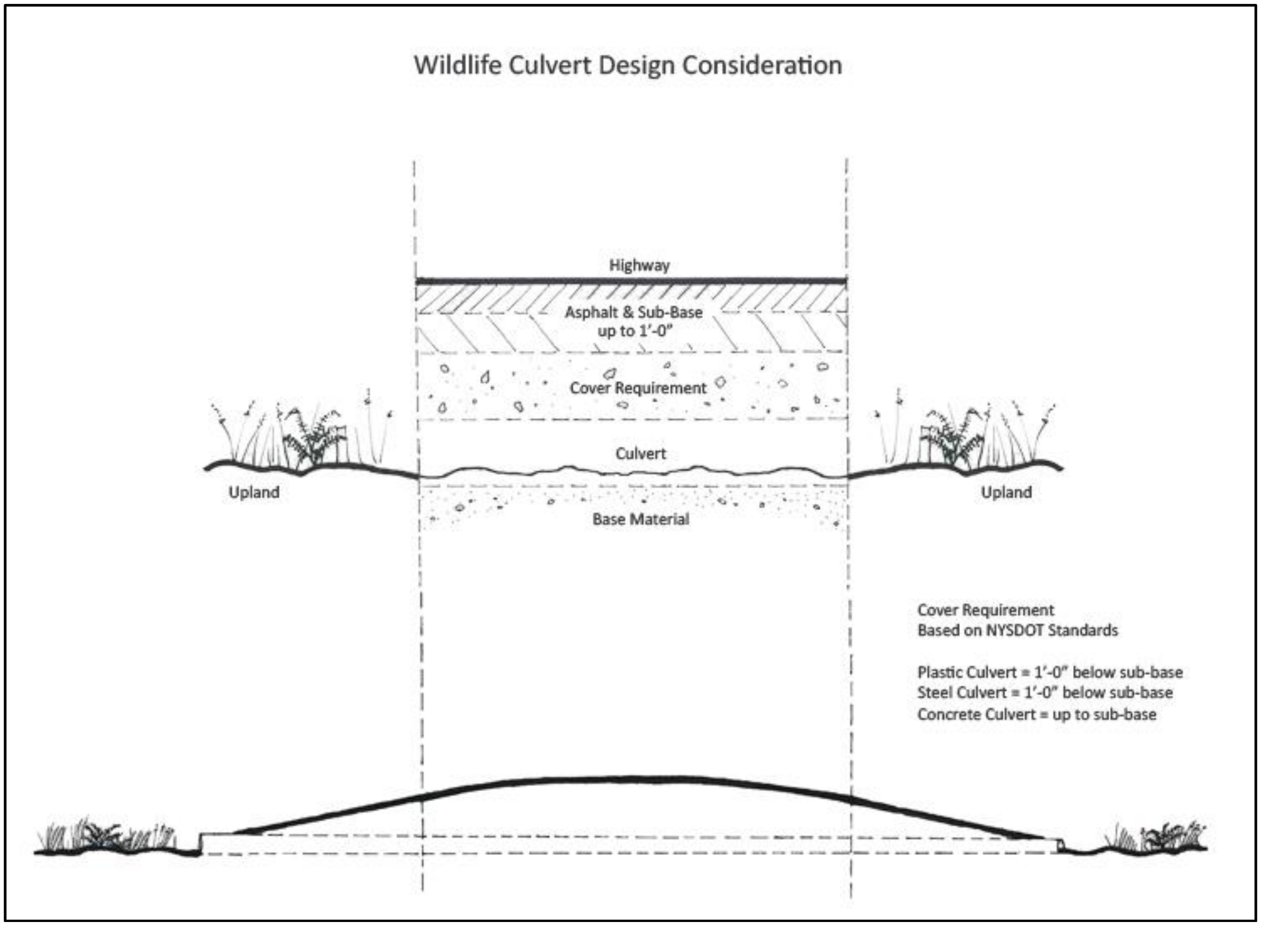

Figure 8. Wildlife Culvert Design Considerations related to highway profile and cover requirements

Small Culvert Crossings

As noted previously the minimization to wetlands by decreasing the embankment elevations also reduced the opportunities to install small wildlife crossings. A typical three-foot concrete culvert required approximately 4 foot of embankment elevation above existing. Highway embankment areas that were less than us would mean smaller culverts if at all feasible.

The decision to install these culverts has been determined to be successful based on some limited camera monitoring, trails and tracks present. Some remote camera monitoring has shown that several species of wildlife use them on a regular basis. Some could argue to what value this really adds beyond saving some individual wildlife that is common to the area. In the big picture this could have significant influence on population's species if this becomes a more common consideration in all future transportation construction / re-construction projects. Many studies have shown transportation has significant impacts on wildlife populations in some areas. Additionally, there is not good data on accidents caused by small wildlife, but there are plenty of individuals who know of accidents that have been caused by smaller wildlife. One of the photos below show wildlife exiting the culverts with headlight in the background indicating collisions may have resulted had the animals crossed over the highway. Many recorded photos showed this potential beyond what is shown here.

Figure 9. Wildlife culverts in use

Things we have observed thru remote cameras at 4 of the 14 locations and field assessments include: 7 species using the small culvert underpasses including Virginia opossum, Raccoon), Mink, Woodchuck (*Marmota monax*), and Long-tailed weasel), Grey fox, and Red fox. We have not observed Stripped skunk or Eastern coyotes using the culverts to date. No predators were observed staging at culverts hunting or preying on species, wildlife trails go to these culverts, and paralleling wildlife trails to the highway that are selecting the culverts over more direct routes over the highway.

Large Culvert and Stream Mitigation

As a note, culverts are considered spans up to 20 feet by NYSDOT. The recessing of pre-cast concrete culverts (and small bridges) has been a consideration in this Region 2 of NYSDOT since about 1997 where conversations between the Regional Environmental Manager and the Regional Structures Engineer discussed the issue following a culvert installation that resulted inadvertently in creating a barrier during low flow conditions. From that day forward the recessing of culverts of all sizes was evaluated regardless of any specific fish species. In many situations the focus by the responsible resource agency focused concern only to trout bearing streams. The additional consideration by Region 2 NYSDOT was justified by the environmental ethic promoted in NYSDOT and that the effort in many situations posed no significant engineering considerations or costs. Typically, projects that were studied to satisfy engineering considerations (i.e. constructability, no threat to downstream culverts, etc.) included a 1 foot recessing of the culvert bottom below existing stream profile. In cases this could be designed the Structures Engineer noted this can be a positive benefit from a storm event perspective in that a larger structure can accommodate greater storms maybe preventing a culvert failure and highway closure. This initiative pre-dated any permitting language that is known being implemented nationally under Federal regulations.

Mud Creek was the widest stream crossings within the project corridor and involved the longest culvert in the project corridor. The stream is located at an interchange area and to minimize wetland impacts, and multiple stream crossing structures a single point interchange was selected versus a partial clover leaf. The single point interchange has had limited use in NYS, but is used in other parts of the country. The single point interchange consolidates the ramps adjacent to the mainline. The result is one wide crossing whereas the partial clover leaf fragments a greater area, has multiple crossing locations, and a greater net total length of culvert needed due to multiple highway embankments. The culvert was designed to be recessed below the existing stream bottom profile by approximately 1 foot. Upstream of the culvert several stream, enhancements were added including boulder placements, and pool diggers. Since the installation, the culvert has typically 1 foot of water during low flow. There is limited material accumulation in the culvert, and may be a consideration in the future to consider baffles to catch material.

In addition several smaller intermittent streams and perennial streams were crossed using recessed culverts below existing grade.

Wildlife Warning Reflectors

At the time of the project development there was no conclusive research on whether these devices were effective or not. Because Oneida County has one of the highest deer/vehicle accident records in the state and a portion of the project area had high deer incidence it was determined that this technology would be implemented on about 2 miles of the project corridor. The project cost for this item resulted in a very minor overall project cost, and for the first 6 months only one deer vehicle accident was reported. Since this is a new highway, no means to determine effectiveness of this system can be made. Since the project at least one university research study has concluded that the effectiveness of these products is not effective. Though we have no evidence in this project to dispute this finding we do have results from an installation area in another portion of Oneida County that does show a reduction in deer vehicle accidents in the years following installation of these devices. The area where these warning devices (Swareflex reflectors) were installed was highlighted by a traffic report that determined an accident history warranted action. The area was determined to be a priority accident location and the cause of 30 plus accidents was White-tailed deer. Since the installation several years of follow up traffic accident data shows over a 60 percent decrease in these types of accidents and the area is no longer an accident priority location. Other factors could be contributing to the accident reduction, but something has changed since the installation of the wildlife warning reflectors.

Spoil Berms

In the reconstruction and construction of new projects surplus excavated material is often generated. The material is referred to by many names from waste material, overburden, and spoil. It will be referred to as spoil in this discussion. As a result of undercuts, and cuts for portions of the alignment more than 100,000 cubic yards of spoil was to be generated. This creates not only a problem for contractors, but this material often times finds it ways into floodplains and wetlands illegally. In addition trucking spoil material has a cost and safety consideration for added trucks on the highway. It has been a practice in this Region of NYSDOT to try and minimize its generation and find options for it use that has a positive benefit. Re-use of this material in the project design is one option, and flattening slopes to eliminate guiderail is another option. Many factors can influence the opportunities including available right of way and environmental resources such as adjacent wetlands.

The project generated more spoil than could be designed into the project. This resulted in the need for an off-site location to the project that the contractor secured with a private adjacent landowner. One option that was designed into the project for spoil was use of spoil berms. They were designed as an option to screen the highway from a future business park, create some noise reduction to adjacent properties, and overall provide a feature that could maximize disposal for the contractor within the project area.   When considering the relationship of these earthen berms it was decided that there may be a benefit to designing the berms to direct wildlife to the small crossing culverts. Depending on the adjacent land two options were used near these wildlife culverts. The first option was to create an opening in the berms where a small culvert crossing was designed and the second option was to carry the culvert through the berm to undisturbed habitat adjacent to the transportation corridor. Figure 10 is a diagram of the second option type. Through the use of remote cameras the small culvert crossings with spoil berms have proven effective. Further research would be needed to prove how effective these spoil berms are in directing wildlife to the crossing culverts. It is not certain whether this has ever been used by other states in design of wildlife crossings, but it may be of value in future design where project spoil is present.

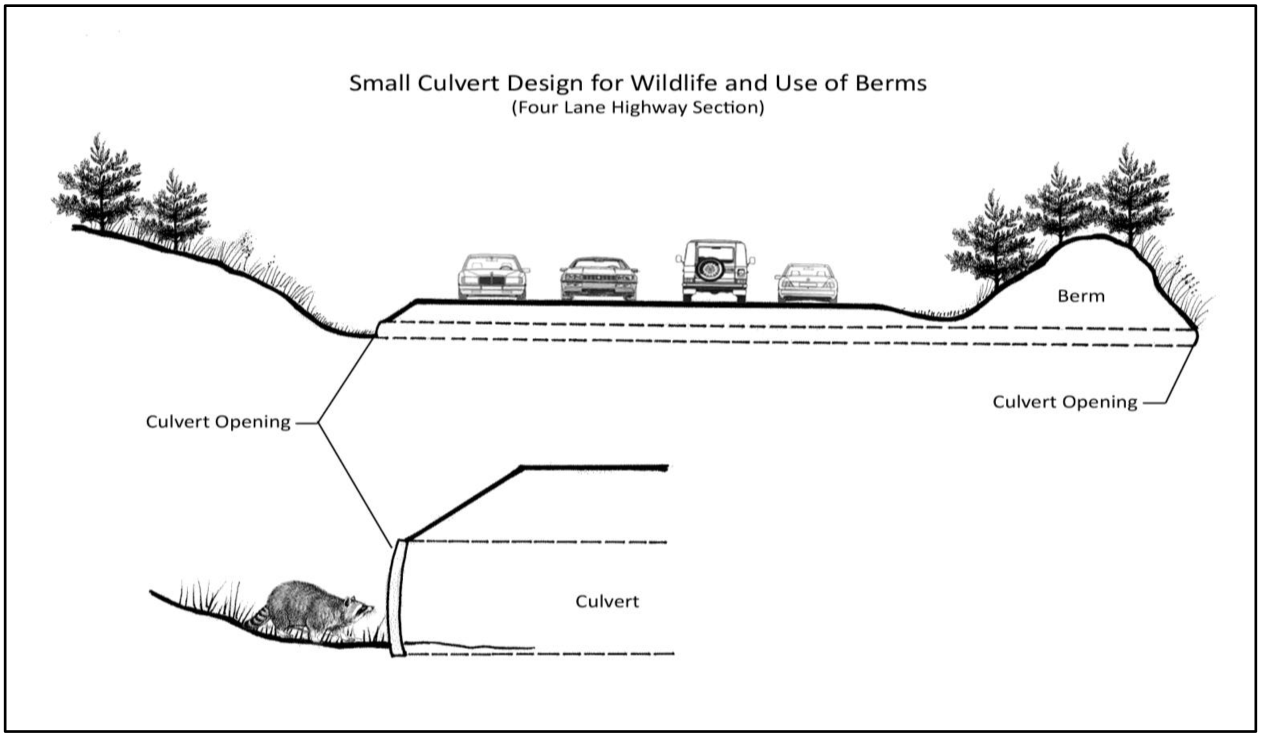

Figure 10. Road, Spoil Berms, Wildlife Culverts, example shown is for culvert under spoil berm

Invasive Species

This topic is very familiar to most people today, and continues to one of the fastest growing challenges to many of us. The project area had some typical invasive plant species found in New York State, and more so in the eastern project area near more concentrated development. The primary species included Common reed, (P*hragmites australis*), Purple loosestrife, (*Lythrum salicaria*), and Honeysuckle, (*Lonicera spp.*) What was unique that early in the wetland studies a shrub was noted that was not common. At first it was assumed that it was not very common and not necessary for wetland study purposes, so it was avoided for identification. As the wetland studies progressed from west to east soon the shrub became more common and it was decided it needed to be identified. It was keyed as Glossy buckthorn, (R*hamnus frangula)*, and the key noted it was a common invasive along railroad corridors. Interestingly enough the heaviest concentrations were adjacent to the abandoned railroad grade. It is noted because even today the actions associated with transportation can lead to the introduction and spread of invasives. Long after a new or a maintenance project is complete the greatest threat to the adjacent areas may be what was introduced or spread by the project. The spread of invasives tends to lead to overall less species diversity and it should be a pro-active consideration in all transportation projects. Where ever possible invasive species should be identified within project work areas early in the project development phase, treated and controlled in advance of the project, the issue highlighted to the contractor(s), develop appropriate contract items, the project area monitored following construction, and treatments/controls as necessary following project completion.

Long Term Assessment of Environmental Mitigation

One area that that should be given more consideration is the long-term assessment of environmental mitigation that is done as part of transportation projects. Many things can be learned as a result of these efforts though it is often done only as part of permit requirements. Many times this has limited effectiveness if the ownership of these results is merely passed along to the permitting agency and the DOT does not use it for their benefit. As an example, there was no requirement to monitor the wildlife crossing structures as part of the Judd Road connector project and some difficulty was had in purchasing cameras after the project was complete. Funding for cameras took some effort, but the results show that the installation of the small culverts was beneficial. Not all of the culvert crossings had been monitored to date, but it is planned in the future. Recently another region in NYS DOT was developing a project and had a question regarding the effectiveness of using small wildlife crossings. Based on the monitoring done for the Judd Road connector project recommendations could be made to assist in another project. The region had made a

comment during a request for information that they had heard that these culverts have a minimum value. By sharing some of the simple photographs of wildlife using our structures a new perspective on the topic was realized.
Lastly, wetland mitigation, wildlife crossing structures, stream enhancements, buffer area preservation, etc. should consider some means of long-term communication of the purpose as transportation assets. Many times record plans are the primary source of transportation information. For example, in the Judd Road connector project it will be critical that the buffer area of 62.5 acres be maintained in some permanent record so that someday future transportation decisions do not compromise this mitigation measure. It would be unfortunate if someday the small culvert wildlife crossings built are faced with removal due to a lack of understanding in a future reconstruction project with new designers who do not understand why a culvert was built with no water conveyance. It is a challenge to be faced by all DOT's across the country as environmental mitigations continue to be intricate parts of balanced transportation projects.

Closing Thoughts

Delivering transportation projects can be a challenging and rewarding experience. The linear nature of these projects makes them unique, and broad reaching. Where other types of projects may be in one defined area (watershed, community, habitat, district, etc), transportation projects often cross boundaries of many area types. This can lead to a wide range of issues and settings that takes in many disciplines of environmental considerations, engineering, and other concerns. Furthermore, some issues can appear minor or less important without the appropriate understandings. With any good project, including transportation, many factors can lead to difficulty in getting the project approvals. Often times project delays, increased costs, wasted time, and poor environmental mitigations result from some basic facts that were missing or limited. Lack of, or missing communication being the obvious reason that often results from not having the appropriate expertise or level of expertise involved in a collaborative project from initiation through construction. On the contrary, taking careful consideration can result in project cost savings, sound schedules, improved Agency relationships, and positive environmental mitigation.

Considerations and applications of environmental mitigation are relatively new, and often times there are limited resources to draw from to accomplish the project objectives. With limited information it can sometimes lead to in action or poor decisions thus making collaboration of expertise even more important. Many of the ideas developed into mitigation for the Judd Road Connector came from this type of collaboration within DOT and with the involved Agencies. In many cases it led to good decisions based on collaborative professional judgment that considered such things as benefits, costs, constructability, feasibility, alternatives, etc. The overall outcomes from this project have been positive with some challenges we have and should continue to learn from.

Acknowledgements

Many people have had involvement in the Judd Road Connector Project, but the author would like to recognize the major contributors that helped deliver the environmental considerations of this project: Heather Pritchard, Becky Tobiasz, Walt Derucher, Ray Oram, John Hallock, Kathy LoConti-Lee, Mike Reed, Margaret Reilly, Gary Dempster, John Kenty, Tim Lusher and Design Squad, Eric Celia and Construction staff; Agency staff Pat Clearey, Joe Homburger, Sandy Doran, Bridgett Brown, Dave Pohle, Alex Chmielewski, Carl Schwartz, and Mike Townsend. Special thanks to Marcy Shaul for graphic support with line figures.

Biographical Sketch

Since 2006 Ed Frantz serves as the NYSDOT Adirondack Park and Forest Preserve Manager. The position was established to implement consistent DOT practices, corridor planning, best practices, training, and other initiatives across the Adirondack and Catskill Parks. Previously he served as the NYSDOT Region 2 Environmental Manager. Prior to working for NYSDOT Ed served 6 years with the NYS Dept of Environmental Conservation as a Wetlands Specialist. Ed is a Graduate of the SUNY College of Environmental Science and Forestry at Syracuse, and SUNY Morrisville. He currently serves on the board for the NYS Wetlands Forum, is Chairman of the NYS Flora Association, and is a former board member for the NYS Invasive Plant Council.

AVIAN PROTECTION PLAN FOR THE NEBRASKA DEPARTMENT OF ROADS

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Abstract

Compliance with the Migratory Bird Treaty Act (MBTA) has presented challenges for the Nebraska Department of Roads (NDOR) and its contractors. NDOR has worked to reduce avian mortality through implementing changes in project scheduling, increasing migratory bird surveys, and introducing changes in project construction timelines to avoid avian conflicts. The attractiveness of bridges/culverts and ROW habitat for migratory bird nesting, coupled with the overlap of the primary nesting period and construction season are the basis of the conflicts between avian conservation and construction of highway projects. The implications of the conflicts range from construction delays and shutdowns to the potential for violating the federal law (MBTA), resulting in costly claims and fines.

NDOR was one of the first state transportation agencies to employ a Liaison with USDA-APHIS-Wildlife Services (WS). NDOR sought the expertise that the liaison provided concerning migratory birds. Additionally, the Liaison was able to use the WS depredation permit to take migratory birds if a conflict arose during construction. In 2006 though, an informal opinion from the United States Fish and Wildlife Service (FWS) solicitor's office ended the use of the WS depredation permit (on NDOR projects), prompting NDOR to explore other avenues to comply with the MBTA, while minimizing effects on NDOR's construction program.

Avian Protection Plans (APP) are being developed by public and private entities nationwide, and NDOR recognized this as a way to formalize our MBTA procedures and to provide a resource for NDOR employees and contractors. NDOR's APP is one of the first among transportation agencies.

By implementing the APP, NDOR will attain its goals of 1) protecting and conserving avian populations and 2) reducing conflicts between construction of NDOR projects and the laws governing migratory bird protection. NDOR's environmental stewardship will be enhanced, detrimental effects on migratory birds will be reduced, and regulatory compliance will be achieved with the implementation of this new plan.

Preface

Nebraska Department of Roads (NDOR) holds a responsibility to the traveling public to provide safe, reliable roads to traverse the state of Nebraska. Fulfilling this commitment requires construction throughout the year. For the past several years, NDOR has worked to reduce avian mortality through changes in project scheduling to avoid avian conflicts, increased migratory bird surveys, and changes in project construction timelines. This has resulted in the development of an Avian Protection Plan (APP) by NDOR, representing another milestone in avian conservation in the state of Nebraska. It is NDOR's goal to illustrate this ongoing procedure designed to protect and conserve avian populations and to reduce conflicts between construction of NDOR projects and the laws governing migratory birds.

Regulations

Three federal laws currently protect migratory birds in the United States. Failure to comply with these laws can result in civil and criminal penalties including fines and/or imprisonment.

Migratory Bird Treaty Act of 1918 (MBTA) (16 U.S.C. 703-712):
The MBTA protects all birds native to North America, with the exception of non-migratory upland game birds (e.g. quail, grouse, pheasant, turkey, etc.) and non native birds (e.g., House sparrow, European starling, feral Rock Pigeon, and Eurasian collared doves). The MBTA states that it is "unlawful to pursue, hunt, take, capture, kill, possess, sell, purchase, barter, import, export, or transport any migratory bird, or any part, nest, or egg or any such bird." The MBTA currently protects over 800 species of birds that occur in the U.S.

Threatened and Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531-1544):
The ESA provides protection to our nation's native plants and animals that are in danger of becoming extinct and to conserve their habitats. The ESA makes it unlawful to import, export, take, transport, sell, purchase, or receive in interstate or foreign commerce any species listed as threatened or endangered.

Bald and Gold Eagle Protection Act of 1940 (BGEPA) (16 U.S.C. 668-668d):
Bald and Golden eagles, their parts, active and inactive nests and eggs are afforded additional protected under both the MBTA and Bald and Golden Eagle Protection Act.

Glossary

These definitions have been developed using several resources and may not coincide with established language in the Standard Specifications for Highway Construction.

Active Nest: A nest with an adult and eggs or young present. Nests are *active* primarily during the primary breeding season (April 1st – September 1st). Raptors may nest earlier, and swallows may nest later than some of the other migratory bird species that move into Nebraska during the breeding season.

Awarded: A construction project that has been let will then be awarded to the construction Contractor with the lowest bid. Awarding contracts typically takes place 10 days to 2 weeks after letting.

Construction Start Date (or Start Date): The date the construction Contractor or NDOR determines the project will commence construction.

Fledge: Young have left the nest and are no longer dependent on it for shelter or for feeding from the adult(s).

Inactive Nest: A nest that does not contain eggs or young. Inactive nests may be complete or partially complete, and may be removed at any time throughout the year as long as they do not contain eggs or young.

Letting: An upcoming construction project is “let” out for bids from construction Contractors. Monthly scheduling meetings determine which projects will be let for bids the following month.

Migration: A seasonal or periodic movement of animals in response to changes in climate or food availability, or to ensure reproduction.

Migratory Bird: Any bird which migrates during the year, such as, but not limited to: hawks, American Robins, swallows, Mourning Doves, American Tree Sparrow, Whooping Crane.

Notice to Proceed: Notice given by NDOR to the Contractor that (s)he may proceed with construction on the project.

Raptor: Bird of prey with sharp hooked bill and sharp talons used for killing and eating prey; includes members of the Orders Falconiformes and Strigiformes, and member of the family Cathartidae (i.e. hawks, eagles, owls, falcons, osprey, and vultures).

Take: Defined by federal regulations as: “ to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect.”

Threatened and Endangered Species: Species of animals or plants that are threatened with extinction and are protected by federal and/or state law.

Working Days: The length of the construction contract is determined by how many actual working days the designer designates for the completion of the project. Often seasonal and weather-related delays are accounted for. Conflicts with migratory birds are not accounted for, nor compensated for, and the Contractor must plan accordingly to shift his work to another area of the project to avoid migratory bird conflicts.

ABBREVIATIONS
APP: Avian Protection Plan
BCC: Birds of Conservation Concern, as defined by the US. Fish and Wildlife Service
BGEPA: Bald and Golden Eagle Protection Act of 1940
ESA: Endangered Species Act of 1973
FWS: United States Fish and Wildlife Service
LE: United States Fish and Wildlife Service, Law Enforcement Officer
LOC: Limits of Construction
MBTA: Migratory Bird Treaty Act of 1918
NDOR: Nebraska Department of Roads
NGPC: Nebraska Game and Parks Commission
PIF: Partners in Flight, birds of concern as defined by the Bureau of Land Management
PM: Nebraska Department of Roads, Construction Project Manager
ROW: Right of Way
T/E: Threatened and/or Endangered species, state or federally listed
WS: United States Department of Agriculture – Animal and Plant Health Inspection Service – Wildlife Services

Policy

NDOR personnel shall observe and comply with all applicable Federal and State laws regarding avian protection, and the NDOR Avian Protection Plan (APP), while constructing and maintaining safe, reliable roadways for the traveling public.

To fulfill this commitment NDOR will:

- Implement a comprehensive APP.
- Ensure compliance with applicable laws, regulations, permits, and APP procedures.
- Review future road construction projects and determine potential avian conflicts.
- Attempt to schedule projects' construction activities to avoid conflicts with nesting migratory birds.
- Document bird surveys, the results of those surveys and any active nests.
- Take appropriate measures to prevent migratory bird nesting activities.
- Provide training to improve employee and Contractor knowledge of the APP and avian protection laws.

NDOR's environmental stewardship will be enhanced, detrimental effects on migratory birds will be reduced, and regulatory compliance will be achieved with the implementation of this policy.

Scheduling/Planning

WS reviews NDOR construction projects for the upcoming five (5) years. WS reviews projects involving grading, bridges or culverts with the project designer to examine project details, construction phasing and potential conflicts with migratory birds, bald or golden eagles, or threatened/endangered species. These potential conflicts are noted in NDOR's Clarity project tracking system. Clarity is used to run a monthly project letting report for use in the monthly Scheduling meetings. Potential conflicts, and recommendations to avoid these conflicts, are listed with the associated construction project. This assists NDOR in planning and scheduling projects to have minimal migratory bird conflicts, by allowing them to try to move the projects within the upcoming year so that projects with large areas of tree removal, or major bridge reconstruction, for example, are scheduled to occur outside Nebraska's primary nesting season.

NDOR and WS review upcoming projects with bridge and/or culvert work to determine the need and timing for placement of netting on the structures to avoid migratory bird nesting. If the project will be awarded between August 1 and March 1, the contractor should apply netting on the project if warranted. If the project will be awarded between March 1 and July 31, NDOR may contract with WS to apply netting to culverts/bridges on the project. Projects with netting applied by WS will be turned over to the contractor at project start. It will then become the contractor's responsibility to monitor and maintain the netting.

Project Construction Procedures

During the project's construction within the primary nesting season April 1 – September 1, if unforeseen tree or brush clearing is to take place, a nesting survey must be completed prior to tree or brush removal. The Contractor will contact the PM, who will contact the Environmental Section to schedule a survey. Surveys will be conducted through September 1 for tree/brush removal and through September 30 for bridge/culvert work. Surveys conducted from April

1 through September 1 will be accomplished by qualified biologists from the Environmental Section or WS. After September 1 and before April 1 surveys for raptor nests may be conducted by the PM.

Trees/brush and culverts/bridges that are surveyed during the primary nesting season, and found to be devoid of active nests, will be removed (or netted in the case of a bridge/culvert) within five (5) days. If they are not removed, an additional survey must be conducted.

Areas that are surveyed outside the primary nesting season (before April 1or after September 1), and do not contain active nests, will be considered cleared for removal through the end of the current construction season, not including the primary nesting season. For example: if an area is surveyed and considered clear in March, it will be considered clear until April 1. If an area is surveyed and found clear in October, it will be considered clear until the following April 1.

Construction projects which include culverts/bridges that do not have netting in place will need to be maintained by the Contractor at least twice weekly, between April 1 and September 1, with no longer than five days between inspections. This maintenance should include inspections of the structures for nesting attempts and removal of those nesting attempts. During the inspections any nesting attempts should be removed and documented on a survey report form.

Construction projects that have netting in place on the culverts/bridges will have at least twice weekly inspections, with no longer than five days between inspections, and maintenance performed. This monitoring will ensure that the netting is properly maintained, no gaps or holes have formed, and that the nets are functioning properly. Monitoring will also include removing all nesting attempts and releasing any entrapped birds. If a bird is found to be entrapped in the net it should be immediately freed. If the bird is injured and cannot leave the net, the Contractor will immediately notify the PM, who will notify the Environmental Section for direction on removal. If a dead bird is found in the net, the inspector may remove the bird and will deliver it to the PM, who will report it to the Environmental Section. The Environmental Section will notify FWS LE of the incidental take. Reports of the twice weekly monitoring will be included in the Environmental Section project file, if performed by WS, or in the Contractors'/PM's file on the project site. Reporting style will follow the survey report format. (See Appendix A & B)

<u>Avian Survey</u>

Equipment/Resources Used:
Nikon 10X50 binoculars
8" X 10" mirror on extendable pole
<u>Birds of Nebraska Field Guide</u>, Stan Tekiela
<u>Birds of Eastern and Central North America</u>, Peterson Field Guides
<u>Field Guide to the Birds of North America</u>, National Geographic
<u>Nests, Eggs and Nestlings of North American Birds</u>, P. Baicich, C. J. O. Harrison, Princeton Field Guides
<u>Guide to Bird Behavior Volume Three</u>, D. and L. Stokes
<u>The Nebraska Breeding Bird Atlas 1984-1989</u>, W. Mollhoff
<u>Birds of Nebraska, Their Distribution and Temporal Occurrence</u>, R. Sharpe, W. Silcock, J. Jorgensen
<u>Birds of My Region</u>, Thayer Birding Software, Cornell Lab of Ornithology
<u>Birding by Ear /Eastern and Central North America</u>, Peterson Field Guides, R. Walton and R. Lawson
<u>More Birding by Ear/Eastern and Central North America</u>, Peterson Field Guides, R. Walton and R. Lawson

Methods Employed:
Trees/Brush

- Individual trees designated for clearing are inspected individually.
- Groups of trees less than 0.25 acre are inspected individually.
- Groups of trees greater than 0.25 acre or 10 yards wide are inspected by walking parallel transects, approximately 10 – 12 yards apart.
- Linear formations of trees are inspected by walking the length of the area.
- Brush/shrub areas are surveyed by walking through the area, looking at the brush from all sides since the dense vegetation makes visual observation of nests difficult. Every attempt is made to look at each individual clump of brush.
- Trees and brush are surveyed for stick, grass, leaf and cavity nests from ground level through canopy. Additional time is taken when tree/brush is leafed out to ensure adequate view of potential nests.
- Area is surveyed for any bird activity, via visual and auditory observation. Birds are observed to discern nesting activity and to locate the nest, if present.

- Nests are identified by observing the incubating adult, if present, and identifying its species. Nests without adult present are identified by shape, composition and location of nest. Cavity nests are identified by adult leaving or entering the cavity. Number of eggs or young are counted on nests within reach, either directly or by use of the pole mirror. Species appropriate estimates are given for any nest, appearing to be active based on quality of nesting material, which is not able to have its contents visualized.

Culverts/Bridges

- Culverts and bridges will be visually inspected for the presence of bird nests. Bridges will be inspected under the girders, around the piers, and under the lip of the deck.
- Culverts and bridges will be observed for at least 15 – 20 minutes to determine bird activity surrounding the nests.
- If possible, direct observation into the nests will confirm nesting activity by the presence of eggs or young. This may be accomplished with the use of a pole mirror from the deck of the bridge.

Documentation of Surveys

Results of surveys will be recorded and maintained in the Environmental Section project file for five (5) years. Documentation will include:

- Project control number, project number and name
- Project location
- Surveyor name
- Date and time of the survey
- Weather conditions at the time of the survey
- Bird species observed or heard in the area surveyed
- Location, number and species of active bird nests observed in the project area
- Avoidance measures taken to discourage nesting (i.e. Netting a bridge or culvert, or moving the project within the letting schedule to clear trees outside the primary nesting season)
- Circumstances necessitating the survey (i.e. Project is ahead/behind schedule, project delayed due to late permit acquisition) and description of previous surveys or monitoring (i.e. Project manager has been monitoring the nesting progression of the last swallow nest in the culvert for two weeks prior to survey)
- Recommended actions

Active Nest Procedures

If an active nest is found during the survey, the Contractor should do everything possible to restructure his activities and leave the nest undisturbed until the young fledge. Fledging could occur within a week, or up to a month, after the survey depending on the species of bird and whether the nest contained eggs or young. Also depending on the species of bird and their sensitivity to disturbance, a buffer of up to 30 feet surrounding the tree with the active nest could be required until fledging.

If construction cannot be rescheduled to allow the birds to fledge, and it is determined as an unavoidable “take” circumstance, the NDOR Environmental Section and WS will document when the project let, when construction began, any circumstances that caused the project to be delayed, all efforts made by NDOR and the Contractor to avoid clearing during the nesting season, and impacts to NDOR, the Contractor and the traveling public if the project is delayed to allow fledging of the nest. This information will be presented to FWS LE in Nebraska for review and determination if “taking” the nest will be prosecuted under the MBTA. If prosecution is avoided, then WS, NDOR Environmental Section, or the PM will need to be on site when the nest is removed to properly and humanely dispose of the contents of the nest, and document its destruction.

It is the Contractors' responsibility to schedule his work to accommodate the process of conducting a survey(s) and submitting the necessary documentation if avoidance is not practicable. The Contractor shall be responsible for using any legal and practical method to prevent the nesting of birds in order to prevent the need for any survey and prevent the need for additional surveys. It is understood and agreed that the Contractor has considered in the bid all of the pertinent requirements concerning migratory birds (including endangered species) and that no additional compensation, other than time extensions if warranted, will be allowed for any delays or inconvenience resulting in these requirements.

Other Special Activities

Borrow Site Excavation

Construction Contractors will, at times, require additional fill material to construct a road base. This extra fill is obtained from a borrow site. Often, Bank Swallows, Northern Rough-Winged Swallows, Barn Owl and Belted Kingfisher will nest in the borrow sites because their sheer, vertical faces provide excellent burrowing sites for their nesting cavities. To prevent these birds from nesting in any borrow sites, the Contractor can grade the faces at an angle not suitable for nesting.

If a Contractor wishes to use a borrow site that either has been known to previously have nesting birds or may currently have these birds nesting on site; (s)he has two options:

- Follow the protocol for obtaining a nesting survey, and use a different portion of the site until the birds fledge, if active nests are found, or
- Apply netting over the sheer faces of the site or grade off the faces prior to the nesting season.

Threatened or Endangered Species

Construction activities occasionally occur within known T/E nesting locations or migration corridors throughout Nebraska. NDOR reviews these projects and locations, consults with the appropriate agencies (FWS or NGPC depending on the species federal or state listed status) and conducts the agreed-upon conservation measures (usually to include migration or nesting surveys during construction). Currently, NDOR monitors and conducts nesting surveys for the Piping Plover and Interior Least Tern, and roosting surveys for the Whooping Crane. If nesting activity or an active nest is found, construction must stop and the PM will immediately notify the Environmental Section for direction. The same procedure is followed for roosting or feeding Whooping Cranes. NDOR follows a specific protocol, approved by FWS and NGPC, for each T/E species, for conducting surveys and documenting reporting. (See attached species information sheets, Appendix D)

Raptors, including Bald and Golden Eagles

As stated in the MBTA and the BGEPA, active and/or inactive raptor nests are protected and cannot be removed. NDOR reviews projects with known nest locations to determine if the LOC include the nest, or are within distances specified in the BGEPA. If the nest does occur within the LOC, then construction activities, including construction timing, may be adjusted to occur outside the primary eagle/raptor nesting season. If trees must be removed in the vicinity of the nest, then an appropriate buffer will be left to offer a visual buffer to the nest. Surveys will be conducted, and active nests will be monitored during the construction project.

Birds of Conservation Concern and Partners in Flight Areas

NDOR and WS review the upcoming projects with extensive grading and tree removal, and compare them to BCC and PIF areas. Potential nesting birds are identified and the project is monitored to determine if a special nesting survey is needed, if the BCC or PIF occur in that specific construction project area. Rarely do NDOR construction projects contain areas that may be nesting habitat for BCCs, but the projects are none-the-less identified and monitored for the need for a potential survey. If trees must be cleared during the BCC's nesting season, then special attention is directed towards potentially locating that/those species during the survey. To date, no BCC has been found in NDOR construction project surveys.

Avian Reporting System

All avian incidents involving the MBTA, ESA, or BGEPA will be reported to NDOR Environmental Section personnel immediately or within 24 hours following a weekend or holiday.

Incidental Take

NDOR and/or contractor personnel discovering the accidental and unintentional damage or destruction of a migratory bird, nest, eggs, or young that results from otherwise lawful activities, are required to notify the Environmental Section. The Environmental Section will investigate the "take", fill out the appropriate form, and, if necessary, make notification to LE.

Emergency Take

NDOR and/or contractor personnel encountering an active nest and/or T/E species or nest during an emergency situation (i.e. bridge failure, flooding event, human injury, etc) may remove the nest from (or continue working in) the work area and proceed with emergency activities as needed. The nest is to be left onsite. The Environmental Section is <u>not</u> required to be notified prior to the "take", however after the emergency situation is secured, the Environmental Section shall be notified. The Environmental Section will investigate the "take", fill out the appropriate form, and if necessary, notify LE.

Record Keeping

The NDOR Environmental Section will maintain a copy of all surveys and other correspondence related to migratory birds or T/E species. These records will be kept in the project's file located in the Environmental Section, and will be available until the construction project is closed out. Survey and take records are maintained electronically in a database.

Training

NDOR Environmental Section personnel will provide training to appropriate agency personnel and contractors to include the NDOR Avian Protection Plan (APP), avian protection laws, liability issues, and avian species identification as warranted. PMs and other NDOR District personnel are reminded of NDOR's migratory bird policy and procedures and are given any new developments at their annual PM Conference.

Key Resources

Nebraska Department of Roads (402-479-4766) Environmental Section, 1500 Highway 2, PO Box 94759, Lincoln, NE 68509-4759 USA

USDA-APHIS-Wildlife Services (402-263-2123) NDOR/WS Liaison, 1109 S 12th St., Union, NE 68455 USA

USFWS Law Enforcement Officer, Mike Damico (308- 534-0925, Mike_Damico@fws.gov), Special Agent, P.O. Box 1086, North Platte, NE 69103 USA

Nebraska Game & Parks Commission, Rick Schneider (402-471-5569, fax 402-471-5528, rick.schneider@ngpc.ne.gov), Heritage Program Manager, 2200 North 33rd Street, Lincoln, NE 68503 USA

Biographical Sketches

Dionne Gioia received her B.S. in Forestry, Fisheries and Wildlife from the University of Nebraska – Lincoln in 2001. Since then she has worked as a wildlife specialist for USDA – APHIS – Wildlife Services at Offutt AFB, NE, where her main focus was keeping the airfield clear from avian and mammalian hazards to aircraft. She then went on to work for USDA – NRCS in several locations in Iowa as a Soil Conservationist, focusing on wetlands and wildlife habitat enhancements. Dionne returned to Wildlife Services in 2004 and now works with the Nebraska Department of Roads to avoid migratory bird conflicts, and threatened and endangered species conflicts in their road construction projects and maintenance efforts.

Eric Zach received his B.S. in Forestry, Fisheries, and Wildlife from the University of Nebraska-Lincoln in 1998. Since then he has worked as wildlife biologist for Pheasants Forever, USDA-APHIS-Wildlife Services, and the Nebraska Game and Parks Commission. Currently Eric is a Highway Environmental Biologist with the Nebraska Department of Roads, focusing on threatened and endangered species reviews of transportation projects.

Appendices

Appendix A. Migratory Bird Nesting Survey Report Form
Appendix B. Migratory Bird/Egg Take Form
Appendix C. Survey Timeline

Appendix A. Migratory Bird Nesting Survey Report Form

Migratory Bird Nesting Survey Report Form

NDOR
Nebraska Department of Roads

Project Name:		Highway No.:
Project No.:		Control No.:
GPS Coordinates:	Survey Date and Time:	Biologist:
Conditions: Temperature:	Cloud cover:	Wind direction/speed:
Survey Description (area location and size, composition of area, needs, purpose):		
Were there active nests within the area surveyed? ☐ Yes ☐ No *If yes, list each occurrence separately and record activity:*		
Were there birds exhibiting nesting behavior? ☐ Yes ☐ No *If so, list the species and behavior observed:*		
Is there a need for future surveys? ☐ Yes ☐ No		
If so, list the time of next survey or frequency of surveys:		
Additional Comments?		

Appendix B. Migratory Bird/Egg Take Form

Migratory Bird/Egg Take Report Form

NDOR
Nebraska Department of Roads

Project Name:		Highway No.:
Finder's name and phone number:		Control No.:
GPS Coordinates:	Discovery Date and Time:	Project No.:

Total number and species of:

Dead birds: Active nest/eggs:

Active nest/young: Live/Injured bird:

Location of take (area location and size, composition of area, reference post or station):

Was the area previously surveyed for nesting activity? ☐ Yes ☐ No

If yes, list each occurrence separately and record activity:

Do you know the cause of the mortality? ☐ Yes ☐ No

If so, list the cause, or describe the probable cause of mortality:

Disposition of the bird/nest:

Humanely euthanized:

Buried: Bagged and discarded:

Other:

Additional Comments?

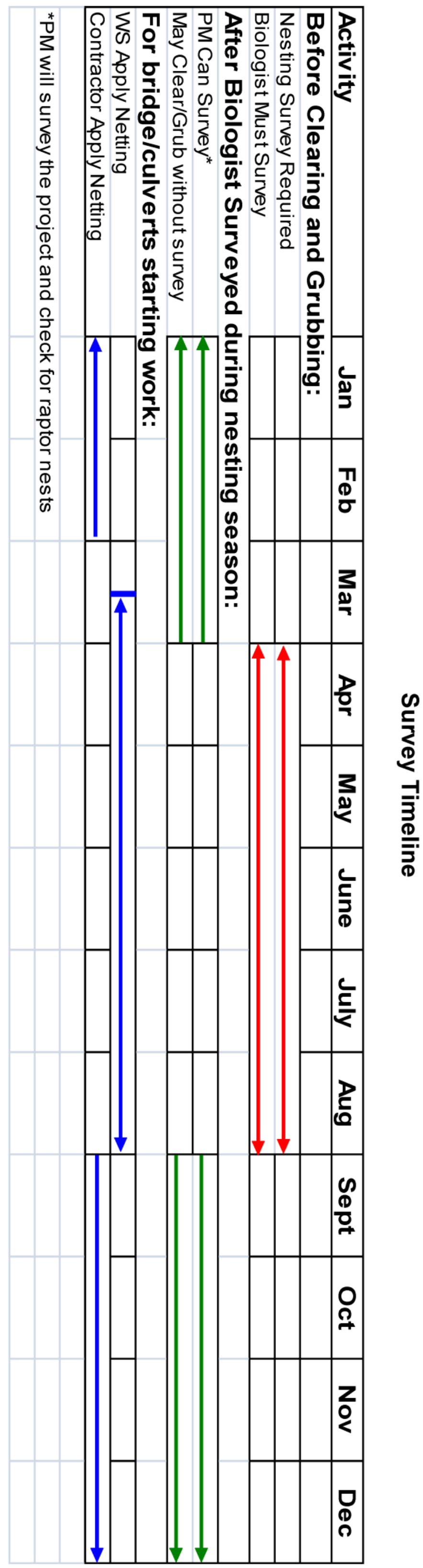
Reporter's name:

Reporter's signature: ____

Reporter's phone number:

Date sent to USFWS:

Appendix C. Survey Timeline



How Do Major Roads Affect Barn Owls?
Distribution, Space Use, Food Source and Mortality

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Abstract

Road network expansion is known as one of the main factors responsible for the decline of Barn Owl (*Tyto alba*) populations in Europe, although the full causes of this decline are still poorly understood. In this context we evaluated several issues related to Barn Owl's ecology, in Southern Portugal, when interacting with major roads: (a) the effect of highway distance on owl's occurrence pattern, (b) the behavioral in the vicinity of major roads, (c) the role of road verges as an attraction factor due to prey abundance, and (d) owls' spatial and temporal patterns of road mortality.

To assess species occurrence (presence/absence) we broadcasted Barn Owl adult calls in 122 sites at several distances from major roads and detected 47 individuals. From the set of environmental and road-related variables tested using logistic regression, only the distance to the highway showed a significant positive influence on Barn Owl presence ($\beta = 0.995$; $p<0.05$).

Space use patterns and road crossing rates were investigated on the basis of seven radio-tagged individuals (4 ♂, 3 ♀), captured in their nests located close to the highway (<5 km). The crossing rate was low (one road crossing per 34.19 hours of radio-tracking). Of the tracked individuals only four (3 ♂, 1 ♀) had sample sizes strong enough to provide robust estimates of home-range size (Fixed Kernel Density Estimator 95%) and just a peripheral overlap between home-ranges (ranging from 2.61 km^2 to 9.37 km^2) and the highway was observed.

The overall abundance of small mammals, assessed through live-trapping, was significantly higher in highway verges (n=248) than in the two other dominant land uses (cork oak woodlands (n=35), and croplands (n=64), suggesting that road verges could be a suitable habitat for hunting.

Between 2004 and 2007, 373 road-kills were detected in 314 km of national roads surveyed (0.30 Barn Owls $kills.km^{-1}.year^{-1}$). A higher number of casualties was registered in fall and winter months when the dispersion of juveniles occurs, while lower mortality frequencies were detected in the end of summer and early spring, corresponding to hatching and fledgling periods. Mortality hotspots revealed to be strongly related with altitude ($\beta = -0.026$; $p<0.05$), eucalyptus or pine forest cover ($\beta = -0.001$; $p<0.05$) and percentage of cropland areas crossed by the road ($\beta = 0.332$; $p<0.05$).

Although major roads do not seem to act as effective barriers to Barn Owls' movements, their occurrence pattern is significantly affected by this linear structure. Moreover, the potential attraction effect due to higher prey density in the highway verges does not seem to have an effect in the foraging behavior of adults.

Introduction

There is a growing consensus in the scientific community (Percival 1990, de Bruijn 1994, Shawyer 1994, Newton *et al.*1997, Fajardo 2001) that Barn Owl (*Tyto alba*) populations have been declining across Europe. The decreasing availability of structures for breeding and roosting (Taylor 1994, Martínez 2004), changes on the agricultural production system and, more recently, the road network expansion (Meek *et al.* 2003, Erritzoe *et al.* 2003, Martin *et al.* 2005), have been referred as the factors threatening Barn Owl populations. A 15 years study conducted in Great Britain on Barn Owl mortality showed that 48% of the recorded deaths were attributed to road collisions and 31% to starvation (Newton & Wyllie 2002). Low fitness condition may pre-dispose Barn Owls to vehicle collisions if: i) it forces them to spend more time hunting, ii) animals do not find other places to hunt unless road verges, or iii) they are less able to avoid vehicles (Newton *et al.* 1997). Supply of perching sites (Meunier *et al.* 2000, Forman & Sperling 2003), temporary blindness on the attempt to cross the road (Hernandez 1988), or inexperience during juvenile dispersion (Massemin *et al.* 1998) are also potential causes of the high mortality rate.

Nevertheless, roads seem to propitiate antagonistic effects. Besides potential attraction due to higher prey density in road verges, (Meunier et al. 1999; Erritzoe et al. 2003, Orlowski 2008, McGregor *et al.* 2008), a repulsive effect due to its inherent disturbance (Ramsden 2003) may explain the lower number of individuals within an area of a dense road network, as documented by Fajardo (1999) and Martinez & Zuberogoitia (2004).

Issues mentioned above underlie the question: Is the Barn Owl repulsed or attracted by major roads? To address this question the following aims have to be considered: (a) to evaluate the effect of highway distance on owl's occurrence pattern; (b) to analyze the behavioral patterns in the vicinity of major roads, (c) to identify the role of road verges as an attraction factor due to prey abundance, and (d) to describe the spatial and temporal patterns of road mortality.

Methods

Study Area

This study was conducted in Alentejo province, in Southern Portugal, a region marked by a recent highway expansion and road's improvement to allow larger traffic volume. In this study we have focused on several segments of the national roads and two highways (A2 and A6), to assess temporal and spatial patterns of owl distribution, foraging behavior and mortality (Fig. 1). The region is dominated by an agricultural landscape and comprises a mosaic of cork oak woodlands (savannah-like woods of cork oak *Quercus suber* and holm oak *Quercus ilex*) and croplands. The human population density (excluding the two major cities, Évora and Beja) is 21 inhabitants.km^{-2} and the road network density is low, averaging 0.25km.km^{-2}, about half of the mean national road density.

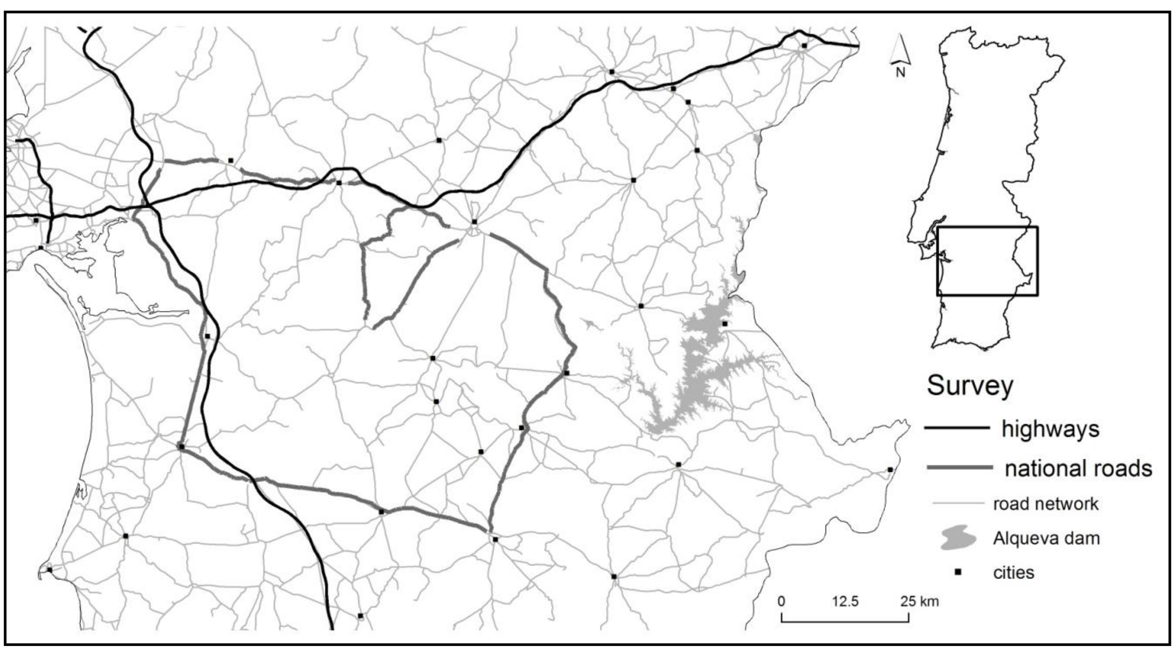

Figure 1 – Study area in Alentejo Province (southern Portugal).

Distribution

From November 2007 to January 2008, we have broadcasted 122 barn owl territorial calls and compared results under the highway effect (< 2000 m) and locations considered to be out of the highway effect (> 2000 m) in order to test the influence of the highway on barn owl occurrence, a set of environmental descriptors (weather, topography, land use, landscape metrics, roost availability, human presence, road-related features) was estimated for each sampling location and a logistic regression model was run to evaluate their relevance to barn owl presence (Hosmer & Lemeshow 2000).

Space use

Between May 2008 and May 2009, seven adult Barn Owls were captured and tagged with a VHF radio-transmitter (Biotrack LTD TW-3 single celled tag); female individuals were assigned as F1, F2, F3 and males as M1, M2, M3, M4. Individuals were radiotracked from dusk to dawn, and located with successive biangulations at 30' intervals. The bearings were taken synchronously by two observers, each driving independent vehicles, using hand-held three-element Yagi antennas. Fixes were obtained using Locate 3 software package.

The minimum convex polygon (MCP, Burt 1943) was used to visualize the largest foraging area recorded for each Barn Owl (White & Garrot 1990) while the fixed kernel density estimator (FKD; Worton 1989), was used to provide a probabilistic measure of use intensity of the foraging area (Anderson 1982, Harris *et al.* 2001, White & Garrot 1990). Spatial autocorrelation was not relevant for these data because this study followed a sampling strategy that considered the circadian activity (Kernohan *et al.* 1998) and thus all animal movements were regularly recorded (Otis & White 1999). Animal Movement Analyst Home Range Extension for the ArcView v. 3.3 and Hawth's Tools Extension for ArcGis version 9.2 were used in home range estimations. The Euclidean distance from radio-tracking fixes to the highway were estimated to assess the magnitude of the road avoidance or attraction effects. Each Barn Owl path was further analyzed and classified in terms of tortuosity using the fractal dimension estimate (D, D=1 linear movement, D→2 random movement, D>2 tortuous movement). Tortuous *vs.* linear movements and tortuous *vs.* random movements were compared in terms of highway distance using the Mann-Whitney test (Katz & George 1985).

Prey Abundance

For each Barn Owl nest found in the vicinity of a highway the relative abundance of small mammals was estimated in the two dominant landscape types (cork oak woodland and cropland), as well as in the nearest highway verge section.

The live-trapping of small mammals resulted from the use of Sherman traps (type "E" 23x9x8 cm and type "F" 38x12x11 cm), baited with cereals and caned sardines, and placed 10 m apart along two lines separated by 15 m. Each sampling session consisted of five consecutive nights, during which all the individuals captured were marked with fur cuts, weighed, sexed and released at the capture location.

The species abundance was estimated using Pounds (1980) index:

$$I_{ij} = \frac{N_{ij}}{T_j . R_j - \sum_j^i C_j - r_j} \times 1000$$

, where for trapping set j:

I_{ij} is the abundance index of species i;
N_{ij} is the number of individuals of species i captured;
T_j is the number of traps available (left open) for the species i;
R_j, is the number of repetitions (sampled nights);
C_j is number of catches (new and recaptures) of other species that species i;
r_j number of species i recaptures considering all repetitions.

To compare the different samples we used the factorial ANOVA.

Temporal and Spatial Road-Kill Patterns

We analyzed road-kill data obtained from January 2004 until December 2007 along 314 km of national roads (Fig. 1). Road surveys were made twice a month at a maximum speed of 30 km.h^{-1}.

The temporal analysis resulted from the comparison of the road-kill counts in the following life-cycle periods: laying, hatching, fledging and juvenile dispersal. To test whether there are differences in mortality among the four biological periods Chi-square statistics was used (Quinn & Keough 2002).

To evaluate the spatial patterns of road-kills, and determine their causes, we identified and described the location of road sections with high mortality incidence (hotspots). The number of road-kills to define a hotspot was estimated according to Malo *et al.* (2004) procedure and the hotspots location was defined using the Nearest Neighbor Hierarchical Spatial Clustering using the software CrimeStat III (Levine 2004). A logistic regression was used to model the occurrence of Barn Owl hotspots along the surveyed roads regarding several environmental and road related-attributes (topography, hydrology, land use, availability of breeding structures, human presence, road topography and width. The model validation was performed using the Jackknife procedure (Olden *et al.* 2002). All statistical procedures were run using SPSS v.15.0.

Results

Distribution

The call-playback method allowed detecting Barn Owl presence in 47 locations. From the environmental variables used, only distance to the nearest road was retained in the final regression model, being positively correlated with barn owl occurrence ($\beta=0.995$; $p<0.05$).

The logistic regression model obtained correctly predicted 69.8% of cases (70.2% of species presences and 69.4% of species absences). The jackknife validation procedure showed that the obtained and classified results were associated in 69.7% of the cases, indicating a good explanatory power.

Space use

Over 123 radio-tracking nights, we obtained a total of 1532 locations of the seven tagged individuals. Of these individuals only four achieved a sufficient sample size to allow home range estimation; three individuals were killed in a vehicle-collision and other three have disappeared being presumably dead. The home range estimations (Kernel 95%) ranged from 2.61 km^2 (M4) to 9.37 km^2 (F1) and assumed an average value of 5.78 km^2 (Fig. 2), which shows to be significant higher than Shawyer's (1998) estimation of 1 to 3 km^2. The core areas (Kernel 50%) ranged from 0.30 km^2 (M4) to 1.43km^2 (M2) having a correspondent average of 0.8 km^2. The MCP representation, as expected, is an over estimation of the actual home range (Fig. 2).

All nest-sites previously identified (F1, M1 M2) were located in the core areas of the home range (Kernel 50%), even those located very close to the highway (less than 500 m, F1 and M2).

The three individuals whose nest-sites were located further than 2 km from the highway showed no interaction with the highway (F2, F3, M4), while F1, M1 (nest-site closer that 500 m), M2 (nest < 2000 m) and M3 (trapped in a roosting place further than 1000 m from the highway) showed interaction with the highway. Nevertheless, these interactions were mainly highway crossings in areas marginally overlapping with this linear structure (Fig.2), since home ranges (Kernel 90%, 95%) mainly extended to the opposite direction of the highway (Fig. 2).

Figure 3 illustrates the higher number of fixes between 250 and 500 m from the highway (68.42%) than within a buffer of 250 m from the highway (30.58%). F1 and M1 with nests located closer than 500 m from the highway showed an evident preference to forage within 250 and 500 m from the highway, while M2 and M3, whose nest and resting place were located further from the highway (> 1000 m) preferred to forage far away from the highway (Fig. 3).

The average rate of highway crossings was 1 crossing per approximately 17.09 hours of monitoring, and a two way (go and return) crossing per approximately 34.19 hours of radiotracking. The two owls that died from vehicle collisions presented high values of highway crossing rate (Table 1)

Only the four individuals (F1, M1, M2, M3) that had a peripheral home range overlap with the highway showed tortuous movements. Mann-Whitney tests found significant differences between random vs. tortuous paths ($U=62428$, $p<0.05$) and linear vs. tortuous ($U=20129$, $p<0.05$), for owls that interact with the highway (nests located at < 2000 m from it) and owls whose home range do not overlap with the highway (nests located > 2500 m from this linear structure).

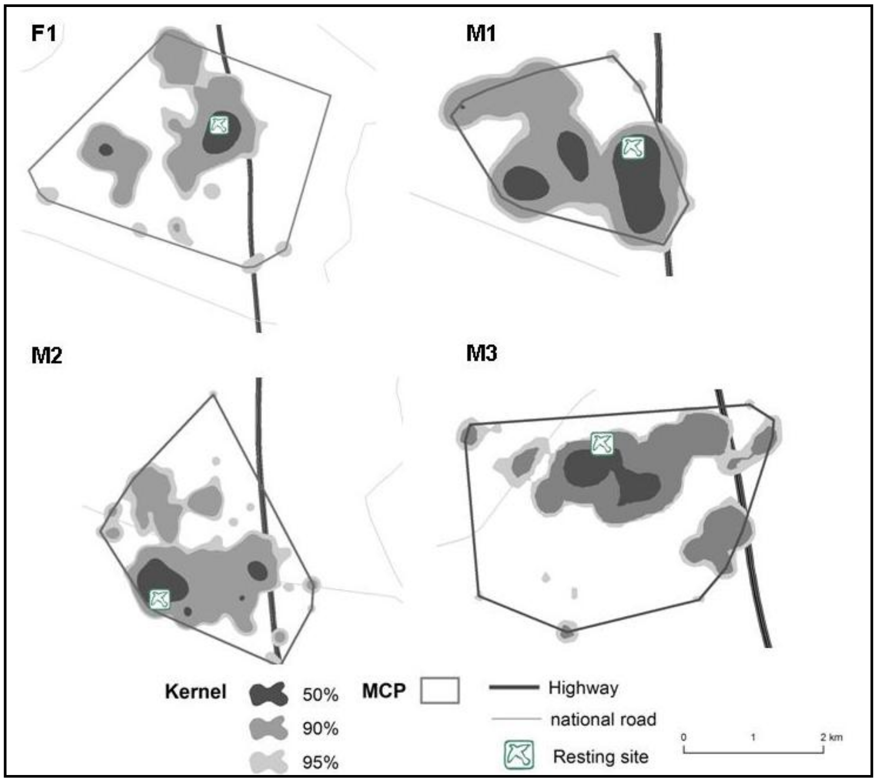

Figure 2 – Kernel home ranges (95%, 90% and 50% estimates) and minimum convex polygons (MCP) for the four individuals that interacted with the highway (♀:F1 and ♂: M1, M2, M3).

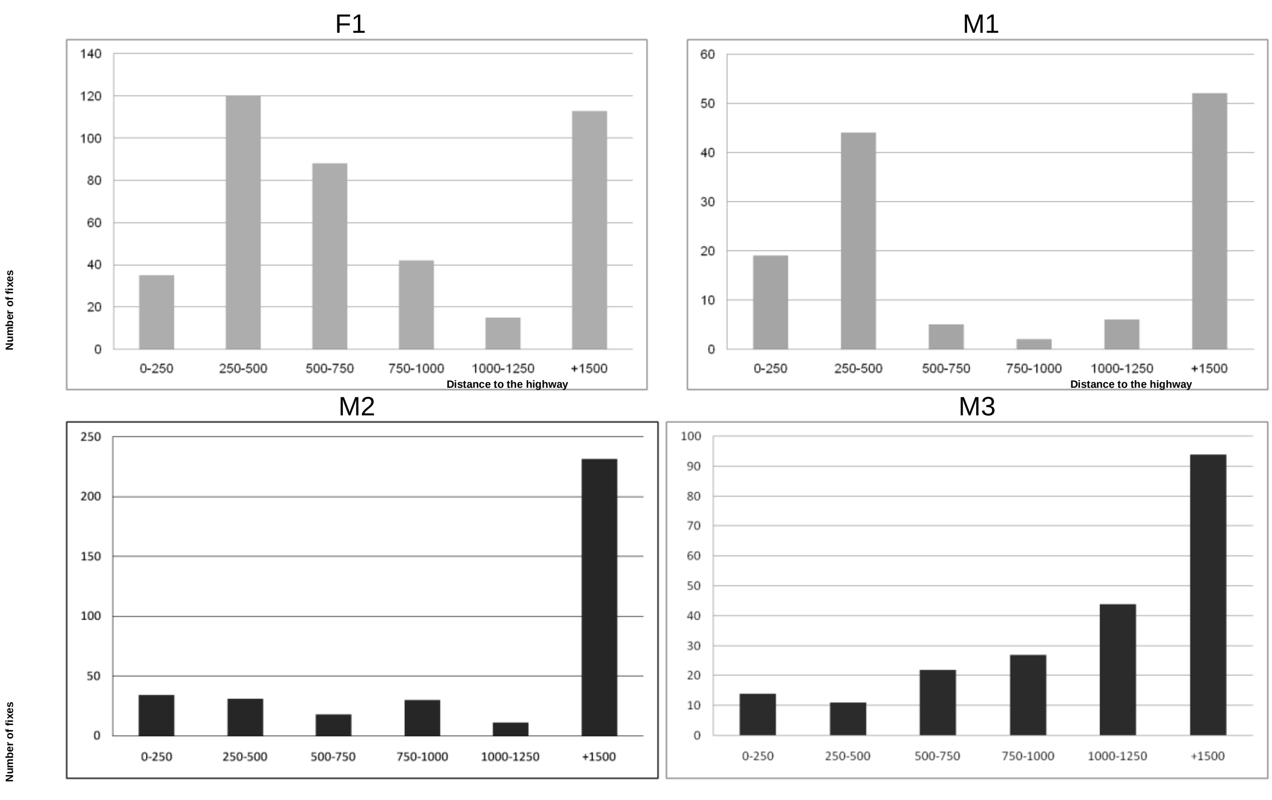

Figure 3 – Number of fixes at 250 m distance intervals from the highway (♀:F1 and ♂: M1, M2, M3).

Individual	Highway crossings	Hours Sampled	Crossing Rate (per 100 hours)
F1	4	270.45	1.48 (one crossing per ≈ 68h)
M1	4	107.12	3.73* (one crossing per ≈ 27h)
M2	7	213.28	3.28* (one crossing per ≈ 30h)
M3	2	62.27	3.21 (one crossing per ≈ 31h)

* - individuals that died from vehicle collisions.

Table 1 – Highway crossing rate (considering go and return as one highway crossing) for the four barn owls that have interacted with the highway.

Prey Abundance

The total sampling effort was 7200 traps set along the study area. The factorial ANOVA showed that the abundance of small mammals was significantly higher in highway verges (n=248 *Apodemus sylvaticus*=110; *Crocidura russula*=70; *Mus spretus*=65; *Microtus cabrerae*=3) than in cropland areas (n=64) and in dense oak woodland forests (n=35) in the surroundings of Barn Owl nest-sites (p-value=$1.34E^{-08}$, Fig. 4).

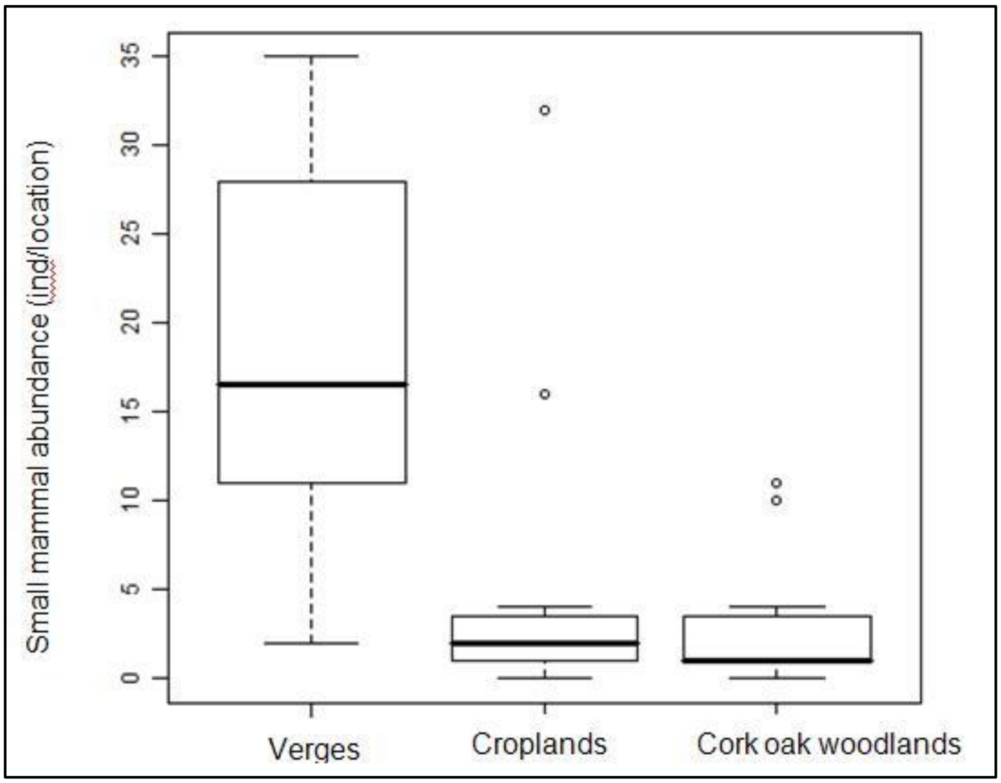

Figure 4 – Small mammal abundance in highway verges, croplands and cork oak woodlands.

Barn Owl Mortality Patterns

A total of 373 Barn Owl individuals were detected dead along the four years of roads survey, with an average of 0.30 road-kills.$km^{-1}year^{-1}$. Temporal analysis revealed a strongly marked seasonal pattern in Barn Owl mortality (Fig. 5). From May to July mortality rate reaches the minimum values (hatching and fledging) and, on the other hand, the critical mortality period corresponds to the months from September to January (juvenile dispersal, Fig. 5). Thus, the number of road killed Barn Owls varies significantly among the life-cycle of the species (χ^2=25.75, p-value<0.05), being higher during the dispersal period (n=41) when juveniles search for food and settlement area, while the lower mortality rates appear to be associated with hatching and fledging (n=17 and n=14). During these last periods females spend most of the time in the nest which can contribute to the lower mortality rates.

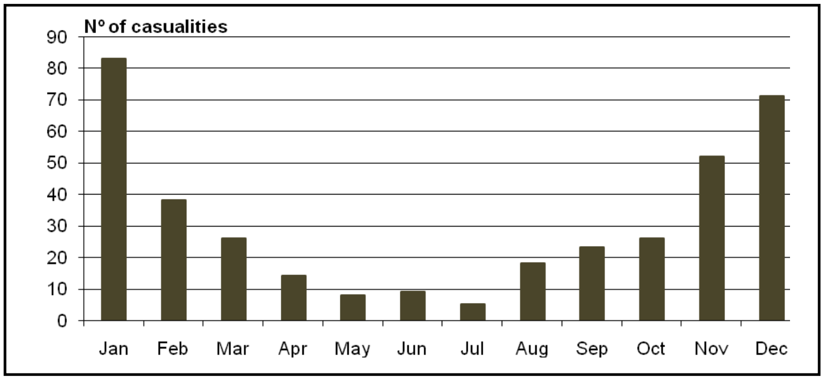

Figure 5 – Number of Barn Owl carcasses found in national roads of Alentejo in each month, from January 2004 to December 2007.

According to Malo *et al.* (2004) procedure, twenty-eight Barn Owl mortality hotspots were identified in the study area, with a hotspot being a minimum of four road-kills per 2000 m road section.

Altitude (β=-0.026, p=0.003) and Eucalyptus and Pine plantations showed a negative correlation with road-kills incidence (β=-0.005, p=0.009) while the percentage of cropland crossed by the road showed a positive correlation with Barn Owl road kills (β=0.046, p=0.041). The model correctly explained 90.9% of the presences and 85.2% of the absences. The Jackknife validation revealed that 75.5% of observed and classified results were associated.

Discussion

Our findings revealed that roads can have a potential attractive effect and a limited avoidance effect. More specifically: 1) roads appear to cause an avoidance effect on the establishment of Barn Owl territories; 2) home range core areas do not include the highway but crossings observed indicate a relative permeability to movements; 3) Barn Owl did not frequently used highway verges, although highway verges have higher small mammal density than the other landscape elements in the vicinity; 4) mortality patterns showed that most road-killed Barn Owls could be juveniles in dispersal, and that the continuity of suitable habitat in both sides of the road increases the likelihood of vehicle collision.

Our estimates of Barn Owl home ranges were the first in the Mediterranean context. The home range estimation for the Barn Owl in Southern Portugal (2.6-9.37 km^2) showed a wider interval than the estimate of Shawyer (1998, 1-3 km^2) and Taylor's (1994, 2-5 km^2), and a slightly narrower range of values than de Bruijn (1994) estimation for Holland (5-10 km^2). Although highways may induce changes in the home range size, we still do not have a big enough sample that allow us to address whether this estimate is biased due to highway effect or not. Barn Owls living in the vicinity of highways seem to avoid this infrastructure, foraging within the 250 m buffer from the highway (even when the nest is located at less than 500 meters from it) and having core areas that do not incorporate this structure. Moreover, the home range generally extends in an opposite direction to that of the highway, and all these traits could reveal the unsuitability of these nearby-highway habitats, which consequently could contribute to reduce the risk of car-collision. Although small mammal abundance was higher in the highway verges than in croplands or cork oak woodlands near nest-sites, Barn Owl radio-tracking revealed that the foraging behavior was not in agreement with the pattern found by Meunier (2000) for diurnal raptors, or the hypothesis of attraction effect related with prey density. Thus, up to now, and despite the higher prey abundance in the highway verges, this structure cannot be considered as attractive to owls. The highway induces an avoidance behavior testified both by the broadcast calling and radiotracking as well as some resilience to the highway effect since they are still able to nest very close to the highway and to cross it without being killed.

Road induced mortality assumes more relevance during fall (juvenile dispersal) and winter periods (both due to juvenile and adult activity). The higher number of fatalities that occur during these months may be related to the inexperience of dispersing individuals seeking for settlement areas that, at the same time, are in unfamiliar regions (Bruijn 1994, Newton et al. 1991). Results showed that it is possible to identify the variables associated with road-killing and predict the areas with higher risk of collision where mitigation measures should be firstly applied. It was also possible to ascertain that landscape structure and composition may influence the road-kill rate, since Barn Owls were associated with habitats with particular characteristics. The continuity of favorable habitat for Barn Owl on both sides of the road shows to be a strong environmental predictor for mortality hotspots for this species.

The high mortality rate on the national roads survey was confirmed by the high rate of vehicle collision of the radiotracked individuals. This indicates that in spite of the observed avoidance behavior towards the highway, there is still a high risk of mortality. The reason that leads the owls to cross the highway remain unclear and further information is needed to fully understand it. Likewise more research on spatial patterns of mortality along highways is also needed since it is a specific feature that may show other and/or observed implications on Barn Owl.

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Joana Sousa has a Master degree in Conservation Biology (Faculty of Sciences - University of Lisbon). Currently, she has been working on road ecology in southern Portugal and she is a member of the Road Ecology Group of the Environmental Biology Center.

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Clara Grilo is a biologist graduated in the Faculty of Sciences - University of Lisbon. She is currently working on her Ph.D. at the University of Lisbon related with the impact of habitat fragmentation and linear infrastructures on small and medium sized carnivores. Also, she joined the Road Ecology Research Group from Centro de Biologia Ambiental/ Faculdade de Ciências de Lisboa and she is participating in a project related with effectiveness of mitigation measures of negative effects on wildlife.

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Wetland Mitigation in Abandoned Gravel Pits: Creating Fresh Meadow and Shrub Swamp

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Abstract

It is becoming increasingly difficult to provide on-site mitigation for wetland impacts due to road construction in northeastern Minnesota counties that retain greater than 80 percent of their pre-settlement wetlands. Abandoned gravel pits are one of the few remaining areas that can serve as wetland mitigation sites within the impacted watersheds. The overall goal of the project is to develop cost effective methods for creating functional mitigation wetlands on abandoned gravel pit sites to compensate for wetland impacts due to road construction in northeastern Minnesota. More specifically, the aim is to achieve "in-kind" compensation by creating wetlands of the same type and function as those being disturbed, such as fresh meadow and shrub swamp.

A 1.3 hectare wetland demonstration site was established in an abandoned gravel/borrow pit within the U.S. Trunk Highway 53 reconstruction corridor in July 2007 to evaluate techniques for creating fresh meadow and shrub swamp wetlands. Aggregate material was removed from the site to a level below the water table and the resulting basin was filled with organic soil displaced by the road construction. Construction activities were monitored for subsequent cost analysis. A total of 50 – 5 m x 5 m plots were established to determine the effect of donor wetland soil applications, wetland temporary and native sedge/wet meadow seed mixes, and native willow hardwood cuttings on wetland establishment. Additional plots were established to determine growth and survival of hardwood cuttings of five native willow species. Plant species and percent cover, and willow survival and height were recorded for each plot in June and September of each year following establishment. Water level monitoring was conducted at the site throughout the growing season.

Preliminary results for the site overall indicate a steady increase in plant species richness over time (September 2007 – 64 species, June 2008 – 101 species, and September 2008 – 130 species). Percent plant cover is variable with native species dominance also increasing. Analyses of treatment effects and construction costs are ongoing. Reed canary grass is present, but effectively controlled by spot spraying with glyphosate herbicide. Mean hardwood willow cutting survival in treatment plots after the first year was approximately 65 percent. In the willow species trials, *Salix planifolia* and *S. petiolaris* had the top survival rates at 88 and 84 percent respectively.

Ongoing monitoring and data analysis will help determine the efficacy of the various wetland establishment strategies resulting in more cost effective strategies for creating mitigation wetlands in abandoned gravel pits.

Introduction

Wetland impacts are often an inevitable consequence of road construction. Federal and State "no-net-loss" wetland policies require compensatory mitigation for any unavoidable wetland impacts. A recent report by the Minnesota Board of Water and Soil Resources (BWSR) predicts potential wetland impacts due to public road projects in northeastern Minnesota of approximately 60 hectares annually through the year 2012 (BWSR 2006). This 18 county area still retains more than 80 percent of its pre-European settlement wetland acreage presenting very few opportunities for traditional mitigation such as wetland restoration. Abandoned gravel pits are one of the few remaining areas that can serve as wetland mitigation sites within the impacted watersheds. These mitigation wetlands can potentially be created as an integral part of the road construction process.

For the purposes of this project and to comply with regulations concerning mitigation wetlands, abandoned gravel pits are defined as those depleted of usable material that have no more value for borrow. This includes: 1) recently depleted pits to be used as project specific mitigation with either an exposed water table or no standing water; or 2) pits that have been depleted for some time, but have no standing water or other wetland characteristics. Application for mitigation credit must be made within 10 years after the last day that extraction activities have taken place.

New U.S. Army Corps of Engineers mitigation guidelines (USACOE 2009) state a preference for "in-place" and "in-kind" wetland mitigation, generally meaning compensation within the same watershed with the same wetland type as those being impacted. Mitigation provided in other watersheds and/or with different wetland types are subject to higher compensation ratios that could result in substantially higher costs. To date, most compensatory mitigation wetlands associated with highway construction in Minnesota have been deep marshes or open water ponds, even though most of the impacted wetlands were originally a different type.

The U.S. Trunk Highway 53 reconstruction in northeast Minnesota resulted in approximately 34 hectares of unavoidable wetland impacts. These impacts included fresh meadow (0.6 ha), shrub swamp (11.5 ha), wooded swamp (11.5 ha), bog (10.0 ha), and other wetlands (0.4 ha). This resulted in an abundance of high quality displaced soil that could potentially be used for mitigation wetland creation.

The overall goal of the project is to develop cost effective methods for creating functional mitigation wetlands on abandoned gravel pit sites to compensate for wetland impacts due to road construction. In keeping with the new USACOE mitigation guidelines, the aim is to achieve "in-kind" compensation by creating wetlands of the same type and function as those being disturbed, such as fresh meadow and shrub swamp.

Materials and Methods

The study was conducted at a site located within the U.S. Trunk Highway 53 reconstruction corridor in central St. Louis County in northeastern Minnesota (47°38' N, 92°34' W). The project location was previously an upland home site that was mined for borrow material for the road construction and was also the site for a road connecting the new Highway 53 with the old highway. Two gravel pit basins were excavated, one on each side of this road. In one basin, the goal was to create wooded swamp and bog wetlands, and in the other, fresh meadow and shrub swamp. Due to unexpected flooding on the wooded swamp and bog site, the site required extensive remedial planting and water controls in 2008. Therefore, only the fresh meadow and shrub swamp site will be discussed in this paper. All references to "the site" pertain to the fresh meadow and shrub swamp mitigation site.

Construction

Wetland hydrology at the site was achieved by excavating borrow material to a level below the water table. Approximately 23,000 m^3 of borrow material was removed and used in the road construction leaving a mineral substrate of predominantly loamy sand in the basin. The entire 1.3 hectare site was then covered with a 60 cm layer of organic soil or "muck" salvaged from the road construction (approximately 7,650 m^3). The pH of the muck was around 5.5. The goal was to have a saturated soil with minimal standing water for most of the growing season. Three water table wells were installed at the site to monitor water levels. Due to a wet spring, major site construction was not completed until the end of June 2007.

Experimental Treatments

The goal for the site was to establish vegetation characteristic of fresh meadow and shrub swamp wetlands. Several approaches used to establish wetland vegetation included donor soil applications, direct seeding, and planting of hardwood willow cuttings. To test the various vegetation establishment strategies, a total 10 experimental treatment combinations were applied. These treatments included the following:

1) Donor soil,
2) No donor soil,
3) Wetland temporary seed mix,
4) Wetland temporary seed mix + donor soil,
5) Willow cuttings,
6) Willow cuttings + donor soil,
7) Native sedge/wet meadow seed mix,
8) Native sedge/wet meadow seed mix + donor soil,
9) Willow cuttings + wetland temporary seed mix,
10) Willow cuttings + wetland temporary seed mix + donor soil.

The study was established in a randomized block design with five replications of each treatment combination resulting in a total of 50 – 5 m x 5 m (25 m^2) plots.

Donor Soil

Donor wetland soil applications have been shown to increase plant species richness, percent wetland plant cover, and soil organic matter (Brown and Bedford 1997, Stauffer and Brooks 1997, Johnson and Valppu 2003, McKinstry and Anderson 2005). Where available, donor soil applications generally result in wetland vegetation better adapted to the site.

Displaced donor soil was salvaged from a nearby alder swamp being impacted by the road construction. The alder swamp donor soil was collected with a backhoe and then hauled by truck to the research site and stockpiled. Only the surface 10-15 cm of soil was used as donor to insure an adequate supply of viable seed/diaspores. Because of the wet conditions at the time of construction, the donor soil was transported from stockpiles to the individual plots using a large plastic snowmobile sled pulled behind a tracked ATV. The donor material was spread on the designated plots by hand in a thin layer (~ 2-3 cm) at a rate of approximately 1 m^3 per 25 m^2 plot.

Direct Seeding

Direct seeding of appropriate wetland plant seed mixes can aid native vegetation establishment on restored or created wetlands. Two wetland seed mixes, wetland temporary and native sedge/wet meadow, developed by the Minnesota Department of Transportation and Minnesota Board of Water and Soil Resources (Jacobson 2006) were applied to selected plots in the study.

The wetland temporary seed mix, also known as WT1, consists of 30 % American slough grass (*Beckmannia syzigachne*), 40% annual rye-grass (*Lolium italicum*), and 30% fowl bluegrass (*Poa palustris*). The intended purpose of this temporary seed mix is to provide short-term stabilization of a site while the permanent vegetation establishes from the donor soil seed bank (Jacobson 2006). The wetland temporary seed mix was applied at the recommended rate of 22.4 kg pure live seed per hectare.

The native sedge/wet meadow seed mix (also known as W2) shown in Table 1 contains species from both community types that grow in saturated or moist soil (Jacobson 2006). The mix can be used state-wide. The native sedge/wet meadow seed mix was applied at the recommended rate of 9.0 kg pure live seed per hectare.

Willows

In addition to the trees and shrubs that will likely establish from the seeds, roots, and rhizomes in the donor soil, hardwood willow cuttings were planted at the site. Willows will root readily from dormant hardwood cuttings collected in the winter or early spring and kept in cold storage until planting in mid to late May. Hardwood willow cuttings were collected in late March 2007 west of the town of Cook at a St. Louis County brushland site managed for sharptail grouse habitat. The site had been sheared in the last several years resulting in an abundance of new willow shoots. A total of 500 willow (*Salix petiolaris*) cuttings (each 20 cm in length) were planted at 1 m spacing on the designated plots (25 cuttings per plot). An additional five plots were established with five cuttings each of *S. petiolaris*, *S. bebbiana*, *S. planifolia*, *S. pyrifolia*, and *S. serissima* to determine survival and growth differences between different willow species. Not only are the willow cuttings expected to establish a shrub swamp wetland, but willows have also been shown to reduce reed canary grass invasion (Kim et al. 2006).

Mulch

Minnesota Department of Transportation (Mn/DOT) certified Type 3 weed free straw mulch was spread over the entire wetland site at a rate of approximately 2,250 kg/ha. Spreading was done with a tractor pulled round bale spreader and by hand to ensure adequate coverage. Mulch was spread equally over all research plots, and it was not tested as an experimental treatment.

Monitoring

Along with wetland hydrology, the criteria for successful wetland creation are wetland plant cover, shrub survival, and absence of invasive species. Three water table wells installed on the site were monitored on a biweekly basis throughout the frost free period. Plant surveys to determine percent cover for each plant species were conducted for each 25 m^2 plot in September 2007, June 2008, and September 2008. For plots containing willows, survival and individual plant height was determined in September of 2007 and 2008.

Construction Costs

Construction costs for the fresh meadow and shrub swamp mitigation site were monitored and recorded by the Mn/DOT engineers in cooperation with the contractor KGM Contractors, Inc.

Data Analyses

Statistical analyses were conducted on study data to determine the treatment effects on percent plant cover and species richness for total, native, introduced, seeded, and invasive species. SigmaPlot® 11 software was used to conduct the analyses and graph the results.

Common Name	Scientific Name
American slough grass	*Beckmannia syzigachne*
Fringed brome	*Bromus ciliatus*
Blue joint grass	*Calamagrostis canadensis*
Virginia wild rye	*Elymus virginicus*
Reed manna grass	*Glyceria grandis*
Fowl manna grass	*Glyceria striata*
Fowl bluegrass	*Poa palustris*
Bottlebrush sedge	*Carex comosa*
Porcupine sedge	*Carex hystericina*
Fox sedge	*Carex vulpinoidea*
Slender rush	*Juncus tenuis*
Green bulrush	*Scirpus atrovirens*
Wool grass	*Scirpus cyperinus*
River bulrush	*Scirpus fluviatilis*
Soft-stem bulrush	*Scirpus validus*
Canada anemone	*Anemone canadensis*
Marsh milkweed	*Asclepias incarnata*
Swamp aster	*Aster puniceus*
Flat topped aster	*Aster umbellatus*
Joe pye weed	*Eupatorium maculatum*
Boneset	*Eupatorium perfoliatum*
Grass leaved goldenrod	*Euthamia graminifolia*
Sneezeweed	*Helenium autumnale*
Serrated sunflower	*Helianthus grosseserratus*
Blue flag iris	*Iris versicolor*
Meadow blazingstar	*Liatris ligulistylis*
Great-blue lobelia	*Lobelia siphilitica*
Monkey flower	*Mimulus ringens*
Mountain mint	*Pycnanthemum viginianum*
Giant goldenrod	*Solidago gigantea*
Blue vervain	*Verbena hastata*
Ironweed	*Veronia fasciculata*
Culver's root	*Veronicastrum virginicum*

Table 1. Native sedge/wet meadow seed mix.

Results and Discussion

Overall, vegetative cover is progressing quite well on the fresh meadow and shrub swamp created wetland (Fig. 1). There is almost complete vegetative cover and species richness has steadily increased from 64 species in September 2007 to 130 species in September 2008. The percentage of total species that are native has also increased from 53 percent in September 2007 to 79 percent in September 2008 suggesting succession to a more stable natural state. Continued monitoring will be required to see if this holds true into the future. Invasive species such as reed canary grass (*Phalaris arundinacea*) and narrow leaved cattail (*Typha angustifolia*) were present at the site, but were effectively controlled by hand pulling and spot spraying with glyphosate herbicide.

Water levels at the site were highest in the spring and fall with the lowest levels observed during July and August. Wetland hydrology was maintained for most of the study period.

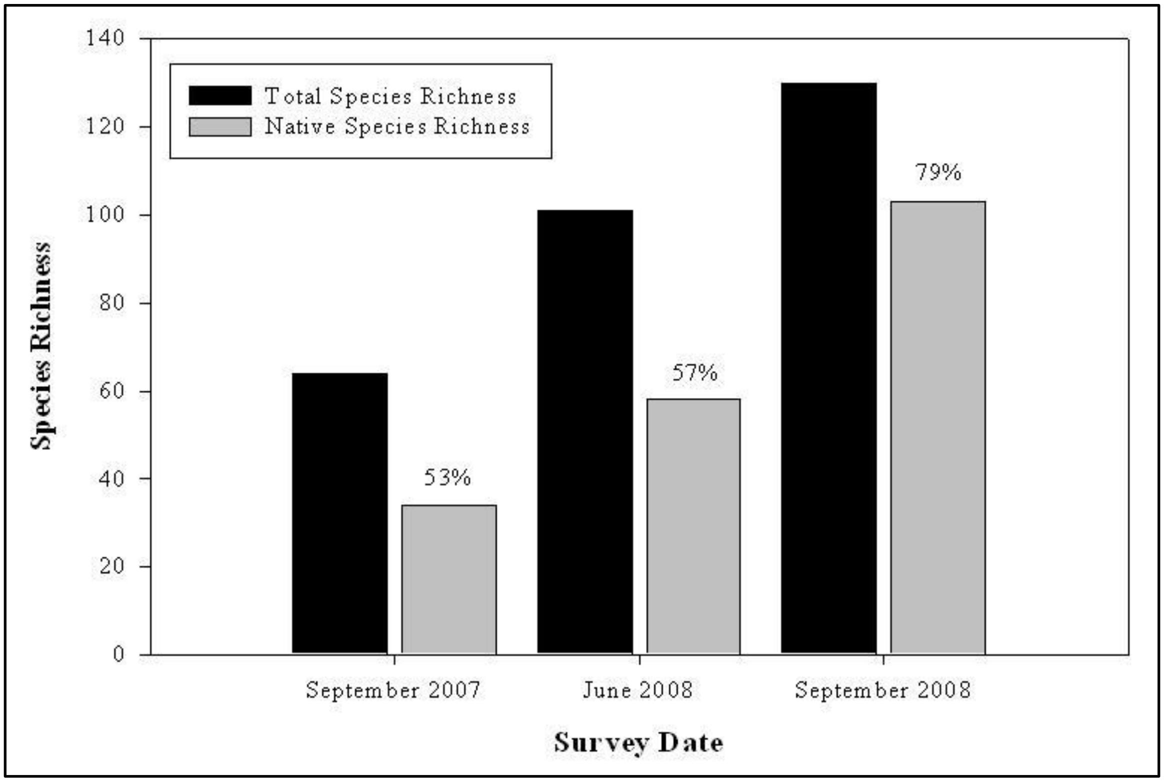

Figure 1. Total and native species richness for fresh meadow/shrub swamp mitigation wetland.

Donor Soil

Donor soil applications significantly increased soil organic matter and potassium on the research plots. There was no significant effect on vegetation; however, plant species present at the donor site appear to be increasing in the study plots. A mediocre vegetation response to donor soil applications could be caused by several factors. First, the 60 cm organic soil layer placed over the entire wetland basin may have had a considerable seed bank in itself, and plants originating from this layer may have overshadowed those originating from the donor soil. Also, the donor soil seed bank may not have been as extensive and viable as believed. The construction schedule did not allow a thorough seed bank evaluation of the actual donor soil collected, but rather we relied on the plant species present at the donor site as an indicator of vegetation potential. Collection depth may also have been a factor. If the donor soil was collected too far below the surface, this may have resulted in reduced viability. Also, because native plants can sometimes take several years to germinate and establish, the effect of donor soil applications may be delayed and not evident until sometime in the future.

Direct Seeding

Direct seeding of the wetland temporary and native sedge/wet meadow seed mixes resulted in no significant effect on percent cover or species richness for total, introduced, seeded, or invasive species. Seed mixes did, however, have a significant effect on percent native plant cover. Plots seeded with the wetland temporary seed mix had a significantly lower percent native plant cover than plots seeded the native sedge/wet meadow seed mix or no seed mix at all (Fig. 2). There was also no significant difference in percent native plant cover between the native sedge/wet meadow seed mix and no seed mix. Therefore, it appears that direct seeding with the mixes used in this study did not significantly enhance native plant cover at this site, and in the case of the wetland temporary mix, actually reduced native plant cover.

Again, the 60 cm organic soil layer applied to the entire wetland basin may have had an adequate seed bank to provide substantial native plant cover without seeding. The detrimental effect of the wetland temporary seed mix may be attributed to the annual rye-grass (*Lolium italicum*) that dominated plots and was quite persistent.

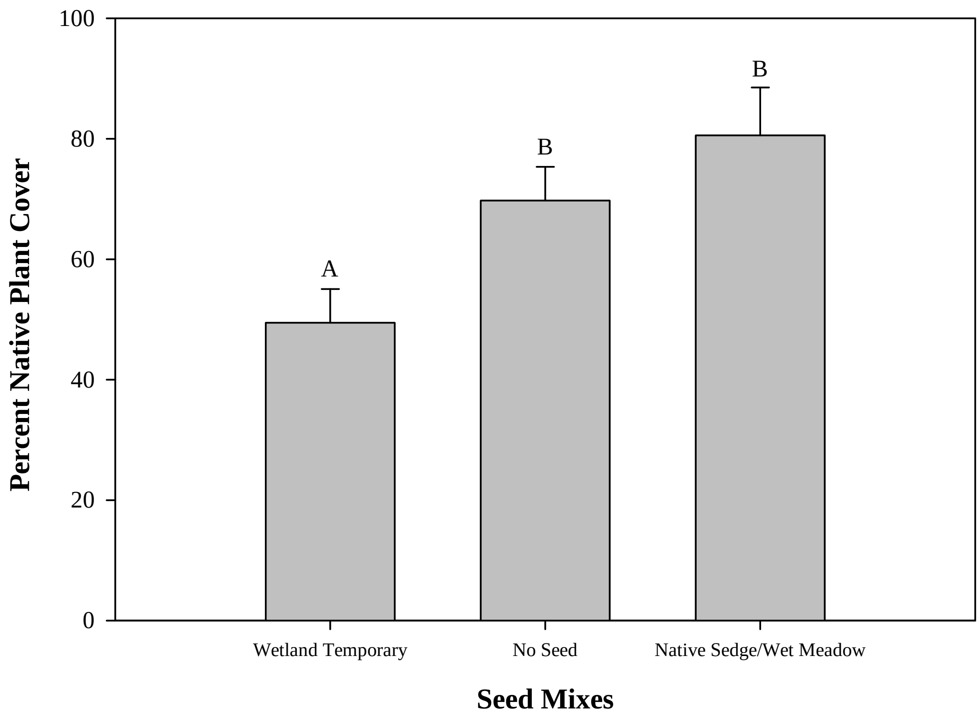

Figure 2. Percent native plant cover for two seed mixes and control. Surveyed September 2008. Means + standard error. n = 20. Means with the same letter are not significantly different at the p = 0.05 level.

Willows

Overall, mean hardwood willow cutting (*Salix petiolaris*) survival in treatment plots surveyed in September 2008 was approximately 65 percent. Mean height was about 35 cm. There was no significant effect of donor soil or seed mix on willow survival or height. Willows had no significant effect on the number or percent cover of invasive species, such as reed canary grass. This condition is to be expected at this time as the willows are still too small to shade out the invasive species.

Mean survival for the five willows in the species trials ranged from 40 to 88 percent as of the September 2008 plant survey (Fig. 3). The only significant difference was between *Salix planifolia* at the highest survival rate and *S. pyrifolia* at the lowest.

Mean height for the five willow species ranged from 20 to 40 centimeters (Fig. 4). *Salix petiolaris* and *S. planifolia* were significantly taller than *S. pyrifolia* and *S. serissima*. *Salix bebbiana* mean height was not significantly different from any of the other species. Based on survival and height growth in this study, the best willow species to use on similar sites in the same geographic area appear to be *S. petiolaris* and *S. planifolia*.

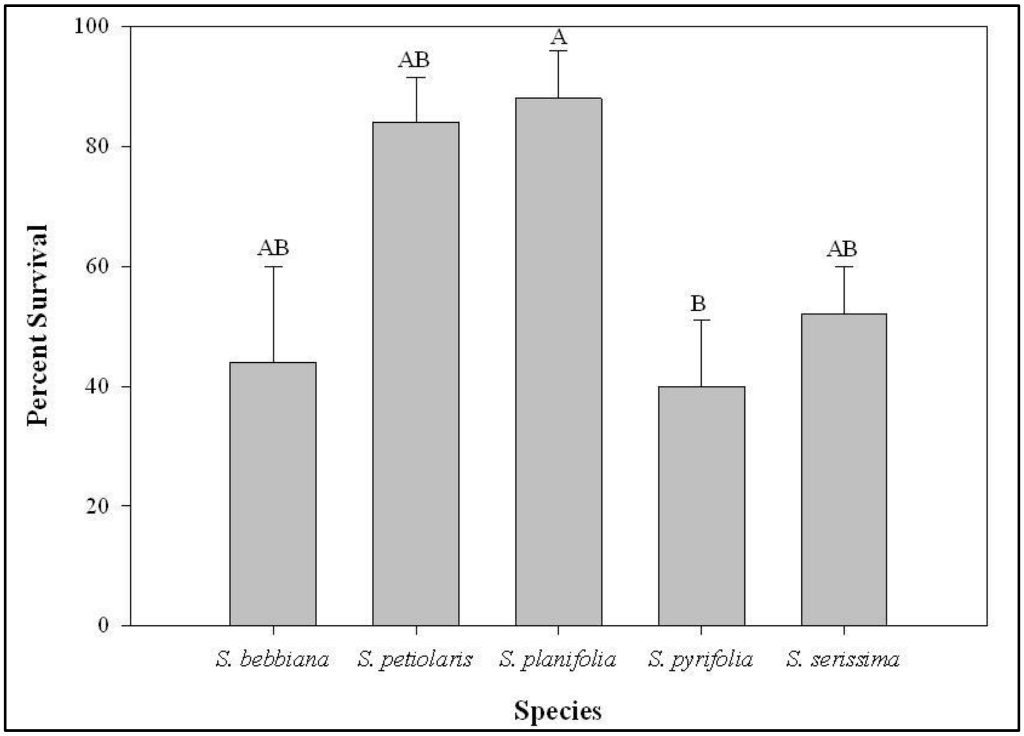

Figure 3. Survival for five *Salix* species. Surveyed September 2008. Means + standard error. n = 5. Means with the same letter are not significantly different at the p = 0.05 level.

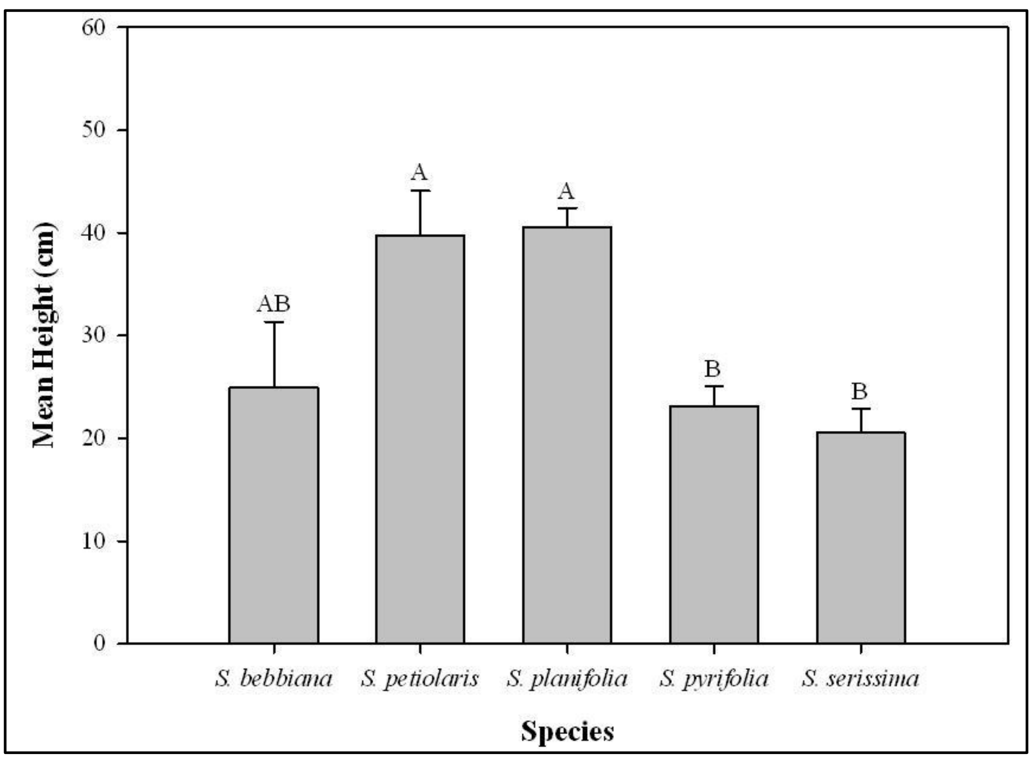

Figure 4. Height for five *Salix* species. Surveyed September 2008. Means + standard error. n = 25. Means with the same letter are not significantly different at the p = 0.05 level.

Construction Costs

Construction costs for the 1.3 hectare mitigation site included: land purchase, clearing and grubbing, borrow excavation, muck excavation, muck placement, and seeding and mulching (Table 2). Excavation and placement costs included hauling. Cost estimates did not include research plot establishment, maintenance, or monitoring costs.

Land purchase	\$15,645/ha	\$20,338
Clearing and grubbing	\$6,030/ha	\$7,839
Borrow excavation	23,750 m^3 @ \$2.06/ m^3	\$48,925
Muck excavation	7,600 m^3 @ \$2.06/ m^3	\$15,656
Muck placement	7,600 m^3 @ \$1.96/ m^3	\$14,896
Seeding and mulching	\$1,606/ha	\$2,088
Total project cost		\$109,742
Total per hectare cost		**\$84,417**

Table 2. Mitigation site construction costs.

Although the construction costs were quite high, it is important to note that mitigation and road construction costs are hard to separate because the mitigation was integrated into the entire road construction project. Much of the mitigation site work would have been done for the road construction anyway. Therefore, it is difficult to get a reliable cost estimate for the mitigation alone. Cost savings were realized on this project because it was a "balanced job", meaning all construction materials were available on site. The cost for the borrow excavated from the mitigation site would have been considerably higher if it had to come from an off-site source. Land costs were also higher at the mitigation site than they would be elsewhere because it was a residential site.

Conclusions

This study to date has shown that there is some potential for creating fresh meadow and shrub swamp mitigation wetlands in abandoned gravel pits. For success, it is important to have a good source of organic soil and be able to maintain wetland hydrology. Additional donor soil had no significant effect on vegetation in this study; however donor soil seed bank testing prior to use may improve results. Based on results to date on this site, the wetland temporary seed mix would not be recommended. The native sedge/wet meadow seed mix showed no significant improvement over no seed mix at this site, but may be beneficial on other sites. Hardwood willow cuttings show good potential for adding a shrub component to mitigation wetlands. *Salix petiolaris* and *S. planifolia* had the best survival and height growth at this site. Continued research is needed to determine the long-term success of these treatments and the overall success of the fresh meadow and shrub swamp mitigation wetland. Cost estimates should also be refined to determine the actual cost of wetland mitigation.

Biographical Sketches

Kurt Johnson is a Research Fellow at the University of Minnesota Duluth, Natural Resources Research Institute. He received his Bachelor of Science degree in Soil Science from North Dakota State University and his Master of Science degree in Environmental Biology from the University of Minnesota Duluth. He has been involved in applied peatland research for 25 years and has conducted peatland and wetland restoration research for the past 10 years.

Gary Walton is the proprietor of a small botanical business, Walton Botany Consulting of Barnum, Minnesota, specializing in the flora of the Western Lake Superior Region since 1995. Clients have included federal and state agencies and private firms.

Andrew Johnson is a Project Engineer with the Minnesota Department of Transportation, District One Office in Virginia, Minnesota. He received his Bachelor of Science degree in Civil Engineering from North Dakota State University. He has 12 years of experience working in road and structural design, and road and bridge construction contract administration with the Minnesota Department of Transportation, Colorado Department of Transportation, and a private consultant.

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Regenerative Stormwater Conveyance (RSC) as an Integrated Approach to Sustainable Stormwater Planning on Linear Projects

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Abstract

Stormwater conveyance practices are grounded in industrial design that neglects integration with system processes, economics, and aesthetics. As a result, the greater volume of runoff from impervious surfaces, coupled with smooth and hardened conveyance systems (e.g., pipes and trapezoidal concrete channels), magnifies and transfers energies to the discharge or outfall. Conventional stormwater outfalls cause erosion, conveyance structures fail, stream channels are degraded, in-stream sedimentation increases the influence of localized erosion upstream and downstream of the outfall, and an increasing spiral of degradation results. Local governments are forced to spend scare public funds on remediation measures. Alternatively, the technique of using stream restoration techniques to create a dependable open channel conveyance with pools and riffle-weir grade controls is a regenerative design since the use of these elements result in a system of physical features, chemical processes, and biological mechanisms that can have dramatic positive feedback effects on the ecology of a drainage area. This approach results in the delivery of low energy storm water discharge, potential volume loss through infiltration and seepage, increased temporary water storage, restoration of lowered groundwater, increases in vernal pool wetland area, improved water quality treatment, improvements in local micro-habitat diversity, and provides a significant aesthetic value. These projects are generally a win-win-win arrangement, as conventional construction practices and materials are more expensive, conventional conveyance provides no environmental benefits and are more difficult to permit, and people generally enjoy the aesthetics associated with a well vegetated channel form when compared to the conventional conveyance alternative.

Introduction

Regenerative Stormwater Conveyance is a large name for an open-channel approach to conveying runoff from developed surfaces. The key element in this name is the term ‘regenerative’, which cannot be applied to grass swales, rock channels, or other features constructed with the singular intent of discharging stormwater from a developed surface to a natural area.

In too many situations, the collection, treatment and conveyance of runoff from developed surfaces results in significant and unanticipated degradation of natural areas. This includes slope erosion at the outfall point, stream channel enlargement at the point of discharge, and other responses to loss of infiltration, increased collection and conveyance efficiencies, and increased volumes of runoff.

For a practice to be characterized as regenerative, it should create resource value. It should function as a part of a larger system. It should be self maintaining and resilient to seasonal and annual variations.

Approach

The major components of the regenerative stormwater conveyance approach include a:

- porous, carbon-rich bed material to filter runoff associated with smaller volume storms and support fungal and microbial metabolism;
- system of riffles and pools to interrupt the development of water depth and velocity along the flow path to maintain non-erosive flows; and
- native plant community that knits the site together, produces native habitat, and contributes carbon to the system.

The porous, carbon-rich bed material is most often an 80:20 blend of sand and shredded hardwood. This bed is designed to have a minimum thickness of three (3) ft, but can be thicker with greater effect. In many cases, severely eroded channel or gullies can be backfilled with this material. This allows stormwater to rapidly infiltrate into the porous media, reducing overland discharge and contributing to loss of runoff volume. In addition, as the stormwater moves through the porous media, the fungal and microbial communities associated with the 20% (by volume) shredded hardwood use nutrients in the water to support their production. This initiates grazing by secondary consumers (e.g., soil micro- and macro-invertebrates) in the porous media, increasing porosity. The establishment of a native plant community reinforces and sustains this process, as roots move through the media, supplying carbon in the form of root material, leaking exudates, and supporting microbial metabolism. Water can only move through this mea slowly, and in addition to losses of this water to the natural geology through increased contact time, each particle in the media retains a coating of water. Additional water slowly seeps through the material until it exits in a cool, clear non-erosive seepage discharge capable of supporting wetlands.

The interruption of the development of runoff water depth and velocity is critical to handling the larger volume runoff events that aren't completely converted to seepage flow in the porous media. The regenerative stormwater conveyance approach uses elements of stream restoration, riffle grade control structures and pools to safely collect and convey larger runoff events. With larger flows, the water moves over a parabolic riffle weir and into a three (3) ft deep pool. The parabolic weir shape doesn't support the development of water depth, as additional water volume results in a greater increase in stream width than depth. This limits shear stresses and transport of bed material. The pool converts the riffle flow into a non-directional turbulent flow. Water exits the pool into the next in a series of repeating series of riffle weirs and pools. The surface discharge from this conveyance system has little ability to erode material, whether discharged onto a floodplain surface or into a stream channel. Depending on the local slope, geology, soils and groundwater, the resulting hydrologic regime can be temporally and spatially complex, supporting a diverse natural community.

Establishing the edges of the flow path and some or all of pool bottom (depending on site conditions and permanence of water) with a native plant community including trees, shrubs, forbs, and floating leaved aquatics contributes functionality to the system. In addition to the replacement of carbon and increase in attachment sites for fungal/microbial production in the porous media bed, the woody root system of the trees and shrubs result in a living mortar for the system. Similarly, the fibrous roots of these plants and the forbs also contribute to structural stability, water and nutrient uptake, and a substrate for microorganisms. Above the ground, these species provide habitat for birds, small mammals, provide shade over the flow path, contribute aesthetically to the landscape, present a natural boundary for maintenance, etc.

These regenerative stormwater conveyance systems do not generally need to mimic the sinuous planform associated with many perennial streams. The horizontally sinuous perennial stream forms in response to stream energy and sediment supply. In the collection and conveyance-oriented regenerative stormwater conveyance system, the repeating riffle grade control to pool sequence limits the development of 'stream' energy. As a result, it is possible to develop a linear regenerative stormwater conveyance system that collects water along a linear feature, like a highway, with non-erosive connections to streams, wetland, and or floodplains in depressional portions of the landscape. As a result, none of the regenerative stormwater conveyance systems need to be large—we generally characterize them as zero or first order man-made stream systems. The riffle grade control structures are generally sized to provide safe-conveyance for the 100-yr storm with shear stresses insufficient to move a 25mm particle.

The use of this approach eliminates or dramatically reduces the need for detention facilities, partly as a result of the in-channel pool storage, but also due to greater roughness, increased concentration time, and water losses through infiltration and evaporation along the flow path. Furthermore, the cost of materials and construction techniques are less expensive than many common practices, including placement of drop inlets, pipes, and headwalls.

In a recent project in Maryland, we replaced approximately 3,500 lf of 15" to 30" concrete pipe and associated infrastructure with a construction cost estimate of approximately $830,000 with a regenerative stormwater conveyance network for a total cost of approximately $405,000, a savings of more than $425,000.

This was accomplished by constructing a linear regenerative stormwater conveyance system within the platted stormwater pipe ROW along the edges of the development roads. In addition to the significant short-term financial benefit, the owner anticipates higher lot purchase prices due to the aesthetics associated with the 'constructed stream' and landscaping and a significant reduction in the projected long-term O&M costs for the system. From the longer term environmental perspective, this system provides better water quality and habitat, no increase in the 100-yr storm discharge relative to the pre-development condition, and is expected to result in higher commitment to environmental stewardship among the public exposed to the project.

Imagine a road system with a ten (10) to 15-ft wide drainage channel which collects, conveys and provides water quantity and quality control treatment for road runoff to a receiving depression, wetland, floodplain and/or stream system. The collected runoff is treated along its flowpath, so the water is a resource suitable for support of groundwater, wetland and stream ecosystem function. The collection, treatment and conveyance system possesses many of the aesthetics of a natural stream channel, all of the material processing capabilities of a natural system, at a significant construction and O&M cost savings.

Summary

The use of regenerative stormwater conveyance, a created stream system for the collection, treatment and conveyance of stormwater runoff, is an innovative best management practice that can be applied to many highway projects with great benefit. The regenerative stormwater conveyance system provides significant natural resource values and ecosystem services important to society, while providing a significant cost benefit and requiring little to no long term maintenance. In addition, the system looks natural and is more attractive to drivers than current practices.

Biographical Sketches

Joe Berg is a restoration ecologist and practice leader with Biohabitats, situated in Baltimore. He graduated with a masters from University of Maryland's Horn Point Lab and has more than 25 years in the environmental consulting field. He has worked in upland forests, headwater streams and wetlands, larger streams and floodplain forests and wetlands, and estuarine habitats. His experience ranges from the assessment of resource presence and condition, mapping of resource distribution, analysis of site conditions supporting restoration, development of restoration concept plans through final construction documents, peer review of restoration plans prepared by others, construction oversight, post construction monitoring, and a variety of other related efforts. Joe is a certified Professional Wetland Scientist (Society of Wetland Scientists) and Certified Senior Ecologist (Ecological Society of America). His work passion is pushing for change in the way the engineering community uses natural resources.

Keith Underwood is a landscape architect that has specialized in understanding, protecting, and restoring bog ecosystems. He is the sole proprietor of Underwood & Associates, a Design-Build firm in Annapolis, Maryland. He has pioneered sand-seepage wetland restoration techniques and has been effective in dramatically increasing the population of Atlantic white cedar in the western shore coastal plain of Maryland.

OREGON DOT'S STORMWATER TREATMENT AND MANAGEMENT PROGRAM: A FRAMEWORK FOR ADAPTING TO CHANGING POLLUTANTS, REGULATIONS, AND PRACTICES

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Abstract

The purpose of the Oregon DOT Stormwater Management Program is to provide a framework that can support effective project delivery and adapt to rapidly changing water quality requirements. The Program provides guidance and technical support to planning, design, construction, and maintenance staff to help ODOT enhance project delivery by achieving compliance with state and federal laws and regulations, promoting species recovery, and improving Oregon's water quality.

Stormwater management has increased in complexity and importance for ODOT, the Federal Highway Administration (FHWA), and the natural resource agencies. In May 2006, ODOT, FHWA, the National Marine Fisheries Service (NMFS), Oregon Department of Environmental Quality (DEQ), the U.S. Fish and Wildlife Service (USFWS), the U.S. Environmental Protection Agency (EPA), and the Oregon Department of Fish and Wildlife (ODFW) embarked on a collaborative venture to promote improved management of stormwater, to ensure that all parties are in alignment on expectations for stormwater management, permitting requirements and to enhance streamlined permitting. The primary product of the effort of the multi-agency working group was Stormwater Treatment Guidance, incorporating the BMP Selection Tool, which provides the framework for addressing highway project water resources issues.

Technical guidance on stormwater was informed and guided by the results of comprehensive literature reviews. Discipline experts were also consulted during the development of the water quality and flow control (water quantity) design storm definitions. The final selections of the design storms and elements of the Best Management Practices (BMP) Selection Tool were consensus decisions by ODOT, FHWA, and the natural resource agencies.

The BMP Selection Tool focuses on selecting preferred (i.e., effective) BMPs for each pollutant of concern. It includes metrics and ratings for treatment effectiveness for pollutants of concern, site suitability and physical constraints, maintenance needs and constraints, and costs. In an attempt to address the issue of varying removal efficiencies reported in the literature, members of the development team agreed that treatment effectiveness be defined in terms of their "primary treatment mechanisms" (or "unit operations or processes") rather than by removal efficiency data reported for specific BMPs. A primary treatment mechanism is that which results in the removal or chemical breakdown of a given compound. The approach identifies a given treatment mechanism that effectively treats a specific target pollutant, and if a BMP employs that treatment mechanism, then by definition the BMP would be considered effective at treating for the pollutants of concern. Ratings of "high, medium, low" are used.

The resulting program easily adapts to changing pollutants of concern, BMP technology, and science. If a new pollutant is identified, the response is easy – simply determine the primary treatment mechanism associated with the target pollutant and assign BMPs that operate via that mechanism. New BMPs can be added in much the same way. When "preferred" BMPs (ratings of "high") are selected for projects in the design stage, the resulting review and permit processing are streamlined.

Introduction

Challenges with Stormwater Management

Stormwater management has increased in complexity and importance for the Oregon Department of Transportation (ODOT), the Federal Highway Administration (FHWA), and the natural resource management agencies. Uncertainty arising from new information about the effects of pollutants on sensitive aquatic species, new pollutants of concern, alternative interpretations of regulations, and emerging structural and non-structural best management practices cause risk to project delivery scope, schedule, and budget.

In Oregon, many resource and regulatory agencies are concerned with stormwater management – often for different resources and under different regulatory drivers. For example, the Oregon Department of Environmental Quality (ODEQ) focuses on state water quality standards and protecting all beneficial uses, whereas the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (FWS) focus on threatened and endangered species and their habitat. These differing focuses pose further challenges for project teams as they enter the permitting stage of a project.

When a new pollutant of concern is identified, the challenges can be immense. When NMFS identified dissolved metals as a key pollutant of concern to ODOT approximately eight years ago, effective BMPs were largely unknown or lacking. Effectiveness data, design criteria, and many other elements were largely unknown. Progress was slow as ODOT, the regulatory community, and others attempted to determine how to address this challenge.

Similar challenges arise when a new structural BMP appears on the market or a regulatory requirement is altered or re-interpreted. Project teams and policy makers struggle to integrate the new pollutant, BMP, or regulation into the existing practice and delivery model.

Framework for Adapting to Change

In May 2006, ODOT, FHWA, and the natural resource management agencies embarked on a collaborative venture to promote improved management of stormwater, to ensure that all parties are in alignment on permitting requirements, and to enhance streamlined permitting (ODOT 2009). The desired outcome was to provide a framework for addressing stormwater that could support delivery of projects within scope, schedule, and budget and adapt to rapidly changing water quality requirements. The natural resource agencies involved were the National Marine Fisheries Service (NMFS), Oregon Department of Environmental Quality (ODEQ), the U.S. Fish and Wildlife Service (USFWS), the U.S. Environmental Protection Agency (EPA), and the Oregon Department of Fish and Wildlife (ODFW).

An important consensus decision of the agencies was that the goal was to ensure the most effective treatment of stormwater achievable for a project, and to not focus on meeting a particular numerical goal. This was based on the understanding that the best that can be done is the best that can be done, and that the pollutant concentrations of concern can change as new studies become available.

The framework, the Stormwater Treatment Guidance (also referred to as the BMP Selection Tool) is transparent and technically based, while documenting the decision-making process. ODOT worked internally with its management, project delivery, and maintenance teams to promote integrated stormwater design and low impact development (LID) in its project development and design process. Under the Program, consideration is given to these approaches at the project development and definition phase and throughout the preliminary and final design phases. The goal for ODOT, which is consistent with the regulatory agencies' position, is to reduce the amount of runoff generated to the extent practicable before relying on engineered stormwater facilities to meet water quality and flow control requirements.

The "traditional" pollutants of concern for roadway projects (e.g., suspended solids, oil and grease, and particulate metals) are addressed in this process, while added focus is given to BMPs that address pollutants of particular concern to the regulatory agencies, namely dissolved metals and polycyclic aromatic hydrocarbons (PAH).

Developed Product

Stormwater Treatment Guidance – BMP Selection Tool

The "Stormwater Treatment Design Process" is a comprehensive process that starts with problem definition and continues through development of the conceptual design of the selected stormwater treatment system. Figure 1 illustrates the conceptual stormwater treatment design process, of which the "BMP Selection Tool" is one part. Through the process, the project delivery team integrates pollution prevention and minimization techniques, LID and other practices to reduce the runoff generated by the project once the project goals and objectives have been defined and site characterization has occurred. The Stormwater Treatment Guidance and the BMP Selection Tool were developed with the recognition that choosing a BMP involves more factors than just effectiveness.

The process includes the development of key decision documents that will be used by ODOT to assist in the permitting process for their projects. One of the key decision documents is the "output" from the BMP Selection Tool. The BMP Selection Tool is used to:

- Evaluate the engineered, post-collection and conveyance facilities used to treat stormwater runoff.
- Document decisions made by ODOT's project development team, which includes water quality specialists, hydraulics engineers, and maintenance staff in a decision support framework.

As Figure 1 illustrates, the BMP Selection Tool is applied after the project objectives and treatment goals have been defined and after the preliminary conceptual site layout and integrated stormwater design considerations have been developed. At this point, the Project Team has already considered appropriate LID options to reduce runoff and the design process is at the point where "end-of-pipe" stormwater treatment options are needed.

The BMP Selection Tool is based on the information from the key references and literature reviewed by the Project Team and a review of other selection processes described in the references and from discussions among the Project Team. The primary references were also used to develop BMP Summary Reports that include the basis for ratings assigned to the metrics in the BMP Selection Tool. Figure 2 shows the components (or metrics) of the selection process, key "check-in" points within the ODOT Project Team and the regulatory agencies, and the "streamlining benefits" of the BMP selection process.

The BMP Selection Tool includes metrics and ratings for treatment effectiveness for pollutants of concern, site suitability and physical constraints, maintenance needs and constraints, and costs. The selection process is generally applied in two steps: (i) BMP screening level; and (ii) treatment train alternatives evaluation. The BMP screening step in the selection process evaluates individual BMPs and is used to identify the most appropriate BMPs for the project. Those BMPs that are screened through are used to develop treatment train alternatives. These alternatives are evaluated further and in more detail with respect to conceptual design layouts for the individual components of the treatment train. The alternatives are evaluated using similar metrics from the screening step. As Figure 2 shows, there are at least two opportunities for the regulatory agencies and the Project Team to discuss documented decisions in the selection process.

"Preferred" BMPs were identified as part of the literature review for treatment effectiveness. Preferred BMPs include infiltration-focused technologies and those BMPs that have a soil-amendment feature. Amending soils in an existing treatment facility may also qualify for "preferred BMP" status. If "preferred" BMPs *for the target pollutants* are feasible and appropriate for the project site, streamlining of the BMP selection process is possible and the formal evaluation and scoring process can be by-passed, as illustrated in Figure 2. While the stormwater/hydraulics engineer still needs to design the system and ensure that the BMP is feasible and meets ODOT's design standards, input and review by the regulatory agencies is minimized and streamlined when the preferred BMPs are selected.

BMPs in the Selection Tool

A focused effort is being placed on updating the types and descriptions of water quality BMPs to be consistent with the stormwater treatment design process developed by the Project Team. The *ODOT Hydraulics Manual Water Quality* chapter has been developed based on input received from the Project Team with respect to new engineered water quality BMPs.

ODOT expects that the class of "standard" BMPs included in the *ODOT Hydraulics Manual* and BMP Selection Tool will change as new technologies are developed and evaluated for their performance to meet ODOT standards.

Other methods of treating stormwater runoff may be proposed but must be evaluated on a project-by-project basis to determine if the proposed treatment methods are adequate. After an experimental BMP or Emerging Technology is approved for use on a specific ODOT project it is placed on an evaluation list. The performance of all BMPs or Emerging Technologies placed on the evaluation list will be assessed for effectiveness, cost and maintenance requirements. Only the approved stormwater management approaches would be added to future revisions to the water quality chapter of the *ODOT Hydraulics Manual*.

In addition to the structural BMPs, there are also non-structural, pollution prevention, and "low impact development" (LID) type BMPs, which essentially act to reduce the amount of pollution generation or pollution-carrying runoff. These BMPs are to be considered prior to the BMP Selection Tool step (see Figure 1).

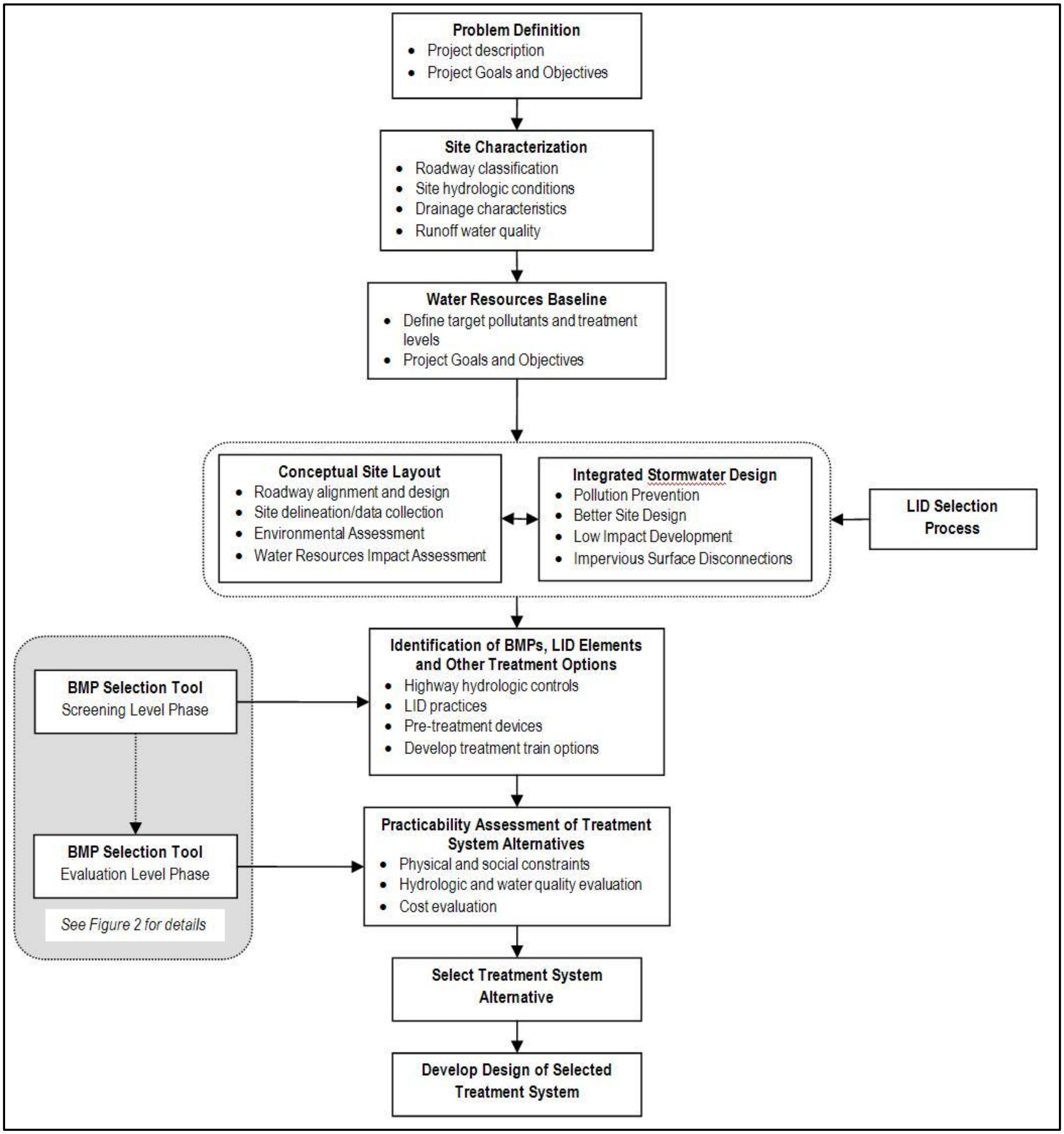

Figure 1. Conceptual Stormwater Treatment Design Process

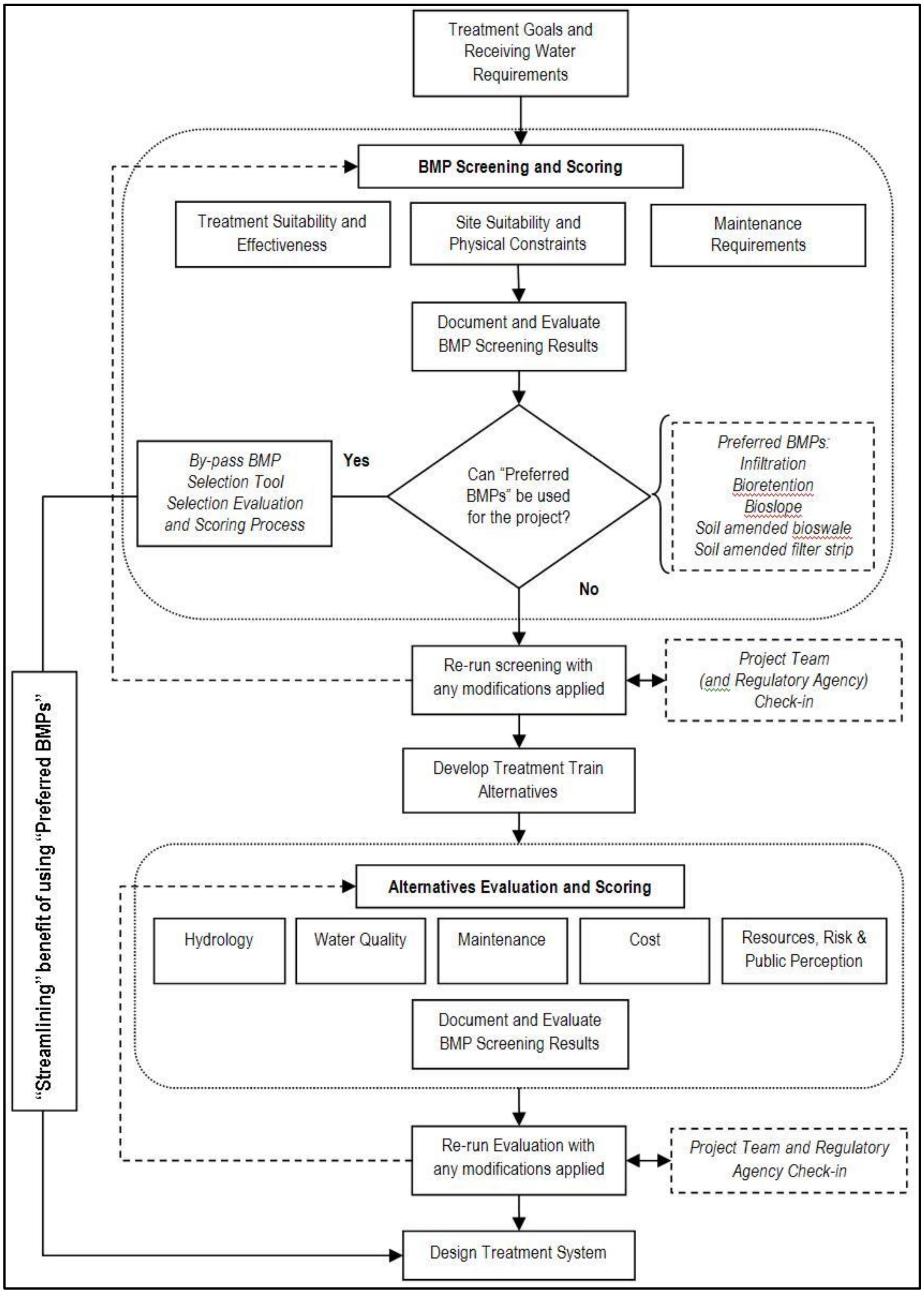

Figure 2. Schematic of BMP Selection Tool

Defining Treatment Effectiveness Using Treatment Mechanisms

The key issue with rating the treatment effectiveness of BMPs in the BMP Selection Tool is the wide range of removal efficiencies reported for the BMPs. One approach is to rate a BMP's treatment effectiveness based on the removal efficiencies reported in literature. However, the reported efficiencies vary greatly (e.g., at times from 20-80 percent removal by concentration). The wide range in removal efficiencies is a result primarily of the varying site conditions, influent concentrations, flow rates, and specific BMP designs. In addition, the number of studies reported in the literature for each BMP is still relatively limited, despite the development of such databases as the *International BMP Database* (http://www.bmpdatabase.org/). Efforts to add to the dataset have so far not resulted in any clear increase in the precision of effectiveness data.

In an attempt to address this issue, ODOT, FHWA, and the regulatory agencies agreed that treatment effectiveness be defined in terms of their "primary treatment mechanisms" rather than by removal efficiency data reported for specific BMPs. Primary treatment mechanism refers to the prevailing unit operations or processes – borrowing the term from the wastewater treatment field – that results in the removal or chemical breakdown of a given compound. The approach defines a given treatment mechanism as effectively treating a specific target pollutant, and if a BMP employs that treatment mechanism, then by definition the BMP would be considered effective at treating for the pollutants of concern. Ratings of "high, medium, low" are used.

Types of Treatment Mechanisms

In general, a limited set of unit processes exist that different BMPs rely on to remove constituents from water. The reality of stormwater treatment is that the more complex unit processes, such as ultraviolet disinfection or chemical precipitation/flocculation, will generally not be used because of the economics of treating such large volumes of water.

The treatment effectiveness of a BMP is essentially related to which processes are actually utilized by the BMP and the ability of the BMP to maximize the process(es). Six primary treatment mechanisms are considered most appropriate for stormwater. The descriptions of these mechanisms are based primarily on information from *NCHRP Report, "Evaluation of Best Management Practices and Low Impact Development for Highway Runoff Control" (2006)*. A brief summary of the primary treatment mechanisms are described below.

- *Hydrologic attenuation* – Hydrologic attenuation achieves pollutant reduction through runoff volume reduction. Infiltration is the primary means of hydrologic attenuation for the purposes of the types of BMPs used in stormwater management. Attenuation reduces the pollutant load discharged to surface waters, but does not necessarily reduce pollutant concentrations. Infiltration includes several different treatment mechanisms. Processes such as sorption, filtration, and microbial degradation occur as runoff infiltrates through the soil matrix.

- *Sedimentation/density separation* – Density separation refers to the unit processes of sedimentation and flotation that are dependent on the density differences between the pollutant and the water to effect removal. Sedimentation is the gravitational settling of particles having a density greater than water. Along with sediment proper, sedimentation removes pollutants attached to the sediment, but is generally ineffective against "dissolved" pollutants. Flotation is similar to gravitational sedimentation except in the opposite direction. Typically, floatable materials such as trash, debris, and hydrocarbons are removed through treatment processes that utilize the location of these pollutants on the water surface for removal.

- *Sorption* – Sorption refers to the individual unit processes of both absorption and adsorption. Absorption is a physical process whereby a substance of one state is incorporated into another substance of a different state (e.g., liquids being absorbed by a solid or gases being absorbed by water). Adsorption is the physiochemical adherence or bonding of ions and molecules (ion exchange) onto the surface of another molecule. In stormwater treatment application, particularly for highway runoff, the primary pollutant types targeted with absorption unit processes are petroleum hydrocarbons, while adsorption processes typically target dissolved metals, nutrients, and organic toxicants such as pesticides and polycyclic aromatic hydrocarbons (PAHs). Different types of filter media may provide either or both of these unit processes.

- *Filtration* – Filtration can encompass a wide range of physical and chemical mechanisms, depending on the filtering media, typically some sand media, natural soil, grassy vegetation, or mixes of chemically active ingredients such as perlite, zeolite, and granular activated carbon. Filtration removes particulate matter either on the surface of the filter or within the pore space of the filter. Filtration such as a sand filter can provide the added benefit of removing stormwater constituents that may be attached to solids such as metals and bacteria. Filtration can also provide opportunities for sorption processes to occur, reducing dissolved and fine suspended constituents. Filtration can often be an effective preliminary treatment for stormwater, by increasing the longevity of downstream BMPs and reducing maintenance frequency.

- *Uptake/Storage* – Uptake and storage refer to the removal of organic and inorganic constituents by plants and microbes through nutrient uptake and bioaccumulation. Nutrient uptake converts required micro- and macro-nutrients into living tissue. In addition to nutrients, various algae and wetland and terrestrial plants accumulate organic and inorganic constituents in excess of their immediate needs (bioaccumulation). The ability of plants to accumulate and store metals varies greatly. Significant metal uptake by plants will not occur unless the appropriate species are selected.

- *Microbially mediated transformation* – Microbial activity promotes or catalyzes redox reactions and transformations including degradation of organic and inorganic pollutants and immobilization of metals. Bacteria, algae, and fungi present in the soil or water column are primarily responsible for the transformations. These transformations can remove dissolved nitrogen species, metals, and simple and complex organic compounds. Soils may be inoculated with desirable microbes to promote specific reactions. Stormwater treatment that incorporates vegetation and or permanent water bodies usually has a diverse microbial population, and it is not possible to optimize conditions for all beneficial species.

Table 1 summarizes the stormwater-related pollutants of concern considered to be effectively removed by each treatment mechanism.

Treatment Mechanism - Target Pollutant Matrix		Mechanism					
		Hydrologic Attenuation (1)	Density Separation	Sorption (chemical activity)	Filtration	Uptake/Storage(2)	Microbial Transformation(3)
Target Pollutant	Sediment/Particulate (suspended solids)	■	■		■		
	Nutrients(4)	■		■		■	■
	Oil and Grease	■	■	■	■		■
	Polycyclic Aromatic Hydrocarbons (PAH)	■	□	■	□	■	■
	Metals (particulate)	■	■		■		
	Metals (dissolved)	■		■	□	□	□

■ = *Treatment mechanism effective for target pollutant removal*

□ = *Depending on chemical activity of filter media*

(1) *Refers to infiltration which is credited for overall pollutant mass load reduction of all target pollutants primarily through volume reduction; pollutant removal is also achived through filtering, sorption, and microbial transformation in the soil column.*

(2) *Dependent on plant species*

(3) *Dependent on types of microbes present (in soil or water column)*

(4) *May not be considered a highway target pollutant, but included for completeness*

Table 1. Treatment Mechanism – Target Pollutant Matrix

Treatment Effectiveness Matrix

Based on information compiled in the BMP Summary Reports, Table 2 relates the treatment mechanisms utilized by each of the BMPs included in the BMP Selection Tool. The table indicates whether the treatment mechanism is a key (or main) pollutant removal mechanism of the BMP, or whether it is a secondary (or “associated”) mechanism.

The lower portion of Table 2 cross references Table 1 with the current list of BMPs to identify which target pollutants are addressed by each BMP. The table indicates whether the BMP has high, moderate, or low capability of removing a target pollutant. The rating is largely a function of whether the BMP employs the key treatment mechanism identified to be effective at removing that particular pollutant. A BMP may be rated moderate or low for a target pollutant if the key treatment mechanism is a secondary process within the BMP. Alternatively, a BMP may be rated high for a target pollutant if at least one key treatment mechanism occurs as part of the BMP treatment process.

In application, this approach indicates that all of the BMPs included in the BMP Selection Tool are considered highly capable of removing particulates and total suspended solids, while infiltration, bioretention, bioslope, and constructed wetlands are the BMPs with high capability to remove dissolved metals. Soil-amended grass swales and filter strips, extended dry detention ponds and wet ponds, proprietary filtration facilities and media filters may also be moderately effective for dissolved metals. Similarly, the matrix can be used to identify which BMPs are considered effective in removing the other target pollutants.

Treatment Mechanism - BMP Matrix		Best Management Practice: Pretreatment		Infiltration				Filtration				Pool-Ponds			Space-constrained or Urban Application			
		Oil Control Facilities (pretreatment)	Sediment Control (pretreatment)	Infiltration pond	Bioretention	Bioslope	Porous Pavement (not stand-alone)	Grass Swale (soil amended)	Filter Strip (soil amended)	Grass Swale (no soil amendment)	Filter Strip (no soil amendment)	Constructed Wetlands	Extended Detention DryPond	Wet Ponds	Wet Vaults	Media Filters (non-proprietary)	Proprietary Separation (pretreatment)	Proprietary Filtration Facilities
Treatment Mechanism	Hydrologic Attenuation			■	■	■	■	□	□	□	□	□	■	□				
	Density Separation (Sedimentation or Flotation)	■	■	□	□	□		□	□	□	□	■	■	■	■		■	
	Sorption	□		□	■	■		■	■	□	□	■	□	□		□	□	■
	Filtration	□	□	■	■	■		■	■	■	■	□	□	□		■	□	■
	Uptake/Storage (1)			□	■	□		□	□	□	□	■	□	□				
	Microbial Transformation (1)			□	■	□		□	□	□	□	■	□	□		□		□
Target Pollutant	Sediment/Particulate (suspended solids)	○	●	●	●	●	○	●	●	●	●	●	●	●	○	●	●	●
	Nutrients			●	●	●	○	○	○	○	○	●	○	○		-		
	Oil and Grease	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●	○
	Polycyclic Aromatic Hydrocarbons (PAH)			●	●	●	○	○	○	○	○	●	○	○		○		
	Metals (particulate)	○	○	●	●	●	○	●	●	●	●	●	●	●	○	●	●	●
	Metals (dissolved)			●	●	●	-	●	●	○	○	●	○	○		○		●

■ = Key treatment mechanism for BMP

□ = Associated treatment mechanism for BMP; dependent on plant species/microbes present

● = High capability to remove target pollutant

○ = Moderate capability to remove target pollutant

\- = Low capability to remove target pollutant

(1) Dependent on types of plant species or microbes (in soil or water column) present

Table 2. Treatment Mechanism-BMP Matrix

Using "treatment mechanisms" (or unit processes) to define a BMP's effectiveness at removing target pollutants circumvents the need to rely strictly on the wide-ranging removal efficiency data for this purpose. ODOT, FHWA, and the regulatory agencies have stated their support in using this approach to define treatment effectiveness of the BMPs in the BMP Selection Tool. It also allows for new BMPs to be easily integrated into the framework.

BMP Selection Tool – Metric Ratings

As noted previously, the BMP Selection Tool includes metrics and ratings for treatment effectiveness for pollutants of concern, site suitability and physical constraints, maintenance needs and constraints, and costs. The current ratings for the BMPs included in the BMP Selection Tool are summarized in Table 3.

The treatment effectiveness ratings are based on the approach described previously. ODOT maintenance staff were consulted to develop the ratings for the maintenance metrics. The site suitability and physical constraints metrics are based on information from the literature review and design criteria in the *ODOT Hydraulics Manual*.

BMP Performance Summary Table*		Best Management Practice																
Rank: ● = high ○ = medium - = low blank = none/not applicable		Pretreatment		Infiltration				Filtration				Pool-Ponds			Space-constrained or Urban Application			
		Oil Control Facilities (pretreatment)	Sediment Control (pretreatment)	Infiltration Pond	Bioretention	Bioslope	Porous Pavement (not stand-alone)	Grass Swale (soil amended)	Filter Strip (soil amended)	Grass Swale (no soil amendement)	Filter Strip (no soil amendment)	Wetlands	Extended Detention Dry Pond	Wet Ponds	Wet Vaults	Media Filters (non-proprietary)	Proprietary Separation Facilities *	Proprietary Filtration Facilities *
Application to Stormwater Management Objectives (1)	Water Quality	-	-	○	●	●	○	●	●	●	●	●	○	○	○	●	●	●
	Channel Protection			●	●	○	●	-	-	-	-	●	●	○	●			
	Peak Discharge			●	●	○	●	-	-	-	-	●	●	●	●	-		
	Recharge			●	○	●	●	-	-	-	-	-	-	-				
Receiving Water Application (2)	Drinking Water Protection	-	-	-	○	○	-	○	○	○	○	●	○	●	●	●	●	●
	Aquatic Species Protection	-	-	●	○	●	●	○	○	○	○	●	○	○	○	○	-	-
	Water Quality Protection	-	-	●	●	●	●	○	○	○	○	●	○	●	-	○	●	●
	Wetlands Protection	-	-	○	○	●	○	○	○	○	○	●	○	●	-	-	-	-
	Sensitive Lakes Protection	-	-	○	○	●	○	-	-	-	-	○	○	●	-	-	-	-
Water Quality - Treatment Effectiveness (3)	Sediments (TSS)	○	●	●	●	●	○	●	●	●	●	●	●	●	○	●	●	●
	Nutrients:			●	●	●	○	○	○	○	○	●	○	○		-		
	Oil and Grease	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●	○
	Polycyclic Aromatic Hydrocarbons			●	●	●	○	○	○	○	○	●	○	○		○		
	Metals (particulate)	○	○	●	●	●	○	●	●	●	●	●	●	●	○	●	●	●
	Metals (dissolved)			●	●	●	-	●	●	○	○	●	○	○		○		●
Rank: ↑ = large ↔ = medium ↓ = small blank = none/not applicable																		
Physical Site Suitability (4)	Surface Area (large is greater area)	↓	↓	↔	↓	↔	↓	↔	↔	↔	↔	↑	↑	↑	↓	↔	↓	↓
	Drainage Area (large is greater area)	↓	↓	↑	↓	↔	↓	↔	↔	↔	↔	↑	↑	↑	↓	↓	↓	↓
	Soil Infiltration Rate (large is higher rate)			↑	↑	↑	↑	↔	↔	↔	↔	↓	↓	↓				
	Slope (gradient) (large is steeper)			↓	↔	↓	↓	↔	↔	↔	↔	↓	↔	↓		↓		
	Groundwater depth (large is deeper)			↔	↔	↔	↔	↔	↔	↔	↔	↑	↑	↑		↑		
	Confined space/safety (large is greater required)	↑	↔	↓	↓	TBD	TBD	↓	↓	↓	↓	↓	↔	↔	↑	↓	↑	↑
	Dependency on Soil Characteristics		↓	↑	↑	↔	↑	↔	↔	↔	↔	↑	↑	↑				
Rank: H = High M = Medium L = Low blank = none/not applicable																		
Maintenance Factors	Maintenance level of effort	M	M+	M+	M	TBD	TBD	L	L	L	L	L	M	M+	H	M	H+	H
	Frequency of maintenance	M	M+	M+	M+	TBD	TBD	L	L	L	L	L	M	M+	H	M	H	H
	Reliability/durability (appurtenances)	M	L	L	L	TBD	TBD	L	L	L	L	L	L	M+	H	L	H	H
	Need for "specialized" equipment	M	L	H	L	TBD	TBD	L	L	L	L	L	L	M	H	L	H+	H
	O&M Cost (including waste disposal)	H	M+	H	M	TBD	TBD	L	L	L	L	H	M+	H	H	M	H+	H
Rank: "+" = Favorable "/" = Neutral "-" = Unfavorable blank = none/not applicable																		
Non-Design Factors (5)	Community Acceptance	/	/	/	+	+	/	/	/	/	/	+	/	/	/	/	/	/
	Construction Cost	/	/	-	/	/	-	+	+	+	+	-	-	-	-	/	/	/
	Wildlife Habitat			/	+	/		/	/	/	/	+	/	+				

Table 3. BMP Performance Summary Table

Regulatory Implications

The products of the collaborative, multi-agency working group have been incorporated into regulatory evaluations of projects. The criteria and BMP evaluations have been used to define stormwater treatment goals, and because all the regulatory agencies were involved, the goals and expectations are essentially identical for each agency. Specifically, the water quality design storm, the flow control design storms, and the preferred BMPs are conditions of a programmatic Biological Opinion issued by NMFS. For Clean Water Act Section 401 water quality certification, the same criteria are sufficient for stormwater management plan approval. When completely meeting the water quality goals are not possible, the BMP Selection tool and selection process provide consistent documentation of how and why treatment decisions were made.

By having consistent stormwater treatment goals and criteria, projects are afforded improved certainty in scope, schedule and budget. Streamlining permitting by the use of the process and tools benefits both ODOT and the regulatory agencies by increasing certainty and reducing the time spend on review and negotiation.

Conclusion

The Stormwater Treatment Guidance and supporting tools developed by the multi-agency collaborative effort provide a consistent and well documented process for selecting the best achievable treatment of highway runoff for a given project and location. The program and the guidance are easily adaptable to changing pollutants of concern and new treatment approaches. New pollutants are addressed by identifying effective primary treatment mechanisms and BMPs that utilize those mechanisms. New BMPs are evaluated based on their incorporation of the primary treatment mechanisms. Assigned effectiveness levels and other metrics can be adjusted as new information becomes available.

By using collaboratively agreed upon BMP metrics, evaluation and selection procedures, regulatory assessment of a project is greatly eased. Using preferred BMPs assures near immediate regulatory approval, while use of the BMP Selection Tool and selection process result in streamlined regulatory review and permit processing.

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Biographical Sketches

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ARBOREAL MAMMALS USE AN AERIAL ROPE BRIDGE TO CROSS A MAJOR HIGHWAY

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Abstract

Roads and other linear infrastructure exert a myriad of negative effects on adjacent landscapes, populations and individuals. Fauna are particularly impacted, with increased rates of mortality, reduced or modified movement patterns, changes to amount, quality and arrangement of habitat. In our study, rope bridges suspended at the tree-canopy level from poles were used to restore connectivity for arboreal species across a major dual-carriageway highway in south-east Australia. Previous radiotracking and genetic studies quantified the extent of the barrier effect prior to mitigation, and mitigation was implemented at the sites exhibiting the greatest barrier effect. In less than two years since installation, we recorded complete crossings by five species, including the endangered Squirrel Glider *Petaurus norfolcensis* and Brush-tailed Phascogale *Phascogale tapoatafa*. Other species using the canopy bridges included the Common Brushtail Possum *Trichosurus vulpecula* and Common Ringtail Possum *Pseudocheirus peregrinus.* We identified regular usage by certain individuals based on identification of unique ear markings. The next stage of the research is to measure gene flow and assess effectiveness of the structures at improving population viability.

Introduction

The long-term viability of wildlife populations is dependent on the ability of individuals to move freely throughout the landscape (Bennett 1991; Forman and Alexander 1998). Habitat connectivity is essential to provide access to critical resources such as food, shelter and mates. In disturbed environments habitat linkages and corridors allow the dispersal and facilitate gene flow between sub-populations (Bennett 1999). Roads subdivide habitat patches, disrupting all of these vital ecological processes. The width of the road zone, traffic volume, vehicle related mortality and road avoidance can result in the creation of functional and behavioural barriers to the movement of many species (Gerlach and Musolf 2000; Goosem 2001; McGregor *et al.* 2008; Oxley *et al.* 1974; Riley *et al.* 2006) This barrier effect ultimately results in smaller, isolated sub-populations with an increased risk of extinction (Fahrig 2003; Goosem 2007)

Wildlife crossing structures are being increasingly used to mitigate the barrier and mortality impacts of roads on fauna (Forman and Alexander 1998; van der Ree *et al.* 2007). Underpasses (e.g. culverts tunnels and pipes) and overpasses, (e.g. land-bridges, canopy bridges and gliding poles) aim to increase road permeability, gene flow and thus population viability, by providing the safe-passage of fauna across roads. Many studies have documented increase in animal movement across the road barrier through observations of use (Bond and Jones 2008a; Clevenger *et al.* 2001; Dodd *et al.* 2004; Mata *et al.* 2005; Ng *et al.* 2004a) Taylor and Goldingay (2003), yet very few studies have quantified an increase in the viability and survival of wildlife populations as a result of mitigation (Mansergh and Scotts 1989; van der Ree *et al.* in press). There is also a notable absence of long-term monitoring of wildlife populations prior to barrier mitigation occurring. Consequently, the placement of many crossing structures generally lack a strong ecological basis (Bissonette and Adair 2008) and as such conclusions regarding effectiveness of these structures are limited.

To date, the primary focus of research and monitoring of wildlife crossing structures and other mitigation techniques has been on terrestrial mammals, amphibians and reptiles. However, there is little knowledge on the impacts of roads on arboreal mammals. The barrier effect of roads on arboreal mammals is likely to be significant, given they are often limited in their ability to cross large gaps in canopy cover (Laurance and Laurance 1999; Smith and Person 2007; van der Ree 2006).

Aerial canopy bridges and gliding poles have been trialed in North America, Canada, Britain, Malaysia and Australia to provide connectivity for arboreal mammals across roads although literature documenting the use and effectiveness of these structures is scarce (Ball and Goldingay 2008; Goosem *et al.* 2006). Research in Australia has documented the successful use of aerial canopy bridges to provide connectivity over narrow rainforest roads for arboreal mammals, including pre- and post-mitigation population monitoring (Goosem *et al.* 2006). Monitoring on similar structures across north-eastern Australia is currently underway.

In south-eastern Australia a long term research project was undertaken to evaluate the barrier impact of a major highway on arboreal mammals in remnant linear habitat. First, this research aimed to quantify the extent to which major roads are a barrier to the movement and dispersal of a threatened gliding species, the Squirrel Glider (*Petaurus norfolcensis*), and a common possum species, the Common Brushtail Possum (*Trichosurus vupecula*). Second, upon identification of a barrier to movement this research aimed to assess the effectiveness of structures and road designs intended to mitigate this effect.

Squirrel Gliders travel by gliding from tree to tree and rarely venture to the ground (van der Ree 2002). The average glide distance is 30 – 40 m with a maximum glide capability of 70 m (van der Ree *et al.* 2004), which is often less than the distance required to cross treeless gaps across roads. The road crossing behaviour of Squirrel Gliders across a dual-carriage highway was investigated using radiotracking and genetic studies (Cesarini *et al.* in review). Both methods demonstrated that roads influence the movement of Squirrel Gliders and that the presence of tall trees in the centre median facilitated crossing attempts by Squirrel Gliders at similar rates to control sites, while sites without tall trees in the median acted as a barrier to movement. Radiotracking of Common Brushtail Possums showed similar trends, with no animals detected crossing the highway in the absence of tall trees in the centre median (Gulle, unpublished data). Furthermore, estimations of the annual survival rate of Squirrel Glider populations living alongside the highway were 60% lower than those observed in populations along unsealed local roads (McCall *et al.* in review).

The identification of the barrier impact of the highway resulted in the installation of canopy bridges at two sites. The aim of these structures was to increase population viability by facilitating the movement of possum and glider species across the highway. This paper details the observed usage patterns of these canopy bridges since their installation in mid-2007.

Methods

Site Description

The study was conducted in rural south-eastern Australia where, due to extensive clearing for agricultural purposes, less than 5% of the original (pre-European) tree cover remains. The majority of this remnant vegetation exists as a matrix of narrow linear strips (10 – 30m wide) of mature woodland vegetation along rural roads, creeks and pasture boundaries. The canopy is dominated by Grey Box (*Eucalyptus macrocarpa*), River Red Gum (*E. camaldulensis*) and Blakely's Red Gum (*E. blakelyi*), with a mid-storey of Golden Wattle (*Acacia pycnantha*) and an understorey of native and introduced grasses. The remaining landscape is dominated by cleared agricultural land and rural urban communities.

The Hume Highway is the major highway between Melbourne and Sydney, the two largest cities in south-east Australia. During the 1970-80's the highway in Victoria was upgraded to dual carriage-way, increasing the average width of the road corridor to approximately 70m. The average, daily traffic volume is approximately 10,000 vehicles, with 25% of traffic occurring between 10:00pm and 5:00am, when native mammal species are most active (VicRoads, unpub data). The speed limit varies between 100 – 110 km/h along the length of the highway.

A canopy bridge was constructed at two sites; Detour Rd, near the town of Longwood, and at Cemetery Rd, Violet Town. At each site a woodland corridor along a secondary rural road is intersected by the highway. These corridors support several possum and glider species, including studied populations of the Squirrel Glider (Cesarini et al, in review) and Common Brushtail Possum (Gulle, unpub.). Both sites lacked the presence of tall trees in the centre median which can facilitate road crossing by possums and gliders (Cesarini, in review, Gulle, unpub).

Bridge Design and Installation

The canopy bridges were installed in July, 2007. Each bridge is approximately 70 m in length and 50 cm wide, constructed of UV stabilised marine-grade rope in a flat lattice-work configuration (i.e. analogous to a rope ladder laid horizontally). The canopy bridge is suspended from two timber poles, each approximately 6 – 12 m tall, depending on the local topography (Figure 1). The height of the canopy bridge above the road surface varies depending on the road profile, but is a minimum of six metres at its lowest point. Single strands of rope extend from the timber poles into the canopy of adjacent trees to facilitate access by arboreal mammals (feeder ropes – see Fig. 1).


Figure 1. Canopy bridge spanning dual-carriage Hume Highway, Victoria.
Photo on right shows "feeder" ropes, connecting the end of the canopy bridge to adjacent trees.

Fauna Monitoring

Remotely triggered infrared cameras (Faunatech) were installed at each end of each rope ladder approximately one month after the bridges were constructed (August 2007). The Olympus cameras were mounted directly to the support poles and powered by a 12 V battery kept charged by a solar panel. Two active infra-red beam sensors were positioned on the canopy bridge approximately one and four metres from each camera. The sensors detected an animal's movement across the bridge, triggering the camera to take a series of five consecutive photos each 3 – 5 seconds apart. This allowed for an entire sequence of the animals crossing behaviour to be recorded. All photos were time and date stamped and stored on a memory card with a capacity of approximately 600 image files.

Image files were transferred from the memory card directly to a laptop computer via USB connection, and were downloaded approximately fortnightly. At each download we also searched for dead animals on the ground within a 50 m radius of each bridge. Animals may have died after falling off the bridge and colliding with a vehicle or after failed predation attempts by owls.

Data Analysis

All photos were examined for the presence of animal activity and the time, date, and direction of crossing sequence of images showing an animal's behaviour was recorded. Three types of crossing attempts were identified; confirmed complete crossings, likely complete crossings, and partial crossings. In confirmed complete crossings (confirmed crossings) an animal was detected beginning the crossing through one camera, and completing the crossing through the camera on the opposite side of the bridge. Likely complete crossings (likely crossings) were only recorded by one camera (usually due to a malfunction of the opposite camera), either as the animal entered or exited the bridge. A partial crossing was recorded when an animal was observed venturing part way onto the bridge, but is seen returning and leaving the bridge without crossing to the other side.

Calculation of Rate of Crossing

The rate of crossing was standardised to account for variation in the number of nights when one or both cameras were operational. We converted the number of detections into a rate of crossing per night based on the number of nights that one (for likely crossings) or both (for confirmed crossings) cameras were functional. The rate of partial crossings was based on the number of nights one or both of the cameras were operational. In other words, if all cameras were functional 100% of the time, we would expect the total number of complete crossings to be equal to the combined total of likely and confirmed crossings. The number of partial crossings would remain unchanged.

Results

Operation Time

Images from the canopy bridges were collected from the 13th August, 2007 - 29th May, 2009. During this period, not all cameras were operational for the same length of time. False triggering due to heavy rain, debris or the presence of spiders and webs around the sensors often resulted in the memory card reaching its capacity at a faster rate than expected. Additionally, in late 2008 the north-bound cameras at both canopy bridges malfunctioned and were removed for repairs, leaving only a single functioning camera at each site. This prevented us from confirming complete crossings during this period, as both cameras needed to be operational simultaneously.

The Violet Town canopy bridge had much higher capacity for confirming complete crossings than at Longwood, with both cameras simultaneously operational 38% and 9% of the time, respectively (Table 1). This was due to a much higher rate of false triggering at the Longwood canopy bridge.

	Violet Town		**Longwood**	
	Nights operational	%	Nights operational	%
No cameras	113	17.3	163	24.9
One cameras	293	44.7	433	66.1
Both cameras	249	38.0	59	9.0

Table 1. Number and percentage of operational nights for cameras at Violet Town and Longwood rope bridges, between 13th August, 2007 and 29th May, 2009 (*n* = 655)

Use by Fauna

Arboreal mammals were detected using the canopy bridges on 633 occasions (Figure 2). The Squirrel Glider, Common Ringtail Possum (*Pseudocheirus peregrinus*), Common Brushtail Possum and Brush-tailed Phascogale (*Phascogale tapoatafa*) were all observed using one or both of the canopy bridges to varying degrees (Table 2). Non-target species observed included two species of reptile, the marbled gecko (*Christinus marmoratus*) and lace-monitor (*Varanus varius*), each detected on a single occasion, as well as various species of bird. At both bridges, multiple species were observed in the same night, often within the same hour, indicating use of the bridge is non-exclusive.

Figure 2. Infrared-triggered digital camera photographs of the Squirrel Glider (left), Common Brushtail Possums (centre) and Common Ringtail Possum with young (right) using a 70 m canopy bridge spanning a dual-carriage highway.

	Confirmed Crossings	Likely Crossings	Partial Crossings	Total
Squirrel Glider	8	304	17	329
Common Ringtail Possum	67	106	81	254
Common Brushtail Possum	0	30	18	48
Brush-tailed Phascogale	0	1	1	2

Table 2. Number of confirmed, likely and partial crossings occurring for each mammal species using the canopy bridges from 13th August, 2007 to 29th May, 2009.

Squirrel Gliders were the most frequently detected species using the canopy bridges with 0.026 confirmed and 0.419 likely crossings completed per night (Figure 3). However, detection levels differed greatly between sites. Complete crossings were only detected at the Longwood site with only four partial crossings observed at Violet Town.

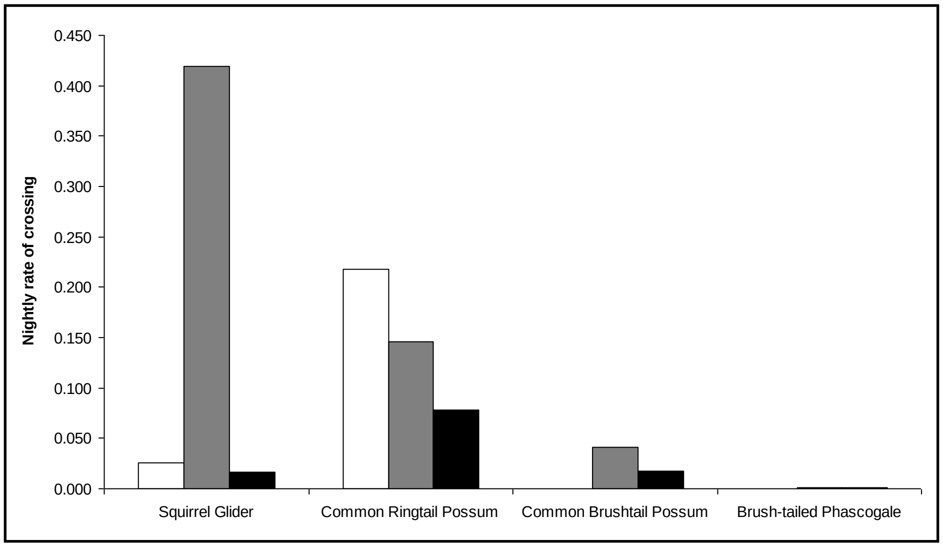

Figure 3. Overall rate of crossing for each crossing type and species using the canopy bridges from 13th August, 2007 – 29th May, 2009. White bars represent confirmed crossings, grey are likely crossings, and black bars represent to partial crossings.

In some photos individual Squirrel Gliders could be identified by ear notches given during mark-recapture surveys at the sites. From these marks multiple individuals of both sexes could be identified regularly crossing the canopy bridge. However, ear markings were not always clearly visible, so it was not possible to accurately track the usage patterns of individual animals. Crossing attempts by Squirrel Gliders originated from both sides of the highway. The time taken to complete a confirmed crossing ranged from one to seven minutes, with a mean time of three minutes.

The Common Ringtail Possum was detected on 254 occasions (Table 2), but only at the Violet Town canopy bridge. Rates of crossings were high, with 0.218 confirmed and 0.146 likely crossings per night (Figure 3). Confirmed crossings were completed in an average of 4.6 minutes (ranging from 1 – 24 minutes) and originated from both sides of the highway. It was not possible to distinguish between individuals, although observations of animal size suggest crossings by multiple animals have occurred. On several occasions, females with one or more back young were also observed making complete crossings.

Crossing activity by the Common Brushtail Possum was generally low with only 0.041 likely and 0.017 partial crossing detected per night (Figure 3). All crossing attempts at Violet Town originated from the south bound verge of the highway, while crossings at Longwood originated from both sides of the highway. As no confirmed crossings were recorded time taken for Common Brushtail Possums to make a complete crossing could not be determined.

The Brush-tailed Phascogale was the least commonly observed species using the canopy bridge and was only detected at the Longwood site on two occasions. The first observation of this species was a partial crossing in March 2009, and later as a likely crossing in May 2009. This is reflected in very low overall rates of crossing, with 0.002 likely and 0.002 partial crossings per night. Both the partial and likely crossing originated from the south bound verge of the highway.

Change in Usage Patterns over Time

Of the three mammal species detected using the Violet Town canopy bridge, all were first detected within 5 months of installation (Table 3). In contrast, no mammal activity was detected at the Longwood canopy bridge until April, 2008, almost a year after construction.

Site	Squirrel Glider	Common Ringtail Possum	Common Brushtail Possum	Brush-tailed Phascogale
Violet Town	3 months	3 months	5 months	-
Longwood	10 months	-	17 months	20 months

Table 3. Time taken for arboreal mammal species to first use the canopy bridges at Violet Town and Longwood sites.

Squirrel Gliders showed an overall increase in detection rates over time, with a steady increase in crossing rates occurring from June 2008 (Figure 4). However, usage patterns differed greatly between sites. Squirrel Gliders showed an initial interest in exploring the canopy bridge at Violet Town through infrequent partial crossings but were not detected making a complete crossing, and no gliders have been observed since April, 2008. In contrast, Squirrel Gliders were not observed at Longwood until almost a year after construction (Table 3), initially undertaking only a few partial crossings (0.04 partial crossings per night). Within six months of the first detection, Squirrel Glider activity had increased to 0.98 likely crossings per night (Figure 4). A similar level of likely crossings has been recorded since one of the cameras on this bridge was removed for repairs in December, 2008, suggesting the rate of complete crossings has been maintained.

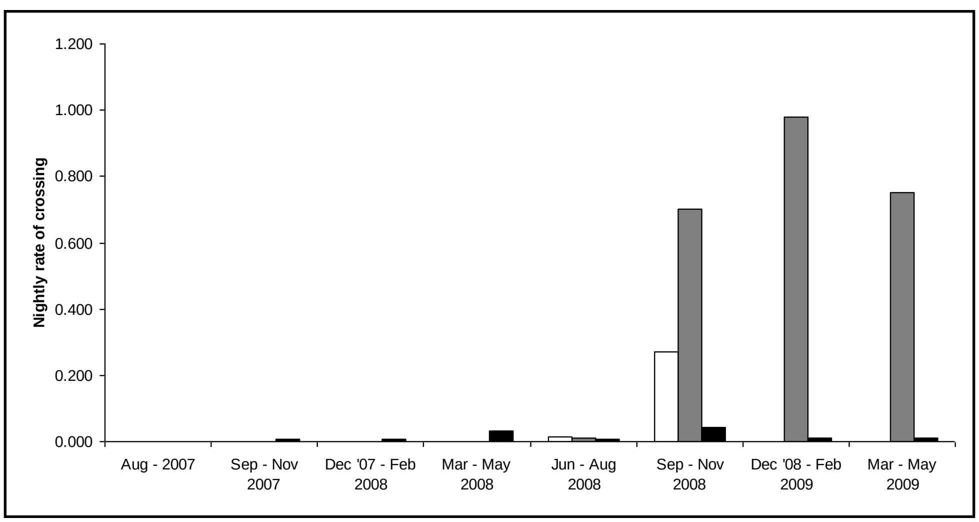

Figure 4. Rate of crossing over time for the Squirrel Glider (*Petaurus norfolcensis*) using both canopy bridges between 13th August, 2007 and 29th May, 2009. White bars represent confirmed crossings, grey represent likely crossings, and black bars represent partial crossings.

The Common Ringtail Possum was the first species to utilise the canopy bridge, making complete crossings within a few months of construction (Table 3). While the Common Ringtail Possum showed high crossing rates from September 2007 to May 2008 (>0.250 confirmed crossings per night) the rate of detection has declined markedly since September 2008 (Figure 5). The time taken for Common Brushtail Possum to first utilise the canopy bridges differed between sites (Table 3). Rates of crossing increased over time, with the highest rates of crossing observed during the warmer months of December to February (Figure 6). Use of the canopy bridges by Brush-tailed Phascogales was rare and they were not detected until March, 2009, over a year after construction. Although infrequent, crossings by the Brush-tailed Phascogale also appeared to follow seasonal trends, with two crossing attempts coinciding with the start of the breeding season.

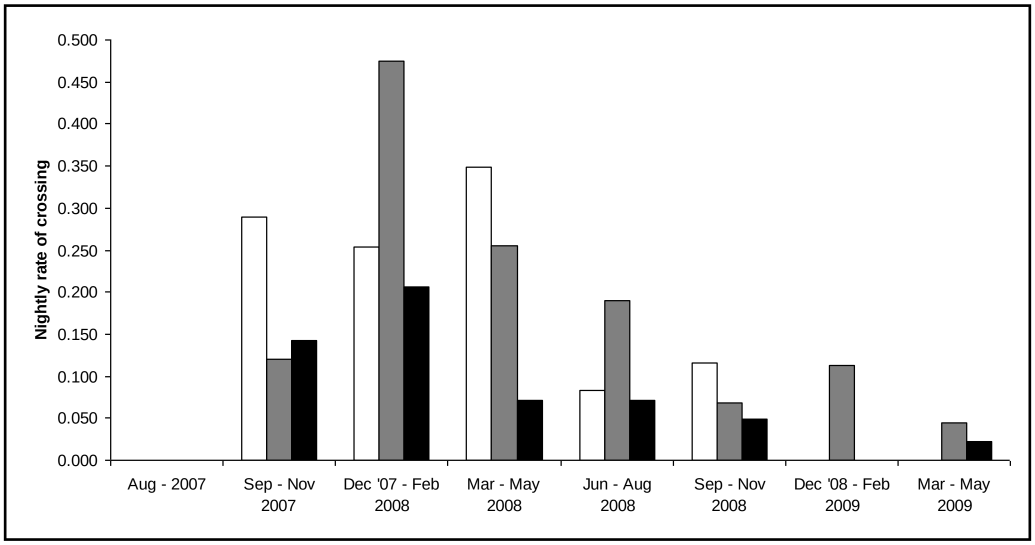

Figure 5. Rate of crossing over time for the Common Ringtail Possum (*Psuedocheirus peregrinus*) using the canopy bridges between 13th August, 2007 and 29th May, 2009. White bars represent confirmed crossings, grey represent likely crossings, and black bars represent partial crossings.

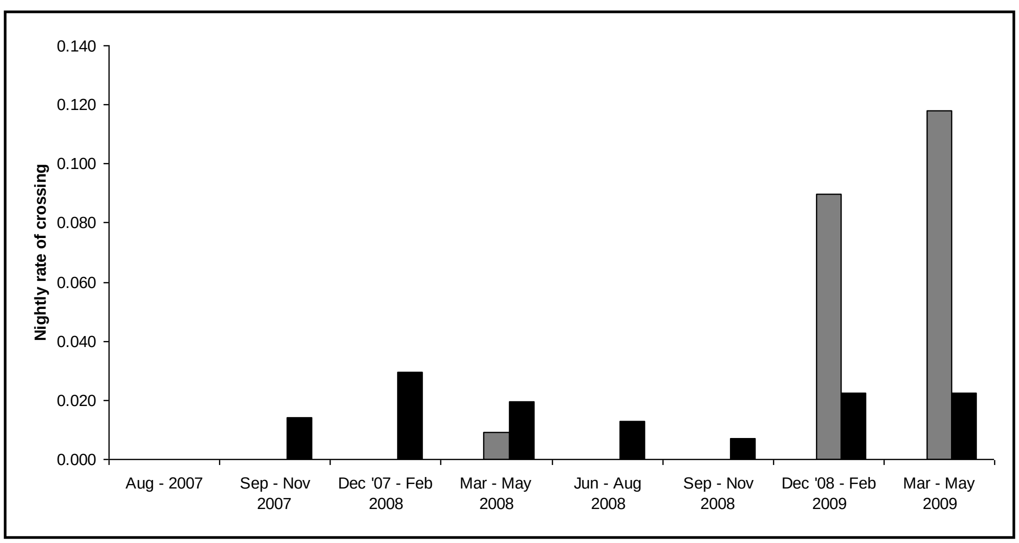

Figure 6. Rate of crossing over time for the Common Brushtail Possum (*Trichosurus vulpecula*) using the canopy bridges between 13th August, 2007 and 29th May, 2009. White bars represent confirmed crossings, grey represent likely crossings, and black bars represent partial crossings.

Discussion

The barrier effect is one of the most significant impacts of roads on fauna (Forman *et al.* 2002). Attempts to mitigate this are an increasing area of ecological research, although research on arboreal species is rare. This study demonstrates the successful use of a 70 m canopy bridge by several species of arboreal mammal to cross a major highway. Our findings suggest that canopy bridges can provide a multispecies approach to mitigating the barrier impact of roads on arboreal mammals.

The species detected exhibit varying degrees of arbroeality and different population dynamics, suggesting that canopy bridges may be useful for arboreal species elsewhere. We also observed crossings by two species of conservation concern, the Squirrel Glider and the Brush-tailed Phascogale. Brush-tailed Phascogales occur at low population densities, and due to their dependence on roadside habitats in our study area are likely to frequently encounter roads (Soderquist 1995; van der Ree *et al.* 2001). Canopy bridges provide an opportunity for Phascogales to cross the road safely, however their effectiveness depends on the ability of individuals to detect and use the structures.

Monitoring the usage of crossing structures is essential in the evaluation of their success. Remotely triggered infra-red cameras are a commonly used technique to detect the presence of fauna on crossing structures (Goosem *et al.* 2006) and were successful in detecting use of canopy bridges by arboreal mammals. In this study the use of cameras at both ends of the bridge allowed for more accurate categorisation of crossing behaviour and increased confidence that complete crossings occurred.

The identification of some individuals with unique markings (ear notches) using structures is unique to this study. Individual identification of Squirrel Gliders allowed us to detect the regular and repeated crossings of the canopy bridge by multiple individuals of both sexes.

Changes in Use over Time

Previous studies have shown the time taken for fauna to habituate to crossing structures varies from a few weeks (Mansergh and Scotts 1989) through to several years (Clevenger and Waltho, 2000; Mata et al, 2005). In this study, possum and glider species were observed completing crossings of a canopy bridge within a few months of construction. Similar length of adaptation time was observed for arboreal mammals on canopy bridges over a rainforest road (Goosem, 2005). Our results, combined with those of Goosem *et al*. (2005) suggest that possum and glider species can utilise canopy bridges after a relatively short period of time. However, the time taken for species to adapt differed largely between sites, with one bridge not used until 11 months after construction. Site specific variations such as this illustrate the risk in evaluating successful use based on monitoring a single structure for a short duration.

After the first crossings were detected, we observed an overall increase in rates of crossing over time. This trend was also seen in rainforest possum species using canopy bridges (Goosem, 2005) and a range of other crossing structures (Bond and Jones 2008b; Clevenger and Waltho 2000; Mata *et al.* 2005). This suggests that once an initial period of habituation has been overcome, an increase in crossing frequencies is likely to occur. Most species detected also displayed some seasonal variation in crossing rates to coincide with breeding and dispersal periods, or times of heightened activity during warmer weather (e.g. Bond and Jones 2008b; Mata *et al.* 2005; Ng *et al.* 2004b).

Given the short time taken for animals to complete crossings of the canopy bridge, it does not appear that arboreal species have physical difficulties using structures. We propose that the rope ladder design used in this study is sufficient to facilitate safe crossings. It appeared that some individuals became familiar with the structure, often stopping to groom or feed on insects resident on the bridge or within the infra-red sensor housing. Common Ringtail Possums were also observed crossing while carrying one or more back-young, indicating these animals were comfortable using the structure even during times of heightened vulnerability.

Level of connectivity

Natural animal movement occurs at a range of spatial scales, from shorter daily movements for resource acquisition, to longer trips for dispersal and migration which facilitate genetic connectivity. In order to provide true connectivity crossing structures should aim to accommodate movement at each spatial scale, and ultimately result in increased viability of surrounding populations. As this study has collected information on usage only, our ability to infer levels of connectivity is limited. However, the frequency and seasonal variations in crossing activity, combined with the behaviour of marked individuals provides some preliminary indication of the levels of connectivity provided by canopy bridges.

Regular crossing by Squirrel Gliders suggest that the canopy bridges were used to access food, shelter and potential mates on the opposing sides of the highway. Marked individuals were observed making repeated crossings with some individuals establishing den sites on opposite sides of the road. During research prior to crossing construction, no Squirrel Gliders were detected establishing den sites across the highway (Cesarini unpub data). This suggests that since the construction of the canopy bridges, these species are able to safely access habitat resources which were previously unavailable, demonstrating their potential to successfully maintain small scale habitat connectivity when a road divides a population.

Given that canopy bridges facilitate the regular movement of animals across the highway, it can be assumed that movement for dispersal is also catered for. Peaks in crossing activity coinciding with breeding and dispersal seasons provide further evidence that some dispersal is occurring. For example, the single likely crossing by the Brush-tailed Phascogale occurred at the beginning of the breeding season (May, 2009). Male phascogales travel widely at this time, visiting multiple females to assess their reproductive stage (van der Ree et al, 2001).

Migration and dispersal of individuals does not necessarily equate to genetic connectivity (Forman and Alexander 1998; Riley *et al.* 2003). Gene flow is dependent on the successful reproduction of migrant individuals, and so the ability of crossing structures to provide gene flow cannot be determined through observation of use alone. However, individuals of both sexes were detected making complete crossings of the canopy bridge, and likely dispersal events were identified, indicating the potential of these structures to facilitate gene flow.

Conclusions and Future Directions

The ultimate goal of wildlife crossing structures is to reduce the risk of extinction to such a level that populations fragmented by road or other linear infrastructure are viable in the long term (van der Ree *et al.* 2007). This is achieved through reducing the barrier effect of roads by restoration of landscape connectivity and gene flow, and reducing vehicle related mortality. While we cannot currently comment on the viability of these populations, our results show that canopy bridges facilitate the movement of arboreal mammals across a highway, thus providing connectivity.

The placement of wildlife crossings rarely incorporates an evaluation of the barrier posed to target species prior to construction. In our study, the negative impact of the highway on target species was quantified prior to mitigation occurring (Cesarini *et al.* in review; McCall *et al.* in review). Canopy bridges were placed at priority sites where the highway was known to inhibit the movement of possum and glider species. Monitoring of arboreal mammal populations prior to mitigation allows conclusions to be drawn about the relative success of canopy bridges through observations of use and subsequent post mitigation population monitoring.

Determining the use of crossing structures by fauna provides evidence of the potential to mitigate the negative impacts of roads on wildlife. However, the effectiveness of crossing structures at restoring connectivity and reducing the risk of extinction still needs to be addressed. Future research on mitigation structures should aim to quantify the effects of crossing structures on population viability in comparison to un-mitigated and control sites using multiple replicates. Rigorous evaluation of their success of crossing structures is imperative given the cost of construction and maintenance. In order for road agencies to make well informed decisions about wildlife conservation, we must also determine how effectively this infrastructure mitigates the negative impacts of road construction relative to other means of conservation. There is inherent risk in relying on post disturbance mitigation rather than eliminating or reducing initial disturbance when new roads are created planned.

Biographical Sketches

Kylie Soanes is a research scientist with the Australian Research Centre for Urban Ecology. She studies the effects of roads and traffic on wildlife populations on a number of different projects across south-east Australia. She completed her undergraduate degree at Monash University in Biological Sciences, and her Honours project investigated the effects of broad-scale habitat fragmentation on persistence and gene flow in the Squirrel Glider.

Rodney van der Ree is Deputy Director of the Australian Research Centre for Urban Ecology in Melbourne, south-east Australia. His PhD, completed at Deakin University, studied the consequences of habitat loss and fragmentation on arboreal mammals, with a focus on the effects of habitat geometry. More recently, Rodney has been studying the effects of human settlements, roads and other linear infrastructure on the natural environment, with a focus on quantifying effectiveness of mitigation efforts. He was a co-editor on a special issue of the journal Ecology and Society that focused of the effects of roads and traffic on populations and landscape functioning.

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Using Global Positioning System Technology to Determine Wildlife Crossing Structure Placement and Evaluating Their Success in Arizona, USA

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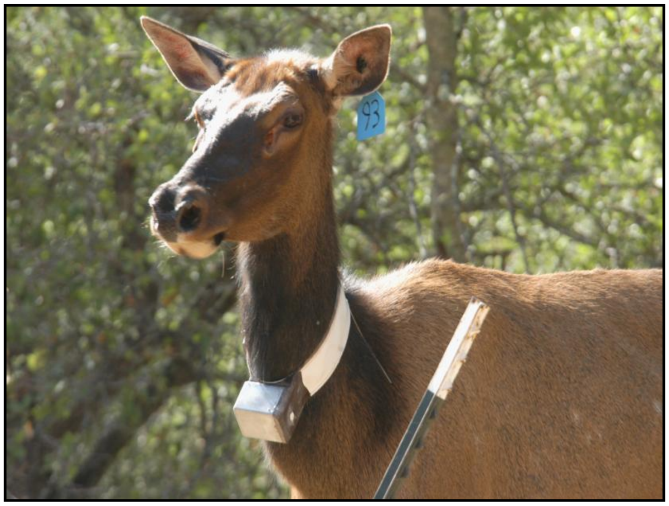

George Andrejko photo, Arizona Game and Fish Department

Abstract

Correct placement of wildlife crossing structures (i.e. underpasses and overpasses) is essential to their success in maintaining wildlife permeability across roadways. Global Positioning System (GPS) technology has proven to be an invaluable tool for placing wildlife crossing structures and fences and for evaluating their effectiveness. The Arizona Game and Fish Department (AGFD), Arizona Department of Transportation (ADOT), and Federal Highway Administration (FHWA) and various federal land agencies are cooperating to locate passage structures and funnel fencing for wildlife and to evaluate their effectiveness through the use of GPS technology.

To date, we have fitted >500 animals with GPS collars providing >2,000,000 locations to determine crossing structure and fence placement, during-construction wildlife behavior, and post-construction responses for elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), American pronghorn (*Antilocapra americana*), desert bighorn sheep (*Ovis Canadensis*), and desert tortoise (*Gopherus agassizii*).

Wildlife-vehicle collision (WVC) data is also useful for identifying crossing structure locations; however, this method cannot be used for species that avoid crossing roads. For example, declining populations of pronghorn are bisected by US highway 89, but no WVC data exists here for this species (Dodd et al. 2009). Therefore, we are using GPS data exclusively to determine where pronghorn approach the highway hopefully indicating where they may use yet to be constructed wildlife crossing structures. To date, we have collected >120,000 GPS locations (taken every two hours) to recommend crossing structure placement for this project. A similar "data-driven" approach was used along US 93 to provide recommendations for placement of three desert bighorn sheep overpasses to be completed in 2010 (McKinney and Smith 2007).

WVC data obviously is absent in areas where roadways did not exist, such as realignments or new highways. Therefore, along the proposed US 95 realignment, AGFD is studying pre-construction desert tortoise movements to determine crossing structure placements sufficient to allow tortoise safety and permeability once the highway is built.

Although reduction of WVCs is an important measure, WVC reduction alone does not tell the whole story. Promoting wildlife permeability is also important. For instance, along an 8-km stretch of State Route 260, where crossing structure frequencies were 1.1 structure/km, Dodd et al. (2007*a*) documented a >80% reduction in elk-vehicle collisions following the implementation of funnel fencing linking crossing structures. Here, GPS passage rates showed that permeability did not change following upgrade of the highway. In contrast, elsewhere on SR 260, where crossing structure were spaced 2.4 km apart, WVCs were reduced by >95% following fencing connecting crossing structures. However, permeability dropped by 70%; so although WVC rates declined, the overall effect could not be determined by WVC alone. Pre- and post-construction GPS movement data are needed to show changes in permeability following reconstruction of highways.

We provide methods and various examples of the use of GPS movement data in Arizona so that highway and wildlife managers alike may be able to use this technology in planning and monitoring their own wildlife-friendly highway projects.

Overview

Recent advances in GPS technology provide opportunity for accurate unbiased data collection. In the field of Road Ecology, GPS can be a valuable tool to providing adequate data for wildlife-highway studies and provides another piece of information to understanding effects of roadways on wildlife as well as success of WVC mitigation efforts.

In Arizona, AGFD in cooperation with ADOT and FHWA have placed GPS collars on more than 500 animals; these collars have recorded fixes every one to two hr for a minimum of a year. To date, we have accrued >2,000,000 locations to determine crossing structure placement, during-construction wildlife behavior, and post reconstruction responses of elk, mule deer, white-tailed deer, American pronghorn, desert bighorn sheep and Rocky Mountain bighorn sheep and desert tortoises (figure 1).

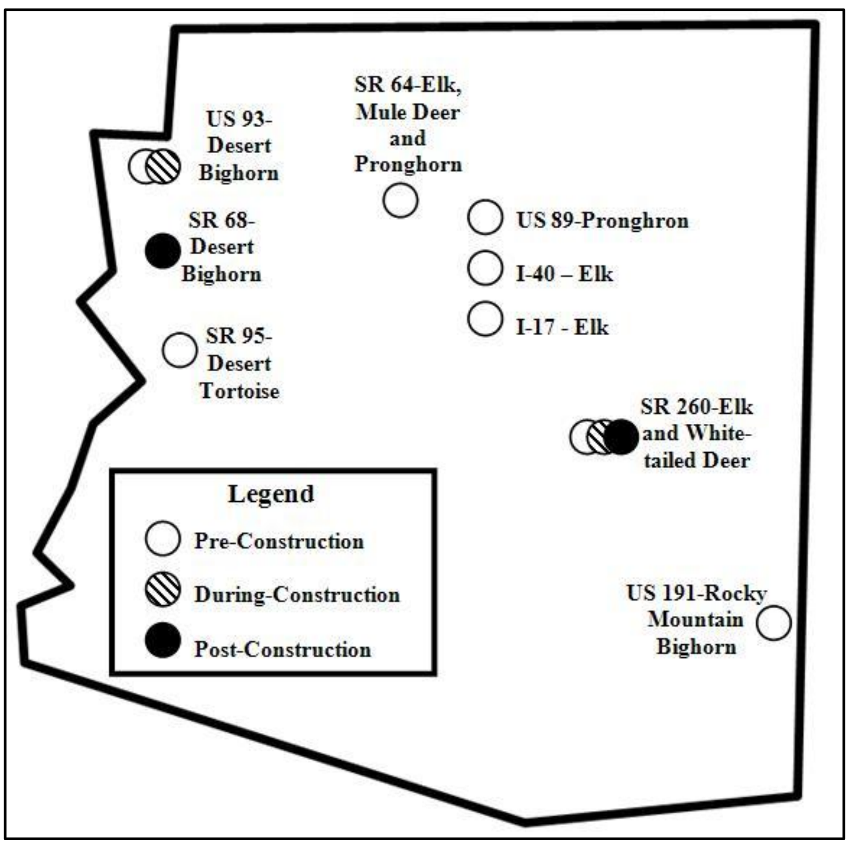

Figure 1. Location of Global Positioning System wildlife-highway telemetry studies, the species studied, and the phases of construction each project was in during our studies from 2002-2009, in Arizona, USA.

Collecting and Analyzing GPS Data for Wildlife-Highway Studies

The objectives of our projects determine the type of GPS collar that we deploy. Three types of GPS collars generally exist. First are "store-on-board" collars that collect GPS locations and store them in the collar; the data will not be available until the collar is recovered. Collar recovery occurs when an automatic release mechanism activates, the collar falls to the ground, is found with a VHF receiver. Data is solely retrieved via cable downloading into a computer. Newer technology "Spread Spectrum" collars allow the user to upload data onto a receiver linked to a computer from an airplane. Thus, this model of collars is suited for projects where data is needed immediately. Lastly, satellite collars provide continuously uploaded data and do not require flights to recover data or check welfare of wildlife. Generally, store-on-board collars are the least expensive as they have fewer components, do not regular flights to recover data, or have satellite user fees. Recent advances in technology however are closing the gap on these costs. Many of these collars can be refurbished, substantially decreasing the cost of collars for repeated use on projects.

We program our GPS acquisition rates with the least amount of time between fixes balanced against battery life and cost allowing for the most accurate assessment of where animals cross or attempt to cross roadways. We have generally programmed our collars for collection of locations no shorter than two hours apart during peak movement times. Our collars generally provide up to two years of data collection for large species such as elk (Dodd et al. 2007*b*). Recent improvements in technology have allowed for similar data collection regimens for moderate sized species such as pronghorn and desert bighorn sheep.

Delineating the roadway into segments, such as 1/10 mi or 1/10 km for larger species has facilitated assessments of wildlife crossing or approach patterns. Once we recover GPS data each crossing is assigned to a given segment of roadway. We determine crossings by connecting a line between two locations and frequency will identifies segments where more crossings are occurring. For animals that don't cross the road regularly, we document approaches by applying a buffer to the roadway and delineating it in the same manner as for crossings. Areas where collared animals approach the road more often are identified. The width of the buffer applied has depended on the focal species and their relative degree of mobility.

We have applied diversity indices (Shannon and Weaver 1949) to correct or weight GPS data to minimize bias caused by individual animals that frequently cross or approach a highway. For example, on State Route 260 (SR 260), Dodd et al. (2007*a*, *b*) documented a single elk crossing the road almost 700 times in two years, whereas the average number of crossings for all elk was <100. Although sample sizes were large, this animal skewed the dataset towards areas not regularly used by most elk. . Weighted crossings thus reflect the crossing frequency, number of crossing animals, and equity in distribution among crossing animals (Dodd et al. 2006, Dodd et al. 2009*b*).

Assessing permeability helps evaluate the overall effectiveness of a WVC reduction or highway barrier mitigation effort. Even if reductions in WVC occur, it is important to determine the degree to which permeability is affected. Dodd et al. (2007*b*) calculated passage rates as a measure of permeability by dividing the number of crossings by the number of approaches. For example if elk approached the road 100 times and crossed the road 50 than the passage rate would be 0.50. This allowed Dodd et al. (2009) an unbiased approach to evaluating the impacts of different phases of construction on elk and white-tailed deer spacing of crossing structures on elk permeability in a "before-after, impact-control" (BACI, Underwood 1994). Gagnon et al. (2007*a*) used probability of a successful crossing once elk approached the road as a measure of permeability during varying traffic volumes.

Before Construction Evaluations

Before-construction baseline data is needed to fully conduct post-construction assessments, though this is often not the case. GPS technology provides an opportunity to evaluate the overall effect of highway upgrading on wildlife movement and is a supplement to spatially-accurate WVC and wildlife passage structure monitoring. For many species, there are three factors that contribute to an effective wildlife passage structure: 1) placement, 2) design, and 3) funnel fencing application. Recommendations for the placement and extent of fencing can be determined from GPS movement data (Dodd et al. 2007*a*). Placement is important so as to ensure that wildlife will encounter and use passage structures (Beier and Loe 1992, Barnum 2003). Placement can be determined through spatially-accurate WVC data for wildlife that are regularly killed on the road (Dodd et al. 2006) providing an adequate dataset is available to make sound recommendations. However, some species avoid roads and traffic to the point where few or no crossings occur (Jaeger et al. 2005). GPS data can define where passage structures and fencing should be placed, while simultaneously providing baseline movement data relative to a roadway. Identifying proper placement of future passage structures is an important step in long-range transportation planning (Cramer and Bissonette 2007).

In Arizona, several projects are underway to define the location of crossing structures and associated funnel fencing several years in advance of highway reconstruction. This information will be to be incorporated into the final plans for highway upgrade or realignment.

US Highway 93 – Placement of Wildlife Passage Structures for Desert Bighorn Sheep

One of the first studies in Arizona to use GPS data to define crossing structure placement occurred along US 93 in northeastern Arizona (figure 1). McKinney and Smith (2007) placed GPS collars on desert bighorn sheep and monitored their movements for more than two years to determine where peaks in highway crossings or approaches occurred (figure 2). They identified five locations where wildlife passage structures were recommended to promote permeability. Three of these locations were approved by ADOT and FHWA for wildlife overpasses. Construction on these overpasses began in spring 2009. Researchers will continue to evaluate sheep movements during and after construction once the highway is expanded to four lanes to determine changes in WVC and sheep movement across the highway with passage structures and funnel fencing.

Figure 2. Aerial capture of a desert bighorn sheep along US Highway 93, Arizona, USA. Photo courtesy of George Andrejko, Arizona Game and Fish Department

US Highway 89 – Placement of Wildlife Passage Structures for Pronghorn

Declining pronghorn populations in Arizona can be attributed to a combination of issues, although a primary cause is the barrier effect caused by roadways contributing to population and habitat fragmentation and reduced population persistence through genetic isolation (Epps et al. 2005, Jaeger et al. 2005). Roads with moderate to high traffic and adjacent right-of-way fence constitute a significant barrier to pronghorn (van Riper and Ockenfels 1998, Sawyer and Rudd 2005). Along US Highway 89 north of Flagstaff, GPS movement data collected from 2007-2008 on 37 pronghorn collared on both sides of US 89 providing 121,000 locations, of which we documented highway crossings by one pronghorn (figure 3).

The data collected during the 2007-2008 study is being used for locating crossing structure placement, although this data simultaneously provides baseline permeability data for comparison following construction as well as insights into traffic volume effects on pronghorn (Gagnon et al. 2007*c*).

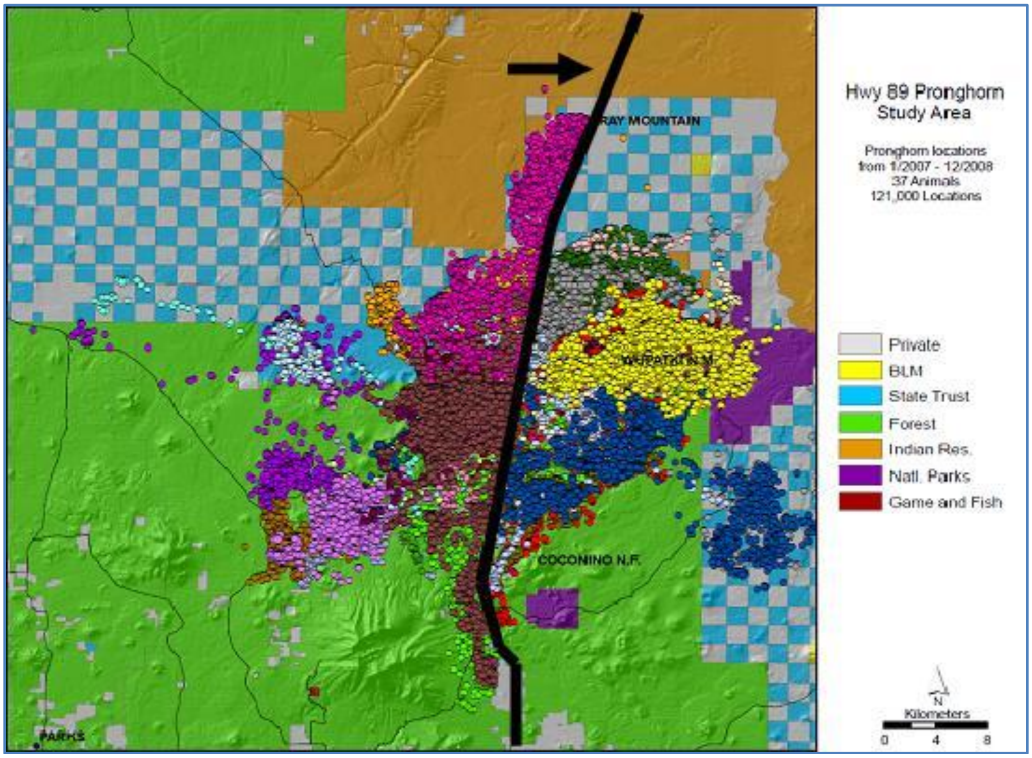

Figure 3. Global Positioning System movement data obtained from 37 pronghorn (locations acquired every two hours) along US Highway 89 north of Flagstaff, AZ USA from 2007-2008.

To determine proper location of passage structures for this study, we evaluated the number of times pronghorn that approached the highway. To account for diversity and to avoid bias provided by those animals that approached the highway relatively more than others, we applied a Shannon Diversity Index similar to that used for elk highway crossings along SR 260 (Dodd et. al. 2006, 2007*a*). The results from this exercise provided a data-driven approach to identification of appropriate locations of crossing structures (figure 4), of which three were recommended, spaced approximately 5 km apart (Dodd et al. 2009*b*).

Placement of Wildlife Passage Structures for Elk, Mule Deer and Pronghorn along Other Highways

Current GPS movement studies are underway involving five other highways and various species of wildlife, including State Route 64 (elk, mule deer, pronghorn), Interstates 17 and 40 (elk), US Highway 191 (bighorn sheep) and State Route 95 (desert tortoise). Data will be available from these GPS studies within the next two years.

State Route 64 is the primary route to the Grand Canyon; greater than 50% of all accidents on this road involve collisions with wildlife. To address this problem, ADOT commissioned a wildlife accident reduction study that evaluated peaks in WVC and provided options for passage structure placements and designs. We are using GPS movement data in a multi-species effort to define suitable locations for passage structures for elk, mule deer, and pronghorn. Elk and deer are regularly struck by vehicles along this road, whereas pronghorn are not, thus providing inadequate WVC records.

Both Interstates-17 and 40 pass through elk habitat in northern Arizona and are planned for reconstruction from four-lane to six-lane divided highways. Elk in these areas present a highway safety concern for motorists. AGFD is working with ADOT and FHWA to reduce elk-vehicle collisions while maintaining permeability across the highway corridor. We have collared 80 elk along each of these highways to determine crossing structure placement and extent of funnel fencing needed to intercept elk and force them to and through passage structures.

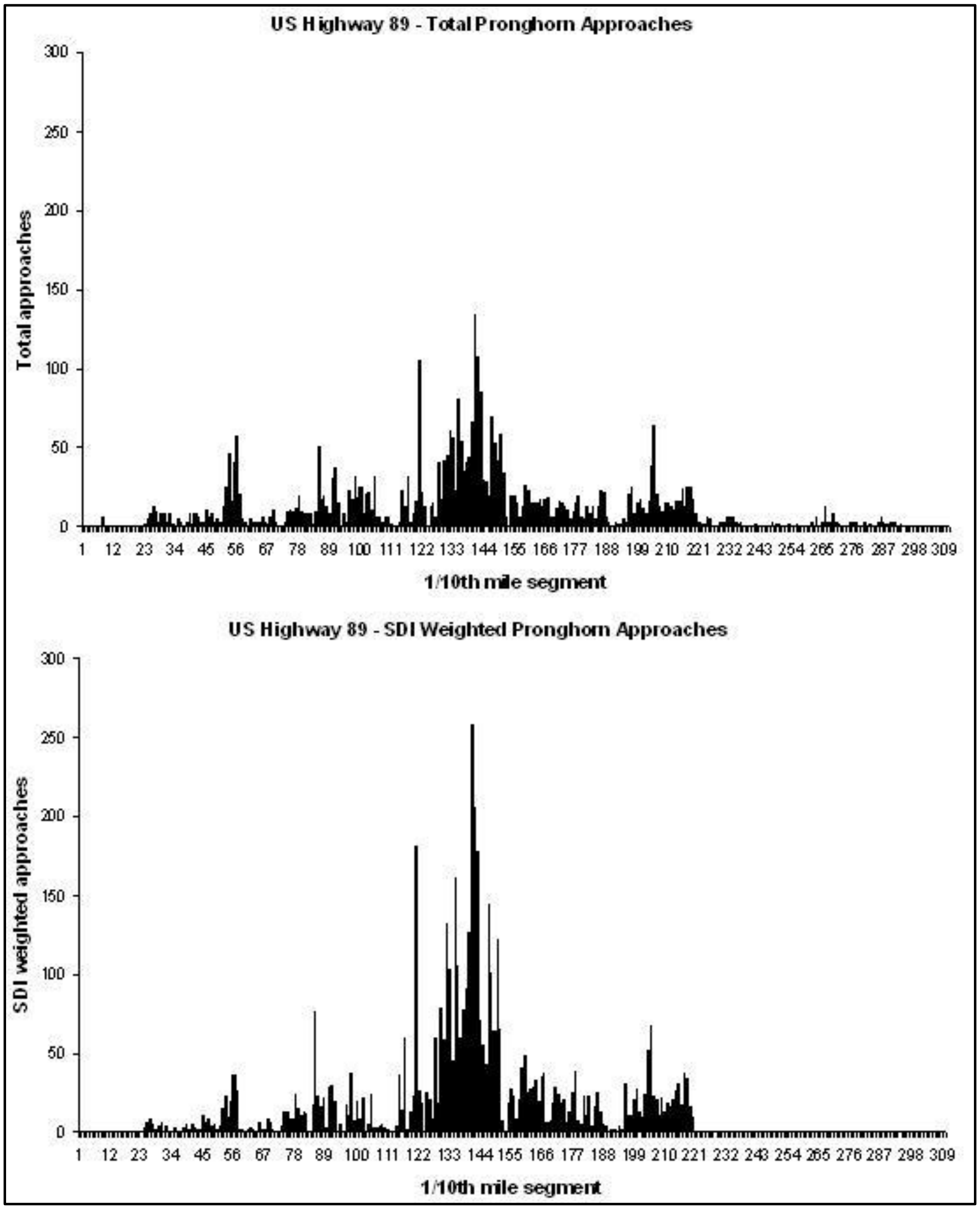

Figure 4. Total (top) and SDI weighted (bottom) approaches of US Highway 89 as determined by GPS collared pronghorn for identification of wildlife passage structure locations in Arizona, USA.

Along US Highway 191 in eastcentral Arizona, Rocky Mountain bighorn sheep are regularly struck by vehicles in and near the Clifton-Morenci, Freeport McMoRan, Inc. mine property. This is one of the largest copper mines in North America and it provides bighorn sheep habitat. Wakeling et al. (2008) documented 17 collisions/year with sheep along an 8-mile stretch of highway. The estimated population of Rocky Mountain bighorn sheep in this area was 250-300 indicating that 5-7% of the population is killed on this stretch of highway. Researchers collared sheep to begin collecting baseline GPS movement data that will be combined with WVC data to develop recommendations to reduce collisions and maintain permeability. One potential option may be the use of a roadway animal detection system combined with fencing to provide a “crosswalk” similar to that on SR 260 that has shown positive results (Gagnon et al. 2009). A GPS movement study following the construction of any WVC mitigation measures will determine the degree to which permeability is maintained, especially if fencing is applied.

GPS applications aren't just limited to large ungulates. In some cases GPS receivers can be mounted to smaller animals such as desert tortoise, a federally threatened species. In western Arizona along the proposed US Highway 95 realignment, researchers are studying pre-construction desert tortoise movements to determine crossing structure placement to facilitate safe tortoise passage once the highway is built (David Grandmaison *pers. comm.).* AS GPS technology advances, smaller animals will benefit from studies such as these to determine the location and evaluate the effectiveness of measures to reduce WVC while maintaining permeability across roads.

During Construction Evaluations

Although the ultimate success of a WVC or highway barrier mitigation effort will be determined by comparison of the pre- and post-construction phases, evaluation of during construction GPS movements can provide valuable insights on the effects of various construction activities on wildlife species. These insights can help provide information for future recommendations to avoid potential impacts to breeding or birthing grounds. Along US Highway 93, evaluation of GPS movements by bighorn sheep is ongoing during construction to determine the effects of major reconstruction activities on sheep movements in these areas, especially critical for this species that must retain access to water sources for survival in harsh desert environmental. Data is being collected via satellite collars and is regularly being analyzed. Along SR 260, Dodd et al. (2007*a*) found that the ability of elk to cross the highway did not decrease during construction in comparison to adjacent control areas.

After Construction Evaluations

Evaluation of wildlife passage structures and associated fencing is essential to determine success of highway reconstruction treatments. GPS movement data can be combined with WVC data, passage structure monitoring, and long term genetic analysis (Hardy et al. 2003). For some species that do not readily cross roadways resulting in a dearth of road kill data, pre- and post-construction GPS movement monitoring may be used to evaluate the effectiveness of passage structures and fencing. The information gained from GPS movement data provides insight into the effectiveness of mitigation options.

Route 260 – Evaluation of Fencing and Wildlife Underpasses

Along SR 260, we GPS tracked movements of elk and Coues' white-tailed deer during the before-, during-, and after-reconstruction phases of three stretches of roadway, and adjacent control sections (Dodd et al. 2009). These data, when combined with passage structure video monitoring and WVC data, provided insight to the overall effectiveness of passage structures and fencing.

Funnel fencing is important because it can reduce some problems with crossing structure placement and design by forcing animals to the structures. In the case of SR 260, the wildlife passage structure locations were determined from WVC data and underpasses and bridges were substituted for drainage culverts.

Along the Christopher Creek Section of SR 260, passage structures were placed 1.1 km apart, however, minimal funnel fencing was used to force animals to these structures; hence, elk-vehicle collision rates increased dramatically. Dodd et al. (2007) found that major peaks in crossings, determined by GPS data, were occurring outside of the wildlife underpasses. Fencing was extended to intercept those crossing peaks and elk-vehicle collision rates dropped by >85% while passage structures use increased dramatically (Gagnon et al. 2005, Dodd et al. 2007*c*). Elk permeability returned to pre-construction levels likely due to funneling of elk to passage structures where traffic volume had minimal effect on below-grade crossings (Gagnon 2007*b*).

In contrast, a similar effort along another stretch of SR 260 yielded different results in permeability determined by GPS telemetry. Following the completion of underpasses and limited fencing along the Preacher Canyon section, accidents continued to occur at similar levels to those prior to reconstruction. Again, GPS data was used to determine placement of ungulate-proof fencing needed to intercept elk crossing the highway. Where the extended fencing was terminated, an animal detection system was installed to detect animals that moved around the end of the fence. Similar to the Christopher Creek section, the fenced area showed a dramatic decrease in elk-vehicle collisions (96% reduction) pointing again to the success of passage structures and appropriate fencing (Gagnon et al. 2009). The one major difference, however, was the effect of fencing on the ability of elk to cross the roadway. In Contrast to the Christopher Creek section, where passage structures were spaced and average of 1.1 km apart, on the Preacher Canyon section passage structures were spaced 2.4 km apart, and we documented a greater decrease in elk-vehicle collisions, however, the passage rate dropped by 70%, to 0.10 crossings/approach. So although WVC rates declined, the overall effect of the highway upgrade and fencing on wildlife could not be solely assessed by WVC alone. This dramatic drop in passage rates was likely due to the greater average distance between passage structures (2.4 km), forcing elk to travel a greater distance to cross (figure 5). This also provides empirical insight into distances needed between passage structures to maintain “adequate” levels of permeability. Bissonette and Adair (2008) recommend a spacing of 3.5 km for elk based on isometric-scaling calculated from home range size. This spacing may not be adequate for elk in some instances depending on the level of permeability desired. Conversely, ungulates that regularly travel along roadways tend to show a broader distribution parallel to the road leading to a greater number of interactions between them and the roadway (Clevenger et al. 2001). The motivation (food, water, migration or mating) to cross the road may also affect spacing between passage structures.

Research in Sweden has shown similar results to the Preacher Canyon Section of SR 260. Olsson (2007) found an 89% drop in moose (*Alces alces*) crossing rates once the highway was reconstructed to include fencing and underpasses. In comparison, fencing did not reduce the movement of European wildcats (*Felis silvestris*) to the level anticipated by Klar et al. (2009). Both studies realized reduction in WVC but the extent of the barrier effect caused by the fencing would not have been evident without before- and after-reconstruction evaluations.

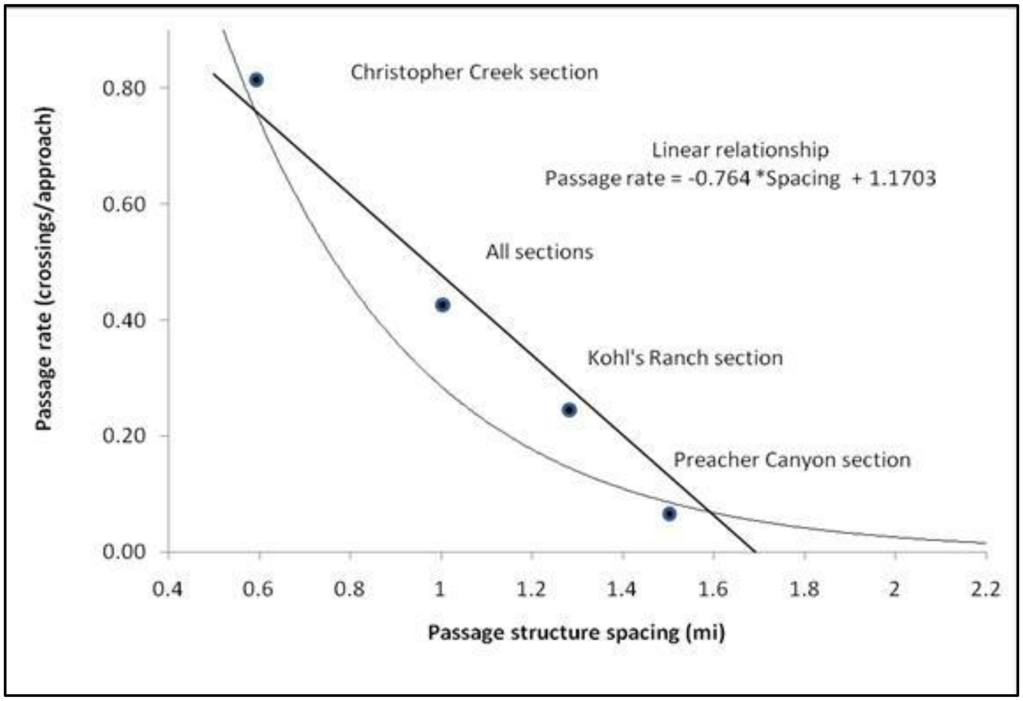

Figure 5. Relationships between mean elk passage rates determined through GPS telemetry and mean passage structure spacing on three reconstructed sections of State Route 260, Arizona, USA. (from Dodd et al. 2009).

We also placed GPS collars on Coues’ white-tailed deer along SR 260 and found a dramatically different outcome for this species when compared to elk. . Prior to reconstruction, very few crossings occurred along this two-lane road and passage rates averaged 0.03 crossings/approach (compared to >0.80 for elk along the same stretches of roadway; Dodd et al. 2009). Following completion of the four-lane divided highway with passage structures and fencing, passage rates increased to 0.16 crossings/approach (Dodd et al. 2009). For the less mobile species, Bissonette and Adair (2008) recommended that passages be spaced 1.5 km apart; the spacing associated with the reconstructed SR 260 sections where we documented increased deer permeability averaged 1.4 km, providing an empirical validation of Bissonette and Adair’s (2008) recommendation. Without the before- and after-reconstruction GPS data, however, the increase in permeability for white-tailed deer would not have been evident. These findings indicate that species that are considered more sensitive to roads can nonetheless benefit from increased passage rates with appropriate passage structures and fencing.

State Route 68 – Evaluating Desert Bighorn Sheep Underpasses and Fencing

The State Route 68 project in western Arizona was one of the first attempts to provide crossing structures for desert bighorn sheep. The locations of the sheep underpasses were determined by a combination of WVC data and topographical features, primarily existing drainages. Bristow and Crabb (2008) used a combination of GPS telemetry, cameras, and track beds at underpasses to monitor sheep use of recently completed wildlife passage structures. They found relatively minimal use of the structures attributable to structural design and placement; they indicated that "placement of crossing structures relative to traditional travel corridors of bighorns is likely the most important factor affecting their use". GPS movement data indicated that no females (ewes) crossed the newly expanded roadway either through passage structures or elsewhere, constituting a nearly total barrier to sheep passage. They did however document several crossings by males (rams) indicating that genetic interchange was likely not eliminated. The most important aspect of the study was the knowledge gained through use of GPS as a supplemental tool to WVC and passage structure monitoring. This allowed us to be able to evaluate permeability across the highway as well a crossings in areas outside of the passage structures that could not be attained by other means since incidence of WVC are limited here. The insights gained from the S R 68 project helped to emphasize the use of GPS data to locate where passage structures should be placed. They also highlighted the importance of passage structure design which was used on future projects such as US Highway 93.

Caveats of Using GPS Data for Roadway Ecology Studies

In many cases, highway studies focus on larger wildlife and. some of the smaller animals can be underrepresented when planning a safe and permeable highway and focus on a few species in an area where many wildlife species exist. However, many studies have documented the use of passage structures by various species indicating that wildlife crossing structures, even when planned for specific species are still effective for many other species (Foster and Humphrey 1995, Ng et al. 2004, Clevenger and Waltho 2005, Dodd et al. 2009).

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Biographical Sketches

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BOZEMAN PASS WILDLIFE PRE- AND POST-FENCE MONITORING PROJECT

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Abstract

The Bozeman Pass transportation corridor between Bozeman and Livingston, Montana, includes Interstate-90, frontage roads, and a railroad. The highway supports 8,000-12,000 daily vehicles during the winter and 10,000 to 15,000 daily vehicles during the summer. The interstate has essentially become a barrier and hazard to animal movements in the Bozeman Pass area. To determine the extent of the animal-vehicle conflicts and where conflicts may best be mitigated, CERI began collecting field data on Bozeman Pass in 2001. Data analysis led to recommendations to incorporate approximately 2 miles of wildlife fencing, cattle guards and landscaping design modifications into the reconstruction of a Montana Rail Link (MRL) overpass. These recommendations were accepted by the Montana Department of Transportation (MDT) and MRL in 2005 and a wildlife fence and four jump-outs were constructed in 2007. Adding relatively low cost wildlife mitigation measures to existing highway projects are effective in increasing highway permeability and reducing animal mortality, and could be incorporated into the Obama infrastructure initiative.

Data on wildlife crossings and animal-vehicle collisions (AVC) were collected before and after installation of the fencing to evaluate if the fencing reduces animal-vehicle collisions, and to determine animal movements under the highway via existing culverts and the MRL overpass. Data collection includes seven tasks, as follows:

1. Road kill surveys between Bozeman and the Jackson Creek interchange.
2. Track bed monitoring of wildlife movements under the MRL bridge.
3. Remote camera monitoring of wildlife movements at fence ends
4. Infrared counter monitoring of wildlife movements at jump-outs
5. Track bed monitoring of wildlife movements at fence ends and jump-outs
6. Remote camera monitoring of wildlife movements in two culverts at east end of fence.
7. Opportunistic snow tracking under MRL bridge and in fenced area.

Power analyses (power = 0.8; α = 0.05) indicated three to five years of post-fencing study would be optimal in order to make reasonable quantitative comparisons between the pre- and post-fencing ungulate-vehicle collision (UVC) data. This presentation reports on 2 years of data.

Nearly 2000 animals have been killed along 23 miles of Interstate 90 from 2001-June 2009. Since the installation of the wildlife fence about 1.5 miles long, two white-tailed deer has been killed within the fenced area and three have been killed at the fence ends. There has not been an increase in AVC at the ends of the fence. Preliminary results indicate an increased use of underpasses and culverts by wildlife.

Costs for this project were much lower than new wildlife crossing structures since the fencing was added on to a structure replacement project for an existing underpass. More wildlife appears to travel through the rebuilt underpass as well as through other existing crossing structures (culverts and county road bridge). This suggests that fencing alone can be added to help direct animals through existing structures.

Wildlife fencing leading to existing crossing structures is a cost-effective method of reducing AVC and thus reducing risk to motorists as well as increasing connectivity for wildlife.

Design improvements in jump-outs and fence-ends will be discussed.

Introduction

There is a wealth of evidence that details the mainly negative impacts that roads have on wildlife populations. When animals are confronted with roads, they potentially face direct mortality, habitat fragmentation, loss of habitat connectivity and genetic isolation (Clevenger and Wierzchowski 2006, Clevenger et.al. 2001, Corlatti et. al. Forman et. al. 2003, Forman and Alexander 1998). When humans encounter wildlife on roadways the effects can also be life-threatening. Every year approximately 200 people die from animal-vehicle collisions (AVC). The cost of wildlife related collisions are staggering with an estimated $1 billion yearly being paid out by insurance companies for automobile repairs (Robbins 2007). In an effort to decrease human and wildlife mortality, transportation planners within the past few decades began incorporating wildlife mitigation features in road construction and upgrades in the United States (Forman et. al. 2003). Methods typically include installing wildlife fencing and jump-outs in conjunction with a variety of underpasses, overpasses or culverts that animals may use to traverse safely from one side of road to the other (Clevenger et. al. 2001, Forman et.al. 2003,). These structures target a wide variety of species depending on the size of the structure, ranging from amphibians, reptiles and small mammals to large ungulates and carnivores (Forman et. al. 2003) While many of these structures are effective in reducing road kill they can be very expensive, costing millions of dollars for a wildlife overpass. In some instances, the cost of mitigation can be lessened by incorporating the structures into planned upgrades and rebuilds of roads already scheduled by departments of transportation.

In 2001, the Craighead Environmental Research Institute (CERI) began the Bozeman Pass Wildlife Linkage and Highway Safety study to identify accurate road kill locations and actual wildlife movement along Interstate 90 (I-90) between Bozeman and Livingston Montana. Analysis from that project, highlighted areas of higher than average road kill within the study area near Bozeman and other areas closer to Livingston. One of these areas of high road kill was in the vicinity of the Montana Rail Link (MRL) bridge that was scheduled to be rebuilt in 2005. From this data, the Montana Department of Transportation (MDT) incorporated wildlife fencing into its bridge replacement plans. In 2003, MDT and the Western Transportation Institute (WTI) contracted with CERI to monitor the pre- and post-mitigation data that would be used to comparatively assess the effect of the mitigation (wildlife fencing, jump-outs and cattle guards) on AVC and wildlife movements from one side of the highway to another after the MRL bridge was rebuilt. The post fencing mitigation study area was limited to the area between Bozeman and Jackson Creek (milepost 309.5- 319.0). Road kill data continued to be collected throughout the entire study area to identify other areas that may serve as mitigation sites in the future.

The Study Area

Bozeman Pass on I-90 is located in southcentral Montana approximately 88 km (55 miles) north of Yellowstone National Park. The study area in and around Bozeman Pass encompasses approximately 908 km^2 and includes the cities of Bozeman and Livingston. Interstate 90 bisects the area between Bozeman on the western edge and Livingston on the eastern edge. The Montana Rail Link line runs parallel to the freeway crossing underneath at milepost 321 and 314. A frontage road also runs parallel to the freeway for a portion of that distance. The distance between Bozeman and Livingston is approximately 33.6 km (21 miles). The highway supports 8,000-12,000 daily vehicles during the winter and 10,000 to 15,000 daily vehicles during the summer. Railway traffic through this area is also a factor, with approximately 30 trains using the tracks daily, moving through the MRL underpass at approximately 48 kph (30 mph) (Dewey Lonnes, personal comm.). See Figure 1.

Bozeman Pass is surrounded by a mosaic of residential, agricultural and public lands. The landscape varies from shrub-grassland communities near Bozeman and Livingston to coniferous forests in the middle section of Bozeman pass. Elevation varies from 1398 meters at its low point near Livingston to 1733 meters at the top of the pass.

Bozeman Pass supports a large amount of wildlife habitat on both public and private lands and serves as a wildlife connectivity link between the Gallatin and Absorka mountain ranges in the south and the Bridger and Bangtail Mountains in the north. The wildlife habitat in the area is somewhat fragmented by human development and transportation routes. Regionally, Bozeman Pass has been identified as an important wildlife corridor connecting wildlife habitat in the Greater Yellowstone Ecosystem in the south, through the Bridger and Big Belt Mountains, to the Northern Continental Divide Ecosystem in the north (Craighead et. al. 2001, Hardy et.al. 2006, Walker and Craighead 1997, Reudiger et. al. 1999). Interstate 90 is the most significant barrier to wildlife movement in the area and in the region.

This area is rich in wildlife including: black bears (*Ursus americanus*), mountain lion (*Puma concolor*), bobcat (*Felis rufus*), elk (*Cervus elephas*), moose (*Alces alces*), mule deer (*Odocoileus hemionus*) and white-tailed deer (*O. virginianus*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*) and a variety of smaller mammals, reptiles, and a diversity of bird species. Many of these species utilize this area on their seasonal and daily migration movements. Grizzly bears (*Ursus arctos horribilis*) are occasionally seen in the area but none have been documented crossing I-90 or recorded as road-kill.

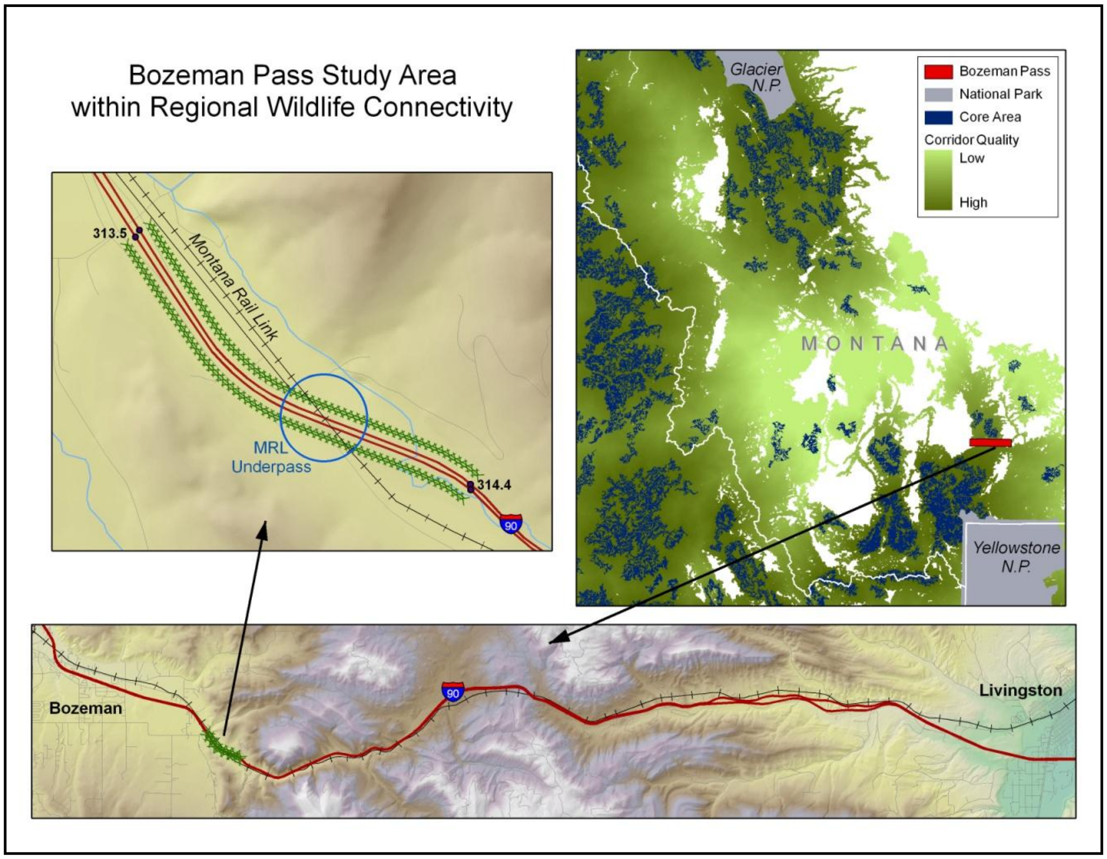

Figure 1. Bozeman Pass Study area

The MRL bridge is located approximately at milepost 314.1 and spans the railroad and access right-of-ways underneath Interstate 90. After the bridge was rebuilt in 2005-2006 wildlife mitigation measures were installed, specifically wildlife fencing, jump-outs, Texas or cattle guards and improved grading underneath the bridge to enhance wildlife movement. Wildlife exclusion fencing (1.2 meter (8 ft.) high) was installed along 1.44 km (.9 mile) of I-90, extending east and west from the bridge that crosses over the MRL railroad. The wildlife fencing is located between milepost 313.5-314.4 along both east and west bound lanes. Four jump-outs were installed within the fenced areas to allow animals that became trapped on the freeway a place to 'jump out' to safety. These are constructed so that animals can jump away (exit) from the roadway but cannot walk back up onto the roadway (one-way). To discourage animals from making "end runs" around the end of the fences, modifications were made to include cattle guards and modified fence ends. Two sets of double cattle guards or Texas guards were installed at the western termini of the fence at the Bear Canyon interchange access ramps. These were installed to deter animals from walking to the end of the fence and then walking up the on-ramp to the freeway. The eastern wildlife fence ends encompass a large double culvert and a steep embankment before tying into the traditional barbed wire fence that runs the length of the right-of-way.

Methods

Road-kill Data Methods

Road-kill data collection began in 2001. Biologists at CERI and volunteers drove along Interstate 90 over Bozeman Pass between Bozeman and Livingston and recorded the date, location (to the closest 1/10th mile using mile markers), and species of road-kills observed. Sex was recorded for carnivores and ungulates if possible. Volunteers usually traveled Bozeman Pass during the five weekdays on their way to work, and CERI personnel drove the pass during the weekend in search of road-kills. Interesting or unusual road-kills were further investigated by CERI personnel. This survey methodology continued through 2002. A more standardized survey method began in 2003, with CERI personnel driving Interstate 90 between Bozeman and Livingston three times a week to collect road kill data. Driver speed for CERI personnel was kept between 88-105 kph (55-65 mph) during the surveys. Thru June 30, 2009, the pass has been surveyed 1066 times representing 80,631 km (50,102 miles) between milepost 309.5- 333.0. It is also important to note that many more animals are killed then ever get recorded; animals get hit and then die some distance from the roadway, people pick up road kill for personal uses and road kill become obscured by vegetation or topographical features. In some cases scavengers such as coyotes will drag carcasses away from the roadside. Road kill data from CERI and other agencies only represent an index of the actual number of animals hit. Data collection will continue until June 30, 2011 in accordance with the MDT contract.

Searches of agency records provided additional wildlife collision data. Road kill data were obtained from a variety of sources including Montana Fish Wildlife and Parks (MFWP) and Montana Department of Transportation (MDT). Typically, MDT removes dead animals from the right-of-way if the animal poses a threat to driver safety. These animals are usually picked very early in the morning before CERI personnel were able to record them. Species that fall into this category typically include moose, elk, deer and other large animals and are removed promptly. However not all species are picked up promptly and carcasses will lie on the side of the road for a period of days or weeks. Some carcasses are never picked up. Supplemental data from MDT Maintenance reports that were included in this project are: carnivores, moose and elk. Deer species (mule and white-tailed) from MDT maintenance records were not included due to the difficulty in trying to reconcile duplicate records. Accurate records contain the date, location and any other pertinent information such as sex of the animal. These data were also entered into the GIS database.

Track Bed Survey Methods

To determine the number and species of animals crossing underneath the bridge, a sand track bed was constructed on the north side of the railroad tracks underneath the MRL bridge. The track bed is approximately 46 meters (150 ft) long and is 2.5 meters (8 ft) wide. Due to the configuration of the freeway and railroad passing beneath it, the track bed covers approximately two-thirds the width of the passage. Since it was not possible to census the entire area for animal movements, the track bed observations provide an index of crossing activity.

Track bed surveys began in October, 2003 and continued through April, 2005 when bridge reconstruction began. During the construction phase, equipment, materials and fill were present at the track bed site making it impossible to maintain and monitor the track bed until construction was completed. Accordingly, the track bed was rebuilt in the fall of 2006. However the fencing was not completed until the spring of 2007. Post-fencing track bed monitoring therefore commenced in May 2007.

Before construction the track bed was counted and then raked every 3-4 days on average. The number of tracks counted was then divided by the number of collection days to provide a count of tracks per day. Post-construction, an alternate method was used: surveys were conducted 4 consecutive days every other week; the bed was completely raked at the beginning of the week and then counted and raked every day for the next four days to provide a count of tracks per day. This was done to avoid any confusion due to large numbers of tracks after multiple days of collection (Hardy et. al. 2006). Due to the difficulties in conducting surveys in the winter with tracks being frozen and weather events confounding track identification, surveys were conducted between May 1- October 31, 2007 through the present.

Jump-out Monitoring Methods

Initially the jump-outs were monitored using small track beds constructed at the top of the jump-out and supplemented with trailmaster motion-sensor counters. The counters soon proved unreliable and were replaced with RECONYX motion-sensor cameras. Jump-out track beds were surveyed in conjunction with the main track bed survey (May 1-October 31). Jump-out cameras were downloaded periodically and batteries were replaced as needed.

Remote Camera Monitoring Methods

Before construction, cameras were placed in culverts at MP 314.6, MP314.8 and MP315. Photo-monitoring was initiated in 1998. The eastern culvert at mile marker 314.6 was monitored from February 19, 1998 until January 23, 2005. The western culvert at mile marker 314.6 was monitored from January 1, 1998 until July 22, 2004. The eastern culvert at mile marker 314.8 was monitored from January 14, 2002 until November 21, 2005, but the western culvert was not monitored because it was full of deep, fast-moving water. The western culvert at mile marker 315 was monitored from July 21, 2003 until July 17, 2005. The eastern culvert was not monitored because it was full of deep, fast-moving water The MP315 culvert had a camera stolen in July 2004, whereupon a new camera was hidden outside the culvert, after which it did not work as well. On August 17, 2004, a camera was added below the Montana Rail Link bridge, where it was maintained until May 4, 2005. Trailmaster cameras were used with both passive IR beam or active IR beam triggers. A trial camera was also placed at the track bed to attempt to duplicate the results of track bed counts. Cameras were operated continually until the camera at MP 315 was stolen. At that point the other cameras were removed although a second camera at MP 314.6 in the easternmost culvert was also stolen before we could remove it.

After construction RECONYX digital motion-sensor cameras were used. Cameras were placed at the eastern fence ends attached to the guardrail with security boxes. At the western fence end a single camera was attached to the bridge supports at the county road underpass. Cameras were deployed in the culverts at MP 314.5 where they were attached to the ceiling of the culvert and secured with locking cables.

Cameras were maintained for constant monitoring. They were downloaded periodically and batteries were replaced as needed. In the case of the culvert cameras, maintenance could not be done during the periods of high water in spring runoff; however batteries were usually replaced just prior to high water so that they operated throughout.

Analyses

Road-kill

Power analyses were applied to the pre-fencing Ungulate-Vehicle Collision (UVC) data to determine what degree of change in UVC rates would be statistically detectable when comparing rates before and after the mitigation fences were installed (Hardy et. al. 2006). Results from the power analyses (power = .8; a = 0.05) indicated a three to five year post-fencing study would be sufficient to allow quantitative comparisons to be made (Hardy et. al. 2006). The post construction monitoring period will include three years of data collection thru June 30, 2010. Data for this paper include road kill numbers thru June 30, 2009.

Research has indicated that while wildlife fencing decreases ungulate mortality within fenced areas, a majority of animals tend to get killed at the fence ends (Clevenger et. al. 2001). To accommodate this end run effect, a buffer of 0.2 miles (322 meters) of additional roadway was added to the analysis area considered as the fenced area (Hardy et. al. 2006). All data representing the fenced area thus includes the actual fenced section plus the buffered area (fence/buff).

Pre-fencing

Pre-mitigation data indicated that UVC rates were significantly higher within the proposed mitigation zone then elsewhere along the highway using 2001-2004 data (Hardy et. al. 2006). We further refined the analysis by including all pre-mitigation UVC data (2001- April 4, 2005) and compared UVC rates inside the proposed fence/buff area to those outside the fence/buff area.

Interim

Due to the longevity of this project, UVC numbers were broken into three separate categories within the mitigation zone; pre construction included 1544 days, interim (MRL bridge reconstruction and wildlife fencing installation) 819 days, and post construction 726 days (thru June 30, 2009). During the interim period, traffic patterns were restricted to two-lanes and speeds were reduced to 56 kph (35 mph). Recorded UVC numbers dropped sharply. To determine if the disruption and changes in traffic were affecting UVC rates, we ran a comparison of pre-fencing and interim UVC means both inside and outside the fence/buff zone. If there was a significant difference in UVC means then the data for the interim period would be omitted from further analysis.

Post-fencing

To determine what effect the fenced area was having on UVC within the mitigation zone, we ran a series of two- and one-tailed t-tests on UVC means both spatially and temporally. Spatial data were examined to see if the fencing was having an effect on UVC inside and outside of the fence. Temporal data were examined to see if UVC rates were different pre- and post-fencing.

After the fencing was completed, we wanted to investigate these three research questions:

1) Did UVC rates significantly decrease within the fence/buff zone during the post-fence period compared with the pre-fence period?
2) Did UVC rates outside the fence/buff zone differ pre- and post-fencing?
3) Are UVC rates in the fence/buff zone different from those rates outside the fenced area during the post-fencing period?

To address these questions, we tested these three null hypotheses.

1) UVC rates post fencing in the fence/buff zone did not differ from those pre-fencing.
2) UVC rates outside the fence/buff zone did not differ pre- and post-fencing.
3) Post fencing, UVC rates in the fence/buff zone did not differ from those outside the fence/buff zone.

Track Bed

In addition to reducing mortality caused by the highway, the mitigation project intended to ensure connectivity or passage across the highway corridor, allowing local and regional migration movement to continue. To test this, we analyzed the tracks per day observed in the track bed data to see if use had increased after fence installation. Track bed data were broken down into pre- and post-mitigation periods. Since the survey methods were slightly different between the pre- and post-fencing periods, only those data collected in a single 24 hour period were used to compare the pre-and post fencing means.

Fence Ends, Jump-outs and Camera Data

Data for the fence ends and jump-outs using remote cameras has only been collected during the post fencing period and will be summarized for animals in the vicinity of the fence ends and jump-outs. There are hundreds of photos from remote cameras at the culverts at mile post 314.6 but due differences in camera type and survey effort we were not able to compare pre-and post-fencing images with any statistical confidence. The culvert photos are useful as an index of animals using the culverts. Species and numbers of animals utilizing these different areas are summarized in the results section.

Track Bed Data for Jump-outs

Track bed data for jump-outs were only collected post fencing. Currently the numbers of animals utilizing the jump-outs is limited. With another year of data collection, jump-out data will provide additional information regarding animals attempting to exit the freeway. A list of species and numbers of tracks are summarized in the results section.

Results

Since 2001, 1,997 animals, representing 49 different species of mammals, birds and reptiles, have been recorded as road kill on Bozeman Pass between Bozeman and Livingston, Montana. See Table 1. The majority of animals killed were ungulates (45%, 901 animals), followed by small mammals (33%, 648 animals), birds (9.6%, 191 animals), carnivores (6.7%, 135 animals) and domestics and unknown (5.3%, 107 animals).

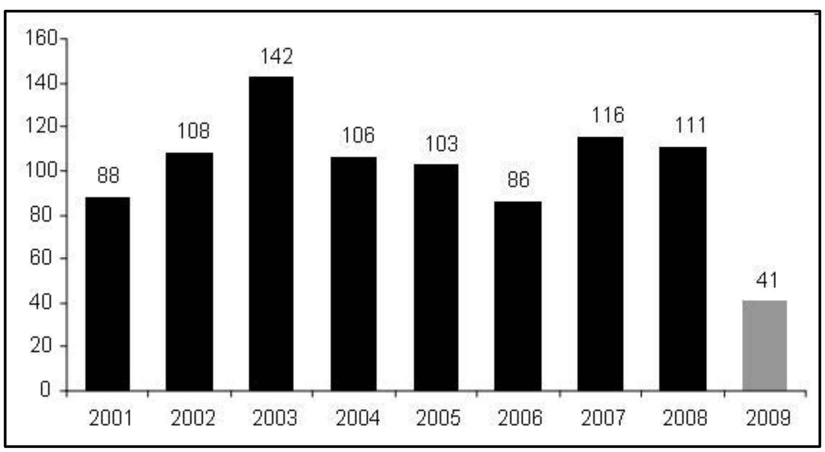

Figure 2. UVC by year (milepost 309.5-333.0) January, 2001- June 30, 2009.

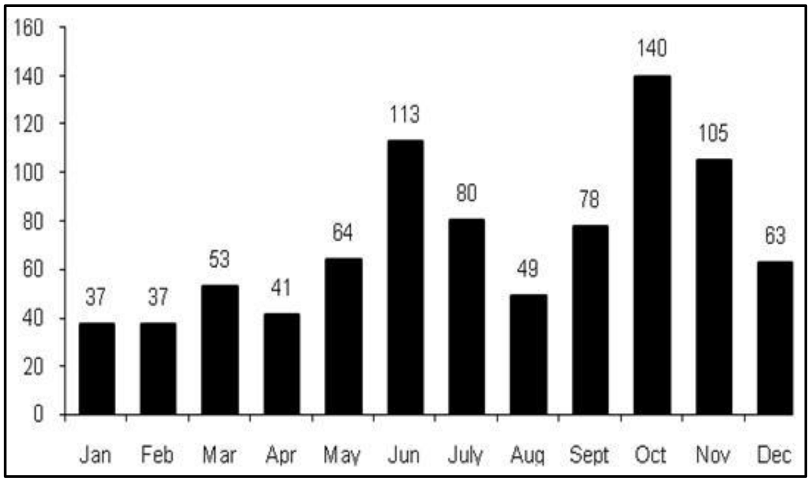

Figure 3. UVCs by month (milepost 309.5-333.0) January, 2001-December 31, 2008

SPECIES	TOTALS
Badger	11
Beaver	9
Bird (Other)[1]	129
Bird (Owl)[2]	49
Bird (Raptor)[3]	13
Black Bear	25
Bobcat	4
Cat (Domestic)	35
Coyote	60
Deer (Mule)	181
Deer (Unk)	273
Deer (Whitetail)	389
Dog (Domestic)	4
Elk	49
Fox	23
Marmot	19
Mink	3
Moose	9
Mountain Lion	5
Pine Marten	1
Porcupine	35
Raccoon	174
Skunk	273
Small Mammal[4]	147
Snake	5
Unidentifiable	68
Weasel	3
Wolf	1
TOTALS	**1997**

1. Includes pheasant, Hungarian partridge, grouse, turkey, goose, duck, heron, raven, crow, magpie, cowbird, robin, pigeon, meadowlark, towhee, tanager, and unknown.
2. Includes great horned, long-eared, and unknown species.
3. Includes red-tailed hawk and northern harrier.
4. Includes rabbit, ground squirrels, and gopher.

Table 1. Total number of road kills recorded between milepost 309.5-330.0 from January 01, 2001 thru June 30, 2009

UVC totals across the entire study area fluctuate yearly over the span of the study with a peak in 2003 and a low in 2006. (Figure 2). Seasonally, the highest number of ungulates were killed in the fall (October) followed by a smaller summer peak (June). Winter tends to have much fewer road kills (Figure 3).

Pre-fencing

Within the mitigation zone, there were significantly more UVCs within the proposed fence/buff area compared with the area outside (data set January 1, 2001-April 3, 2005; two-tailed T-test, P<.00). This finding justifies the placement of the mitigation fencing on this stretch of highway.

Interim

During the interim period of construction and fencing, UVC rates were greatly reduced in the mitigation zone due to lower traffic speeds and two-lane traffic patterns (Table 3). The reduction in mean number of UVCs was significant between the pre-fencing and the interim period both inside and outside the fence/buff zone (paired t-test, P < .01 (outside), P < .02 (inside)). All interim data were therefore omitted from further analyses.

Stretch	Pre	Interim	Post
Fence/buff	10.9	3.8	4.3
Outside	6.9	4.8	7.4

Table 3. UVCs in mitigation zone calculated as UVC per mile per year

Post-fencing

We found that the mitigation fencing significantly reduced the overall UVC rates in the fence/buff area from the pre- to post-fencing period (one-tailed t-test, P<.02). In the two years of post monitoring, UVC rates were reduced from pre-fencing high of 49 animals in the fenced area alone to only 5 animals in the fenced area. Three of the five animals killed in the fenced area were killed at the fence ends. See Figure 4. Additionally, the fencing had no significant effect on the UVC rates outside the fence/buff area (two-tailed t-test, P<.59). Finally, we found that post-fencing UVC rates within the fence/buff area were still higher than outside the fence/buff area within the mitigation zone, however the difference might be considered only marginally significant (two-tailed t-test, P>.11). There was no evidence of increased mortality at the fence ends however this is preliminary data and another full year of data collection may result in different conclusions.

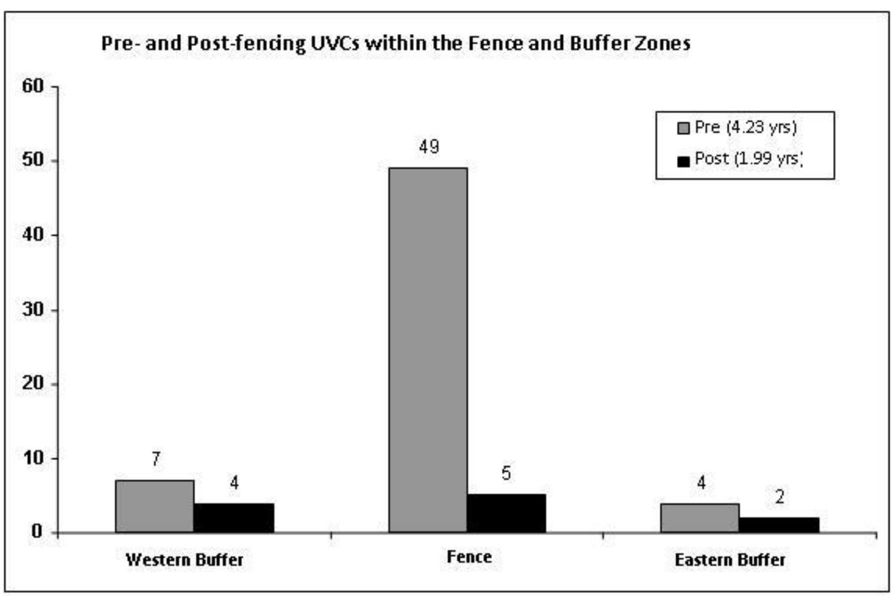

Figure 4. Pre- and post-fencing UVC's within the fence and buffer zone

Track Bed

After the mitigation fencing was installed, we found the number of daily ungulate crossings underneath the MRL bridge had significantly increased (two-tailed t-test, $P < .01$). This, along with the significant reduction in UVCs within the fence/buff area, indicates that this mitigation strategy is beneficial to ungulates in reducing road kill while maintaining connectivity of habitat.

Remote Camera Data for Fence Ends, Jump-outs, and Culverts

Post fencing data indicated that animals are reliably being photographed in the vicinity of the fence ends and jump-outs. These monitoring techniques are limited in determining if animals successfully cross the freeway. See Table 4. Preliminary data indicate that some mammals are trying to cross at the fence ends. In a few instances, animals are successful in finding and using the jump-outs.

The majority of photos taken were birds including, magpies, ravens, crows and robins which tended to flock near the jump-outs. A variety of other mammals were photographed at the fence ends or in the vicinity of the jump-outs.

Species	**Fence Ends**	**Jump-outs**			
		NE	NW	SE	SW
Birds	7	72	10	19	0
Deer	9	1	1	2	0
Coyotes	4	4	0	0	0
Marmot	1	0	0	0	0
Raccoons	0	7	0	4	0
Rabbits	3	2	0	6	0
Skunk	1	1	0	0	0
Weasel	1	0	0	0	0
Black Bear	0	1	0	1	0
Human	2	1	0	2	1
Total	**28**	**89**	**11**	**34**	**1**

Table 4. Animal occurrences near fence ends and jump-outs (January 1, 08 -March 30, 09) using remote cameras.

Pre-and post fencing photograph comparisons in the culverts are not applicable in this study. However, preliminary data show that the same suite of species is utilizing the culverts to pass underneath the freeway. Animals associated with aquatic habitats tend to use the culverts more than other animals with the exception of the black bear. See Table 5. The data also indicate that the eastern culvert (which has little or no water most times of the year) is used more heavily than the western culvert (which contains about 2 feet of water usually).

Track Bed Data for Jump-outs

During the post fencing monitoring period, there have been a total of 36 different tracks recorded representing a variety of mammals and reptiles at the jump-outs. The majority of tracks have occurred at the NE and SE jump-outs. We have found marmots living in the vicinity of the jump-outs and using them as a latrine site, which over represents their presence.

	Pre-fencing		Post fencing	
Species	314.6 E	316.4 W	314.6 E	314.6 W
Beaver	5	0	2	0
Birds	9	0	7	0
Black bear	0	1	1	3
Domestic Dog	4	2	0	0
Duck	0	1	0	0
Frog	0	1	0	0
Mink	0	0	6	0
Mustelid	7	0	0	0
Nest	3	0	0	0
Raccoon	82	1	49	5
Unknown animal	4	0	0	0
Dipper	0	0	10	0
Human	8	0	3	2
Total	**122**	**6**	**78**	**10**

Table 5. Remote Camera Occurrences in Culverts (milepost 314.6)

	Jump-outs			
Species	NE	NW	SE	SW
Black Bear	1	0	0	0
Cat (domestic)	0	1	2	1
Canid	2	0	2	0
Deer	1	1	2	0
Marmot	9	1	5	0
Rabbits	2	0	2	0
Small mammal	1	1	0	0
Snake	1	1	0	0
Total	**17**	**5**	**13**	**1**

Table 6. Track bed data for survey period (Aug. 2, 07 –June 20, 09)

Discussion

Our preliminary findings indicate that the installation of wildlife fencing and jump-outs has significantly reduced UVC's in the fence/buff area near the MRL bridge. Additional monitoring of the track bed underneath the bridge has shown an increased use by ungulates indicating the effectiveness of fencing in funneling animals away from the freeway and maintaining habitat connectivity. Over time, the area underneath the bridge may see increased use as animals discover it and become more accustomed to using it. Animals still try to cross at the fence ends as road kill data and photo monitoring document but our data do not indicate a significant increase of road kills at the fence ends. Data also indicate that animals are occasionally utilizing the jump-outs as an effective means of exiting the freeway. Culvert monitoring has documented the long term use of a variety of animals and people utilizing the culvert as a means to cross underneath the freeway safely.

During the post-fencing monitoring period, there has been a total of five UVC's in the fenced area (2 within the fence, 3 at the fence ends). With another year of data collection, those numbers will change but the overall effectiveness of the fencing is clearly a benefit to animals and drivers. At this time, there has not been an overall increase in UVC's at the fence/buff zone.

While overall UVC rates are slightly higher within the fence/buff area than outside, some of those findings may be attributed to the overall distribution of ungulates in the vicinity of the MRL bridge. Initial analysis documented high UVC's towards the western edge of the fenced area and points further west. Therefore, the fencing seems to be only straddling this hotspot; not completely covering it. In the future, if the fence could be extended to the west then UVC rates inside the fence/buff area may be comparable with outside fence/buff area. Areas to the west and east already contain culverts that could be utilized by animals to cross if fencing were extended and ended at these culverts. The length of the fence could be effectively increased by installing a test section of electric fencing that continues eastward from the east end of the current fence. This electric fence could also tie into two more sets of culverts underneath the highway and thus deflect animals away from the highway and through the culverts. At the northeast end of the electric fencing it could tie into a steep hillside where end-runs of the fence would be minimal. At the southeast end it could stop in a section where the opposite side of the highway is steep hillside and cliff which would help discourage animals from attempting to cross there. Fence ends could be blocked more effectively with the use of an electrified mat that extends from one fence end to the other across the shoulders and the highway surface (East end of fencing project).

The Bozeman Pass project highlights the effectiveness of reducing UVC through wildlife mitigation strategies such as wildlife fencing, jump-outs and modified earthwork. This suggests that fencing projects alone can be added to help direct animals through existing structures. It also highlights the need for innovative monitoring techniques pre- and post-mitigation to provide quantitative measures of effectiveness.

Costs for this project were much lower than new wildlife crossing structures since the fencing was added on to a structure replacement project for an existing underpass. While the cost of these mitigation techniques is not inexpensive, working with transportation managers and planners before planned rebuilds/upgrades can lessen the cost substantially. The cost of the planned MRL bridge rebuild in 2005-2006 was approximately six to eight million dollars (Deb Wambach, pers. comm.). The cost of the wildlife fencing and jump-outs was approximately $100,000 which increased the cost of the re-build by only about 1.25%. While that may seem like a large expense, it is only a fraction of the cost that insurance companies pay out yearly for reported UVC. Taking into account the average cost of repairs to drivers of an ungulate collision ($6,000-$8,000), the costs of injury treatment, the indirect costs of accidents to police and medical personnel, and the ecological costs of highway barriers to wildlife populations, the overall benefits to society have already begun to be realized.

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Biographical Sketches

April C. Craighead received her BA in Ecology, Evolution and Behavior (EEB) from the University of California, San Diego in 1989. She received her MS in Biological Sciences from Montana State University, Bozeman in 2000. April has been working for the Craighead Environmental Research Institute (CERI) since 2000 on a variety of projects. Currently, she continues to work on Bozeman Pass and road ecology issues and climate related projects involving the American pika.

Dr. Frank Lance Craighead is the Executive Director of the Craighead Environmental Research Institute. He is an experienced field ecologist, population geneticist, and conservation planner. His current research interests are focal or umbrella species, population and metapopulation persistence, gene flow, habitat connectivity, core and protected areas, and carnivore ecology. Dr. Craighead has published numerous scientific papers, completed two book chapters, and published one book, *Bears of the World*, for Colin Baxter/Voyageur Press. He is a member of the IUCN World Committee on Protected Areas, the Society for Conservation Biology, The Society for Conservation GIS and the Wildlife Society. He currently serves on the Montana Department of Fish, Wildlife, and Parks Connectivity Working Group to develop connectivity science and policy for the Western Governor's Wildlife Corridor Initiative. He also directs the Craighead Center for Landscape Conservation, a conservation research and education program centered in Bozeman, Montana. The Center is a nexus for field and community work to see that the best science is used in making conservation land-use and policy decisions. Dr. Craighead and Center colleagues develop and refine conservation science tools and apply these tools to community-based conservation projects in the Rocky Mountains, the Madison River Valley, eastern Tibet, Bozeman Pass, British Columbia and Alaska.

Lauren M. Oechsli received her BA in Biological Sciences from Columbia University, N.Y. (1992) and her MS in Biological Sciences from Montana State University, Bozeman (2000). Her Master's work focused on the impacts of exurban development on native vegetation and wildlife diversity. As a GIS Analyst and Manager for American Wildlands (2000-2006), Lauren modeled watershed and river integrity at the local scale for most of the US portion of the Yellowstone to Yukon region. She then worked as a GIS Analyst on various Road Ecology projects at Western Transportation Institute, MSU. Currently, she conducts data analysis, GIS modeling, and mapping on wildlife habitat and connectivity projects for Craighead Environmental Research Institute in Bozeman, MT.

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Predictive Models of Herpetofauna Road Mortality Hotspots in Extensive Road Networks: Three Approaches and a General Procedure for Creating Hotspot Models that are Useful for Environmental Managers

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Abstract

Road-kill and connectivity blockages caused by roads and road traffic can result in serious population declines of amphibians and reptiles. Landscape-scale modeling of road mortality risk and road-caused habitat fragmentation indicate that effective monitoring and mitigation of these impacts on herpetofauna require attention to the entire regional road network. The time and expense to adequately survey an extensive road network may be prohibitive to agencies, however, so there is a need for accurate and efficient models to prospectively identify the most promising sites for monitoring and mitigation. In this paper, I review three general methods by which road-kill hotspots and connectivity blockages caused by roads can be predicted throughout a road network by creation and use of predictive models. I also review two studies, one focused on all herpetofauna and a second focused on freshwater turtles, which were designed to identify valid predictors of hotspots of road mortality in northeastern New York State, USA. In this paper, I propose a procedure to develop survey methodologies and to create and validate predictive hotspot models that use publically-available GIS data to locate severe road-kill sites or connectivity blockages for reptiles and amphibians. I also explain some of the informational and logistical challenges to developing hotspot models that are useful for management agencies. I argue that predictive hotspot models are tools that are essential for effective and economical whole road-network survey and mitigation, and for planning new road routes that avoid areas of high road-kill risk or critical corridors for habitat and population connectivity. While such models have already proven useful for mammals, hotspot models may be especially effective for reptiles and amphibians, which typically have hotspots that are short in length but severe in effect.

Introduction

Mitigation projects aimed at reducing road mortality or maintaining habitat connectivity for reptiles and amphibians are typically implemented at a small number of high-profile sites in response to pressure of local interest groups or regulatory agencies; it is likely that most sites for effective mitigation are missed by this ad hoc approach (Spellerberg 2002, Evink 2002). Reptile and amphibian populations often have the characteristics of either a metapopulation, or a single population in which individuals move among multiple, spatially separated patches (e.g. hibernacula, breeding sites, and foraging habitat); in either case movement between patches often necessitates crossing roads (Marsh and Trenham 2000, Semlitsch 2000, Roe and Georges 2007). Unless mitigation technologies and best-practices for reducing herpetofauna road mortality and maintaining connectivity are implemented systemically throughout a road network, some species are likely to decline in densely-roaded landscapes (Gibbs and Shriver 2002, 2005, Roe et al. 2006, Compton et al. 2007, Litvaitis & Tash 2008). Population declines may be a consequence of excessive road mortality when animals attempt to cross roads, or due to reduced habitat connectivity that results when animals avoid crossing them.

Mitigation technologies such as culverts, fencing, and signage have been used to reduce road mortality and maintain habitat connectivity for reptiles and amphibians. However, these technologies are expensive or labor-intensive, making them impractical to implement throughout a road network (see reviews in Evink 2002, Bank et al. 2002, Forman et al 2003, Bissonette & Cramer 2008, Glista et al. 2009). Methods of efficiently and accurately locating critical sites for mitigation are essential for successful systemic environmental management of road-kill and connectivity, since resources (money, time) are severely limited for installation and maintenance of barriers, passageways, and signage; road networks are vast; and reptile and amphibian populations are likely to be subject to severe road mortality or connectivity blockages at multiple sites. Such critical sites include (1) where herpetofauna are most likely to cross roads, (2) where risk of road mortality is highest, and (3) where structural barriers or behavioral avoidance prevent reptiles or amphibians from crossing roads to access resources or other sub-populations.

Note that these three classes of critical sites do not necessarily overlap: critical sites for connectivity may not correspond to the locations where road crossing and road mortality are highest, if critical connectivity sites have features that deter reptiles and amphibians from attempting to cross the roadway or if populations near these sites are already reduced due to past road mortality. Similarly, sites of peak road crossing are not necessarily sites of peak road-kill, since road-kill numbers are a function of both crossing rate and vehicle traffic volume (Seiler & Helldin 2006).

Numerous studies have concluded that reptile and amphibian mortality is often clustered at hotspots, localized segments of road that have disproportionately high densities of road-kill (Langen et al. 2009). If landscape and road features associated with hotspots could be identified, and if data on the spatial dispersion of these predictive features along roads is known, then these predictors could be used to locate critical sites throughout a road-network. Such hotspot modeling is currently being applied to identify critical sites for road crossing by mammals (e.g. Smith 1999, Clevenger et al. 2002, Malo et al. 2004, Ramp et al. 2005, Seiler 2005), and the potential for aiding in systemic management of herpetofauna on roads appears promising. In this paper, I review three ways in which predictive hotspot models can be created 'from the ground up' for predicting critical road segments for reptiles and amphibians, review two case studies from my own research, and provide some recommendations on how road managers might go about generating and validating useful predictive hotspot models for road networks in their regions.

General Requirements for Creating Hotspot Models

To create valid models to predict hotspots of road-mortality or critical linkages for connectivity, seven components are necessary:

(1) Reference locations of representative hotspots.

On a sample of roads that are representative of the road network, one must have empirical data on where road mortality is most dense (or historically most dense before road-kill associated population declines), or where animals would cross if not inhibited by the road and road traffic. This can be done by directly measuring patterns of road-crossing and road-kill, or by tracking movements of animals to document where they cross or are deterred from crossing.

(2) Database of potential correlates.

To use known hotspots on a road network to predict others, it is necessary to have accessible, accurate data on the locations of relevant potential correlates or determinates of critical locations for connectivity or road mortality. Such data could include road segment traffic volumes; locations and density of populations of focal species; land use and land cover around roads; and locations of wetlands, rivers, and other water bodies. Such data must be accurate to an appropriate spatial scale (see next point) to be usable.

(3) Scale.

Hotspots may be the result of highly local conditions such as the habitat in the immediate vicinity of a road segment and the configuration of the road relative to the surrounding landscape (elevated, level or sunken; straight or curved); or else the locations of hotspots may be determined by landscape level patterns of animal abundance, land use, land cover, hydrology, and topography. In model development, it is necessary to determine the best spatial scale(s) at which putative predictors indicate locations of hotspots.

A second issue of scale is how fine a resolution to define hotspots. This is a factor of the spatial extent (length of road) and severity (e.g. density of road-kill above background levels) of individual hotspots, and the degree of spatial clustering of different hotspots in a network. Ideally, hotspots will be short in length and very severe. Short, severe hotspots can be more easily mitigated by barriers and passageways or other mitigation methods than when road-kill or critical connectivity blockages are distributed over a broader extent of the road.

(4) Model generation.

Hotspot models are typically generated using some form of exploratory stepwise general linear modeling. One typical method is to compare a set of locations that are known hotspots to a set of random locations on the road network. Logistic regression is used, with the dependent (outcome) variable dichotomized as hotspot vs. random location. Backwards (starting with a saturated model of all potential predictors) and forwards (starting with the single best predictor) stepwise procedures can be used, or any other procedure that facilitates exploration of the most promising candidate models. Note that the goal is to identify models that can be used easily by managers to locate hotspots, so simplicity should be a consideration when selecting models to explore. Also note that if the correct spatial scale for including land use (or other predictors) is unknown, multiple models with the same variable set measured at different spatial scales (e.g. land use at 100 m, 500 m, and 1000 m around a location) might be necessary.

(5) Method of model selection.

The method of model selection should provide a clear procedure for evaluating alternative models. Models should be evaluated by both (1) comparing the relative fit of alternative models, and (2) comparing the accuracy of the best model at predicting hotspots. For comparing models and identifying a set of best models, I advocate using methods described in Burnham and Anderson (1998), which uses Akaike's Information Criterion (AIC). The procedures described in Burnham and Anderson's (1998) book indicate how models can be compared, and also provide a way to compare the relative importance of different predictors that are used in the set of evaluated models. To evaluate the accuracy of best models at predicting hotspots vs. other locations (accurate models having both few misses and few false positives), there are several valid methods reviewed in Fielding and Bell (1997). When evaluating models, the 'best' model for the purpose of locating hotspots should be similar in terms of the quantitative criterion (AIC) to the one that is the best by this metric, be accurate at prediction (few misses or false positives), use predictive variables for which accurate data exist along all roads within the network of concern, and be easy to use and interpret by road managers.

(6) Method of model validation.

In principal, during the model development and selection stage, only half of the data could be used to generate the model, and the other half used to validate. This may be unwise if the amount of data (e.g. number of known hotspots) is limited. A better method of validation is a survey that uses the predictive model to indicate hotspots of road-kill or connectivity blockages on a section of the road network that was not use to generate the data for the model development. Paired to the predicted hotspots should be a matched set of random locations in the regions of the predicted hotspots. In the validation phase, the tested hypothesis would be that predicted hotspots have higher densities of road mortality or serve as more important movement barriers than random locations along the road network.

Note that it would be possible with a hotspot model to predict coldspots – locations for which road-kill densities are lower than average or that are the least severe barriers for movement. One could validate by surveying matched pairs of predicted hotspots and coldspots. However, this would be risky, in my opinion, since a significant difference in road-kill densities between predicted coldspots and hotspots could be merely due to the model being successful at predicting coldspots, while performing little better than chance at predicting hotspots.

(7) Adaptive modification of the model.

Even if the model proves to be accurate at predicting hotspots, there is likely to be residual error: predicted hotspots that are no more severe than chance, and sites that are not predicted to be hotspots that in fact are. It is important to evaluate how correctly predicted hits (hotspots) differ from false alarms, and how misses (locations predicted not to be hotspots that in fact are) differ from correctly predicted non-hotspot locations. Based on any insight gained from this analysis of residual error, the model can be modified and again validated on a new road network.

Method 1: Modeling Animal Movements

One method of creating a predictive model of road-kill hotspots or key sites for connectivity involves collecting data on movement patterns of individuals of target species in relation to roads, then using these data to simulate animal movements in other roaded landscapes. By simulating movements of many individuals, one could predict segments of road where animals would be most likely to attempt to cross, or else segments where they would cross if not deterred by the road or road traffic. Using the predicted spatial patterns of road-crossing, one could further model the risk of road mortality to animals crossing at each road segment, and thus spatial patterns of road-kill.

High-resolution measurement of movement patterns of individuals in real roaded landscapes is typically done via intensive radio-telemetry. This method is expensive and time-consuming, and only feasible for sampling a limited number of individuals over a small proportion of a road network. Radio-telemetry of individual reptiles and amphibians can potentially reveal not only where individuals are likely to cross, but also where animals are deterred from crossing (Shepard et al. 2008, Beaudry et al. 2009). This latter information is critical for locating choke-points on population connectivity.

To create a model of critical sites along roads for road mortality and habitat connectivity:

(1) Typical movement trajectories are modeled using data on patterns of actual animal movements generated from radio-telemetry or other methods: e.g. over what land cover individuals of a species prefer to move, how far they travel during long movements between habitat patches, how straight and direct are movements between patches (e.g. for two turtle species, see Beaudry et al. 2009).

(2) The locations of the primary resource patches between which animals move are accurately mapped using GIS in relation to roads. Depending on the taxon, the relevant resource patches may include breeding sites, foraging habitat, and hibernacula (e.g. for vernal pools used as breeding sites for vernal-pool breeding salamanders, see Compton et al. 2007).

(3) Movement trajectories between resource patches of virtual animals are simulated, using the modeled trajectories in Step 1 and the resource patch maps in Step 2. The simplest models are 'gravity models' which model trajectories that are 'least-cost' in terms of distance traveled between patches, with some cutoff for distances that are considered too long to be feasible for the modeled species. An added feature can be to rank the quality of resource patches, and thus simulate trajectories that are a compromise of minimizing the cost of travel while maximizing the quality of the resource patch that is traveled to (e.g. for turtles, see Beaudry et al. 2009).

An even more detailed approach is to incorporate landscape resistance, in terms of different travel cost coefficients for traversing different land uses or crossing roads. For the purposes of modeling movement trajectories, these cost coefficients are based on how they affect animal behavior – how willing individuals of the modeled species would be to traverse habitat of each resistance class. Although ideally resistance coefficients are generated directly from behavioral data, they may also be inferred via 'expert opinion' (e.g. Compton et al. 2007). Similar to simpler gravity models, one models trajectories that are 'least-cost' in terms of the product of distance and the resistance coefficients of the landscape traversed (e.g. for toads see Joly et al. 2003, for vernal-pool breeding salamanders see Beaudry et al. 2009).

(4) For species that are deterred by roads or road traffic, one could create matched simulations of animal movement trajectories with and without roads. Variable road resistance depending on road size and traffic volume could be encoded via different resistance coefficients depending on classes of size and volume. Comparing simulations, locations for which movement trajectories frequently cross in the road-less simulation but are rarely traversed in the roaded simulation are potentially excellent candidates for passageways or other methods to preserve or restore habitat connectivity.

(5) For species that readily attempt to cross roads when traversing between resource patches, the spatial patterns of road crossing produced in Step 3 can be converted into a density of road-kill using standard models of road-kill risk. These models use traffic volume and speed of animal movement when crossing roads to estimate risk (e.g. Gibbs and Shriver 2002, 2005; Litvaitis & Tash 2008). Thus, hotspots of road-mortality are predicted as a function of how frequently animals attempt to cross at each road segment and the probability that crossing animals are killed by vehicle traffic at the segment. The relative severity of hotspots could then be ranked to provide a priority ranking for monitoring and mitigation.

(6) Validation would include monitoring movement patterns of animals in the vicinity of the predicted connectivity blockages caused by roads as indicated in Step 4, or measuring road-kill densities at predicted hotspots as indicated in Step 5, and comparing these to random segments of road within the network.

(7) Assuming that the model is confirmed as predictive, residual error should be evaluated. For example, what features are associated with predicted hotspots that in fact have little road mortality vs. predicted hotspots that (as predicted) do have high mortality? What features are associated with segments predicted to have few road-kill that in fact are hotspots, vs. those for which (as predicted) road mortality is not severe.

(8) Revise the model using the results of Step 7, and again validate it on a new road network. Repeat Step 7 and Step 8, should further improvement of the predictive accuracy of the model be desirable and judged feasible.

The disadvantages of attempting via simulations of animal movements to infer hotspots of road-kill or blockages to habitat connectivity caused by roads and road traffic include the difficulties of (1) gathering enough movement data on animals to accurately infer how movement trajectories are affected by land use, road presence, traffic volume, and distribution of resources, i.e. the data necessary to generate valid cost functions, and (2) assembling accurate data at a useful spatial scale on land use, resource patch quality and other factors required to create a valid 'resistance surface' throughout the road network.

Moreover, given the logistical challenges of collecting adequate animal movement data, this method is only suitable for studies focused on one or a very few species of reptile or amphibian. It is only suitable for locating herpetofauna hotspots in general in the case that the focal species movement patterns indicate movement patterns of the wider community of reptiles and amphibians in the landscape; this may be true for wetland-associated reptiles and amphibians, whose road-kill hotspots overlap (Langen et al. 2009).

The advantages of modeling animal movements as a tool to identify road-kill hotspots include that the simulations can be used to predict not only where road-kill hotspots currently occur, but also locations where road-kill was likely high in the past but is now low because local populations of the modeled species have been reduced by excessive road mortality. The method can predict road-kill hotspots and connectivity blockages of proposed new road routes, so that route modifications or prospective mitigation can be incorporated early in the road planning stage.

Unlike other methods, by modeling animal movements, it is not necessary rely on observed spatial patterns of road mortality to develop the hotspot model. Some road managers may be tempted to infer that road segments with few road-kill are benign, when some of these segments may in fact be severe barriers to connectivity. By modeling animal movements, one can distinguish low road-kill road segments that are unimportant as movement corridors from those that are critical connectivity blockages.

So far, studies that have modeled animal movements in relation to roads have done this mainly as an exercise to estimate regional population viability as impacted by road-kill and reduced habitat connectivity, or else to show how well the method works at predicting crossing patterns at specific road segments. In one of the most thorough studies, Beaudry et al (2003) identified spatial patterns of road crossing for two threatened species of turtle, but found that the predicted crossing hotspots were too broad and too numerous to feasibly mitigate via barriers and passageways. Although this modeling method is promising, I am not aware of any study that has yet tried to use it to predict the location of hotspots or connectivity blockages throughout a large road network, and then tested the predictions to evaluate the utility of it as a network-wide predictive tool.

Method 2: Creating Models Based on Point-Transect Data

Point-transect surveys are short fixed-length segments of road that are sampled intensively for road-kill. Walked point-transects are appropriate when road-kill cannot be reliably detected from a moving vehicle because of small size. Point-transect surveys are suitable as a survey methodology when road-kill is dense, such that remains of multiple individuals are likely to be encountered, at least at hotspots of mortality. Langen et al. (2007), for example, found that amphibians were not reliably detected via driving surveys, but multiple individuals could be detected by walking 100 m segments of road.

To create predictive models of road mortality hotspots, point-transects at known hotspots and at randomly or uniformly-distributed locations can be surveyed. Road, local features, and larger landscape features can then be evaluated as putative predictors of road mortality hotspots using presence/absence of road-kill at point-transects, or the actual number of road-kill recorded at each transect.

To create a model of road mortality hotspots using point-transect data:

(1) Preliminary methodological validation is required to determine the appropriate length of point-transects. Point-transects should be long enough that road-kill is likely to be detected at locations where road mortality is relatively high. Preliminary validation of the survey methodology should also assess the timing of surveys, to optimize the probability of detecting road-kill. Furthermore, it is necessary to quantify the ranked repeatability of point-transect counts, to determine whether multiple resurveys of each point-transect are necessary to accurately rank the relative density of road mortality among surveyed locations. For an example, see Langen et al. (2009).

(2) A sampling protocol for spatially distributing point-transects along surveyed roads must be specified. Point-transects should be distributed throughout a section of road network that is representative of the wider road network for which the model is intended to apply. An adequate number of point-transects is determined by the likelihood that some point-transects will be located within road-kill hotspots. If hotspots are small in spatial extent and few in number along a road network, many randomly or uniformly-spaced point-transects may be required to insure that enough are encountered that the predictive hotspot model can be created. If some hotspot locations are known prior to conducting a survey, they can be included, and fewer random point-transects will be necessary.

In addition to including any known hotspots within a survey, I advocate uniformly-distributed locations over random locations for point-transects. A uniform distribution of survey locations helps to insure that there will be adequate spatial dispersion of samples throughout a surveyed road network.

One methodological problem is that spatially-nearby point-transects are usually surveyed close in time, as a logistical convenience of surveying routes. If so many points are to be surveyed that there is a risk that average road-kill densities will vary over the time-course of a survey period, there must be some methodological measures taken to reduce the risk that spatial and temporal trends are confounded. This may include repeating point-transects in varying temporal order, or clever routing of the survey to minimize the risk that temporal autocorrelation is confounded with spatial autocorrelation. The temporal autocorrelation problem is particularly problematic for amphibian surveys, because amphibian movements are so weather and microclimate dependent and because road-kill amphibians disappear so quickly from the roadway. For a discussion of methodological considerations pertaining to point-transect surveys, see Langen et al. (2007, 2009).

(3) A database of features that are potentially predictive of road-kill density around point-transects must be assembled. Such features could include road attributes (e.g. traffic volume, road configuration, bordering vegetation), land use and land cover at a series of spatial scales around the point, hydrology and topography, and locations and quality of key resource sites that are the target of animal movements (e.g. wetlands, nesting sites). Some features may be noted in the field during a survey, whereas others can be acquired by analyzing GIS data coverages of relevant features.

(4) A valid method of exploratory statistical analysis must be selected to create a useful predictive model. Modeling to evaluate potential predictors of road mortality hotspots based on point-transect data typically is done using stepwise general linear modeling, using a valid method of exploratory model evaluation such as AIC. Depending on the distribution of road-kill counts among point-transects, the dependent variable may either be presence vs. absence of road-kill, if many locations have zero road-kill recorded, or else the number of road-kill per point transect, if the distribution of counts is more continuous. The relative predictive strengths of models are compared, the accuracies of the best predictive models are evaluated, and the relative importance of each potential predictor is determined. A model selected for validation should be one that is accurate at discriminating road-kill hotspots from other point-transects, and uses predictors for which data can be acquired easily on all roads for which hotspots are to be predicted using the model.

(5) A validation study must be done to evaluate the usefulness of the predictive model. Validation is straightforward: use the candidate best predictive model to predict hotspots of road-kill in a comparable road network to the one used to create the model, and survey those predicted hotspots and a comparable set of random locations.

(6) Assuming that the model is confirmed as predictive, evaluate the residual error. What features are associated with predicted hotspots that in fact have little road mortality vs. predicted hotspots that (as predicted) do? What features are associated with random locations that have severe road mortality present, vs. those that (as predicted) are not severe?

(7) Revise the model using the results of Step 6, and again validate it on a new road network. Repeat Step 6 and Step 7, should further improvement of the predictive accuracy of the model be desirable and judged feasible.

An advantage of using point-transects for modeling is that it is relatively easy to collect road-kill data, and point-transects are a valid methodology for estimating road-kill densities. Patterns of road-kill of all reptile and amphibian species can be collected at the same time using this method. It is straightforward and easy to create predictive models of road-kill hotspots using point-transect data, and validation is also straightforward and easy. A disadvantage of walked point-transects is that much less of a roadway can be surveyed during a specified period of time than would be using a driving survey methodology.

A second disadvantage is that point-transects of road-kill are useless at detecting sites where animals are deterred from road-crossing, and thus critical blockages to connectivity caused by road avoidance cannot be directly detected by this method. A related disadvantage of the point-transect method is that it will not detect sites that were formerly road-kill hotspots but are no longer because populations in the vicinity have declined due to past excessive road mortality.

One possible way to overcome these disadvantages would be to conduct the surveys to be used to create the hotspot model in a region where abundant and well-connected habitat, low traffic volumes, and low road density make population declines near roads and road deterrence unlikely. A predictive model created in such a region could be used to predict road-kill hotspots in a region where road densities and traffic volumes are higher, and habitat is scarcer and more fragmented. Road segments for which the model predicts a road-kill hotspot but observed road-kill density is low would raise suspicion that populations bordering the road have declined due to past unsustainable road-kill, or else animals are deterred from crossing.

Case History

As reported in Langen et al. (2009), my students and I surveyed 145 point-transects throughout a 353 km highway network in northeastern New York State, USA for road-kill of reptiles and amphibians. These points included 137 evenly distributed points throughout the network and 8 previously-identified road-kill hotspots. We used 100 m walked point-transects as the method of road sampling, because we previously had found that amphibians could only be validly quantified as road-kill using walked transects (Langen 2007). We used land cover at four spatial scales (50 m, 100 m, 500 m, and 1000 m around the point transect), wetland configuration, and traffic volume to identify features that best predicted hotspots of herpetofauna road mortality. Forty points were resampled an additional 4 times over 4 years to evaluate temporal repeatability of point-transects. We created general linear models predicting presence or absence of road-mortality at point-transects, and evaluated both models and individual putative predictors using AIC.

Both amphibian and reptile road mortality were spatially clustered, and road-kill hotspots of the two taxa overlapped. A single survey provided a valid snapshot of spatial patterns of road mortality, and spatial patterns remained stable across time. Road-kill hotspots were located where wetlands approached within 100 m of the road, and the best predictor was a causeway configuration of wetlands (wetlands on both sides of the road within 100 m of it).

We validated causeways as predictors of road mortality by surveying 180 causeways and 180 random points across five regions (17,823 km^2) of northeastern New York. Causeways were 3x more likely than random locations to have amphibian and 12x more likely to have reptile mortality present, and causeways had a 4x higher total number of amphibian road-kill and 9x higher reptile road-kill than random points. Residual errors were due to inaccuracies in the wetland maps used to identify causeways, and due to including as random points locations that, although not causeways, were adjacent to one large wetland. We concluded that it is possible to identify valid predictors of hotspots of amphibian and reptile road mortality for use when planning roads or when conducting surveys on existing roads to locate priority areas for mitigation.

Method 3: Creating Models Base on Road-Kill Records

The traditional way to identify wildlife road mortality hotspots is via road-kill records; this method has been used primarily to analyze spatial patterns of mammalian road-kill (e.g. Smith 1999, Joyce and Mahoney 2001, Clevenger et al. 2002, 3003, Ramp et al. 2005, Seiler 2005). This method requires a database of accurately-mapped road-kill assembled either from planned road surveys or from ad hoc records collected by law enforcement, road managers, or other sources.

This method is only appropriate for animals that are easily detectable while driving a road, and for which road-kill densities are too low to survey via walked point-transects. To create predictive models of road mortality hotspots using road-kill records, clusters of road-kill are identified using spatial statistics and GIS, and the potentially-predictive attributes of the locations of the road-kill clusters can be compared to a randomly-selected set of locations that are outside of any cluster. Alternatively, attributes around road-kill sites can be compared to a randomly-selected set of locations where no road-kill was ever detected.

To create a model of road mortality hotspots using road-kill records:

(1) Preliminary methodological validation is first required to determine whether targeted reptile and amphibian species are detectable from a moving vehicle. Langen et al. (2007) for northeastern New York State and unpublished data from Costa Rica indicate that slow-speed (less than 40 km/h) driving surveys are adequate for detecting turtles and medium-sized snakes and lizards, but are poor for detecting amphibians and small reptiles. As discussed in Langen et al. (2007), the accuracy of driving surveys at detecting road-kill can be assessed by both measuring inter survey-team repeatability of road-kill detections, and by comparing data collected from road surveys with that of point-transect data collected along the same road network.

Preliminary validation of the survey methodology should also assess the timing of surveys (time of day and season) to optimize the probability of detecting road-kill, and the optimal frequency of repeating surveys. In my experience, except for turtles, reptile and amphibian road-kill disappear quickly from roads, and becomes undetectable via driving surveys within a day.

(2) A valid sampling protocol for driving surveys must be planned. The valid road survey must include (a) a selection of roads that is representative of the characteristics of the wider road-network for which hotspots are to be predicted and (b) a survey route and protocol that results in equal sampling effort and road-kill detectability on all surveyed roads.

Most problematic is when survey effort among roads varies (i.e. some roads are driven more frequently than others), detectability is variable among road segments (e.g. when driving speed varies depending on the road speed-limit), and persistence of road-kill on roadways varies among roads (e.g. when road-kill on high traffic volume roads disintegrates more rapidly, or road-kill on low volume roads is removed more rapidly by scavengers). Presence of any of these biases may result in spurious spatial patterns of road-kill; it may be necessary to correct for these biases before attempting to identify legitimate road-kill hotspots.

(3) Once a sufficient number of road-kill records are assembled, an analysis of the spatial patterns of road mortality can be made. Popular methods include kernel density analysis at a specified road segment length to identify dense aggregations of road-kill, and Ripley's K analysis at a variety of spatial scales to identify the spatial scale of road-kill aggregations (e.g. Clevenger et al. 2003, Ramp et al. 2005). The latter is useful for identifying the length of typical hotspots, which is a key consideration when evaluating mitigation options.

(4) A database of features that are potentially predictive of road-kill hotspots or individual road-kill sites must be assembled. Such features could include road attributes (e.g. traffic volume, road configuration, bordering vegetation), land use and land cover at a series of spatial scales around the point, hydrology and topography, and locations and quality of key resource sites that are the target of animal movements (e.g. wetlands, nesting sites). Some features may be noted in the field during a survey, whereas others can be acquired by analyzing GIS data coverages of relevant features.

(5) Similar to the point-transect method, a valid method of exploratory statistical analysis must be used to create a useful predictive model. This is typically done using stepwise general linear modeling, using a valid method of exploratory model evaluation such as AIC. The dependent variable in such analyses is dichotomous: either road-kill cluster vs. random location or else road-kill record versus no road-kill location. The relative predictive strengths of models are compared, the accuracies of the best predictive models are evaluated, and the relative importance of each potential predictor is determined. A model selected for validation should be one that is accurate at discriminating road-kill hotspots from other segments of roadway, and that uses predictors for which data can be easily acquired before a survey to predict where road-kill hotspots occur within a road network.

(6) A validation study must be done to evaluate the usefulness of the selected putative best predictive model. Validation is straightforward: use the candidate best predictive model to predict hotspots of road-kill in a comparable road network to the one used to create the model, and survey those predicted hotspots and a comparable set of random locations.

(7) Assuming that the model is confirmed as predictive, evaluate the residual error. What features are associated with predicted hotspots that in fact have relatively little road mortality vs. predicted hotspots that (as predicted) do? What features are associated with random locations that have severe road mortality present, vs. those that (as predicted) are not severe?

(8) Revise the model using the results of Step 7, and again validate it on a new road network. Repeat Step 7 and Step 8, should further improvement of the predictive accuracy of the model be desirable and judged feasible.

An advantage of using road-kill locations for modeling is that it is relatively easy to collect road-kill data, and there is a large body of research on how to analyze the spatial dispersion of road-kill to locate hotspot clusters. Moreover, a much larger expanse of road can be surveyed via driving surveys than can be monitored with radio-telemetry or surveyed using walked point-transects.

One disadvantage of using road-kill records is that collecting the data via driving surveys is time-consuming, potentially hazardous, and sometimes expensive since roads may need to be driven many times to acquire adequate numbers of road-kill records for analysis. Another disadvantage is that there is a detection bias toward detecting large individuals; this is potentially a serious problem if smaller-sized individuals, typically younger age-classes, are not reliably detectable and have different movement patterns with respect to roads than larger.

Unlike animals for which vehicle collisions cause human injuries and property damage (e.g. ungulates), there is unlikely to be an existing database of road-kill locations of reptiles and amphibians. Those road-kill records that may exist (e.g. state heritage program databases and herpetofauna atlas records) are unlikely to provide a sufficiently unbiased sample of spatial road-kill patterns.

A second disadvantage of creating hotspot models using road-kill data is that these data are useless at detecting sites where animals are deterred from road-crossing, and thus critical blockages to connectivity caused by road avoidance cannot be directly detected by this method. Moreover, the method will not detect sites that were formerly road-kill hotspots but are no longer because populations in the vicinity have declined due to past excessive road mortality.

One possible way to overcome these disadvantages would be to conduct the driving surveys in a region where abundant and well-connected habitat, low traffic volumes, and low road density make population declines near roads and road deterrence unlikely. A predictive model created in such a region could be used to predict road-kill hotspots in a region where road densities and traffic volumes are higher, and habitat is scarcer and more severely fragmented. Road segments for which the model predicts a road-kill hotspot but observed road-kill density is low would raise suspicion that populations bordering the road have declined due to past unsustainable road-kill or else animals are deterred from crossing.

Case History

In a currently unpublished study, my colleagues and I conducted weekly driving surveys over a two-year period of a 160 km circuit of highway in northeastern New York State, and recorded the location of 162 turtles of three species (*Chelydra serpentina*, *Chrysemys picta*, *Emydoidea blandingii*). Driving surveys were used because we had previously found that this method was valid for detecting road-killed turtles, and that the road-kill density of turtles was too low to detect via short walked point-transects (Langen et al. 2007). We used these data on spatial locations of road-kill turtles to analyze the spatial dispersion and the road and landscape features associated with the road-kill locations. We used spatial statistical methods to identify the degree of aggregation of turtle road-kill, and the spatial extent, severity, and location of clusters of mortality. We compared traffic volume, wetland size and configuration, and surrounding land use (100 m around a point) at turtle road-kill records to random points at least 200 m distant from road-kill, and evaluated both models and individual putative predictors using AIC. For causeways, defined as road segments with wetlands within 100 m on both sides of the roadway, we also created general linear models predicting presence or absence of road-mortality, and again evaluated both models and individual candidate predictors using AIC.

Road-kill was aggregated at causeways that were greater than 200 m in length and characterized by high traffic volumes, close proximity to water, and high forest coverage near the road. The locations of road-kill aggregations, as indicated by kernel density analysis, and the peak spatial extent of aggregations (250 m) as indicated by Ripley's K, corresponded to the locations and average lengths of causeways. We concluded that most freshwater turtle road mortality along northeastern New York State highways is spatially aggregated at short, severe hotspots, and these localities occur at predictable features along or adjacent to a road network. Thus it should be possible to efficiently and precisely locate sites of highest risk of turtle road mortality when the location of wetlands near roads, road traffic volumes, and the land-cover / land-uses bordering the roads are known. Moreover, standard spatial statistical methods used to investigate patterns of road-kill are successful at indicating the location and spatial extent of road-kill hotspots, and can be used to assist in determining the spatial scale and key road and landscape features associated with road-kill clusters. The next step to this project, yet to be initiated, is to validate our best predictive model along other regional road networks.

General Conclusions and Recommendations

All three hotspot modeling methods are promising – each has been used to successfully predict hotspots of road-kill or critical connectivity corridors for a few reptile and amphibian species on some limited stretches of roadway. However, I am not aware of any study that has used a model created by any of these three methods to predict hotspots throughout a large road network, as has been done for mammals (e.g. along the highways of Florida USA, see Smith 1999). In my opinion, a critical next-step in management of road impacts on reptiles and amphibians will be to use a validated model to predict road-kill hotspots or key connectivity linkages throughout a road network, and then devise a plan to implement monitoring and mitigation at the network's highest priority hotspots.

A valid predictive model will also be of great use for estimating how much of a road network is encompassed by hotspots. In the two case studies I reviewed in this paper, causeways were identified as key predictors of road-mortality hotspots. This is not too surprising, since nearly all of the reptile and amphibian species in northeastern New York are wetland-associated. Using the New York State Department of Environmental Conservation Regulatory Wetland Maps for each of the five ecoregions that I and my students surveyed in northeastern New York State, I quantified the fraction of the highway network that was within a causeway, as I defined this feature (i.e. roadway with matched wetlands on opposite sides of the road and each within 100 m of it). Among the regions that we surveyed, highway densities varied between 0.13 - 0.45 highway km / km^2 (this greatly underestimates total road density since these data exclude town, village, and private roads; only about 35% of roads within the region are highway). The average causeway length was 200 - 350 m, and the number of causeways ranged 10 - 43 / 100 km highway, for an average total extent of 26 - 133 m / km-highway.

During our fieldwork, we surveyed an average of 30 locations per workday. Thus, to survey all causeways in a highway network just once using our point-transect survey methodology, 70 - 301 km of highway (290 - 805 km^2 landscape) could be surveyed per day per survey-team in northeastern New York State. A filtering algorithm that incorporated additional predictors such as traffic volume and causeway length would increase the expanse of road that could be practically surveyed within a specified time period, by prioritizing surveys to the causeways that are predicted to be the most severe hotspots.

For most effective management, hotspots need to be spatially restricted in length, so that mitigation measures such as barriers, passageways, and signage are feasible and worthwhile. They need also be severe (have a much higher volume of animal passage or potential passage if unblocked than random locations), so that the impact of mitigation on local populations is sufficiently large. The length and severity of hotspots are a function of how canalized movements are when animals move between resource patches, and the fraction of animals within a local population that use a particular corridor.

Whereas hotspots for mammals are typically on spatial scales of kilometers, many of the most infamous road-kill hotspots for salamanders, frogs, and wetland-associated reptiles are less than 500 m length along a roadway (e.g. sites described in Langton 1989, Elzanowski et al. 2009). These notorious sites are typically either near communal hibernacula, causeways, or migration corridors between breeding sites and non-breeding home-ranges. Hotspot models such as I describe in this paper will be most useful as a tool for monitoring and mitigation for those reptile and amphibian taxa that use movement corridors that are spatially restricted. For some species, such as desert tortoises (Boarman and Kristan 2006) and tropical upland snakes (Langen, unpublished data), animals are much less spatially restricted in where they approach roads, and thus hotspot models may not be a useful tool for road management targeted at these species.

I conclude that hotspot models are a promising tool for environmental management of road mortality and connectivity blockages of reptiles and amphibians caused by roads and road traffic. Hotspot models may well be more effective management tools for reptiles and amphibians than mammals (the usual focus of these models), since herpetofauna hotspots often encompass a narrower length of roadway, are very severe, and are often highly associated with conspicuous landscape features such as wetlands or communal hibernacula. The locations of hotspots for many species of both reptiles and amphibians often overlap. A significant fraction of a local population of a reptile or amphibian species may attempt to cross a road at a hotspot; or would cross should it be unblocked. For such species, management of hotspots is an essential element of an effective conservation plan. Agencies and organizations concerned with the conservation of reptiles and amphibians should collaborate with researchers to (1) identify species that are negatively impacted by roads and for which the impacts are most severe at discrete spatial hotspots, (2) create and validate hotspot models for these species, and (3) develop best-practices that use the models as tools to locate priority sites for monitoring and mitigation.

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Biographical Sketch

Tom Langen is an Associate Professor at Clarkson University. His research focuses on the environmental impact of infrastructure and human land-use practices, including the environmental impacts of roads and the conservation value of wetlands reconstructed under public-private partnership programs. Road- related research in the northeastern US has included the environmental impact of deicing road salt on high-altitude soil and lakes, and methods of predicting and mitigating hotspots of herpetofauna road mortality. In Costa Rica, he is conducting research and leading courses and professional-development workshops on the impact of public roads on national parks and other protected areas in Central America.

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Mitigating Highway Impacts on Ecosystems

EVALUATION OF A RAPID ASSESSMENT PROTOCOL TO ASSESS ROAD-STREAM CROSSINGS FOR AQUATIC ORGANISM PASSAGE

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Abstract

The River and Stream Continuity Partnership has developed assessment protocols for evaluating the barrier effects of road-stream crossings. In addition to these protocols, the University of Massachusetts Amherst created an online database and an algorithm for scoring crossing structures according to the degree of obstruction they pose to aquatic organisms. In 2008, The Nature Conservancy and University of Massachusetts collected data to test the robustness and repeatability of the protocol and compare results with those of other fish passage models. A stratified random sample of 317 road stream crossings in Connecticut, Vermont, New Hampshire and Massachusetts that had previously been assessed using the protocols were re-evaluated by trained technicians. Of these sites, 111 were assessed in sufficient detail to evaluate them using FishXing, the California Salmonid Stream Habitat Restoration course screen and course screens developed by Seth Coffman.

We excluded from analyses 51 crossings (16.1 %) because it appeared likely that the resurvey assessments were not conducted on the same crossings evaluated in the previous surveys. Some of these crossings appear to have been repaired or replaced since the previous surveys were conducted. However, most of these probably represent mismatched locations. Repeat surveys of crossing structures indicate relatively high rates of discrepancies for particular data fields (range from 3.8 to 53.8 percent) but small overall effects on crossing scores. Overall, 46.2 percent of crossings had the same score for the previous survey as for the resurvey and 73.7 percent of previous survey scores fell within one score of those for corresponding resurveys. Flow Conditions was one data field that showed a substantial number of differences (60.2%) between previous surveys and resurveys. We found no significant differences in changes in scores for crossings assessed at different flows as compared to changes in scores for crossings assessed under similar flow conditions.

The two assessment methods that yielded the most similar results were Coffman's Coarse Screens and the Crossings Database. Scores for these two methods were in agreement for 39.6 percent of crossings, with 68.5 percent falling within one unit and 83.8 percent within two units of each other. Comparison of the Crossings Database scores with those derived from FishXing yielded the same scores at only 20.7 percent of crossings and at only about two-thirds of sites did scores fall with two units of each other. There also was little agreement between scores derived from FishXing and those from the Coffman Coarse Screens The scores from these two methods were the same for 23.4 percent of crossings with little over half (52.3 %) falling with one unit and 70.3 percent within two units of each other. It is not clear which of these three methods yields the most credible results.

Results of these analyses are being used to revise and improve the assessment protocols as well as the scoring algorithm used by the database and will ultimately increase confidence and credibility in the data collected as part of the River and Stream Continuity Project.

Introduction

It is estimated that in Massachusetts there are between 35,000 and 45,000 bridges and culvert crossings where roads, railroads and highways intersect rivers and streams. Comparable densities of road-stream crossings are likely to exist throughout much of New England as well as other areas of the Eastern United States. It is reasonable to expect that a substantial number of these crossings represent barriers to movement for fish and other aquatic organisms. The threat that road-stream crossings pose to river and stream ecosystems is related not only to the density of crossings but also by the degree to which these crossings represent a barrier to aquatic organism passage.

A number of procedures have been developed for evaluating the barrier effect of road-stream crossings. These methods range from sophisticated models such as FishXing (http://www.stream.fs.fed.us/fishxing/) to relatively simple "coarse screens" that require less rigorous evaluation of site conditions. One important drawback to these approaches is that they need to be conducted by trained technicians and rely on elevation data collected in the field. The need for surveyed elevations makes it more difficult to systematically evaluate large numbers of structures needed to assess river/stream continuity and set priorities for ecological restoration at broad geographic scales (e.g. major watersheds, statewide).

In New England three organizations, The Nature Conservancy, Massachusetts Riverways Program and the University of Massachusetts Amherst, formed the River and Stream Continuity Partnership to address the impacts of road-stream crossings on river and stream ecosystems. Over the course of several years the Partnership has developed and revised rapid assessment protocols for evaluating the barrier effects of road-stream crossings. These protocols were developed for implementation by trained volunteers or technicians and rely on information that can be readily collected in the field without surveying equipment or extensive site work. In addition to these protocols, the University of Massachusetts created an online database and an algorithm for scoring crossing structures according to the degree of obstruction they pose to aquatic organisms.

The protocols have been implemented in a number of New England watersheds by volunteers as well as trained technicians. Important questions have been raised about the efficacy of using volunteers for conducting crossing surveys. Further, no one has yet evaluated the scoring algorithm to determine how it relates to the actual barrier effects of road-stream crossings.

A project was initiated with several objectives that, together, would increase our understanding of how well the survey protocols and scoring algorithm function, identify opportunities to improve the protocols and ultimately increase confidence and credibility in the data collected as part of the River and Stream Continuity Project.

Objectives:

- Assess the accuracy of crossing surveys conducted by volunteers as well as those conducted by trained technicians;
- Assess the repeatability (precision) of results of surveys conducted by different observers;
- Assess the repeatability (precision) of survey results conducted at different times of year (different flows);
- Evaluate the database scoring algorithm by comparing it with results of crossing evaluations conducted using Fish Xing software and other relevant fish passage models.

Methods

In 2008, The Nature Conservancy and University of Massachusetts Amherst collected data to test the robustness and repeatability of the River and Stream Continuity survey protocols and compare results with those of other fish passage models. A stratified random sample of road stream crossings that had been previously assessed using the protocols were selected for re-evaluation by trained technicians.

A total of 317 crossings that had been previously surveyed (2003-2007) were resurveyed in select watersheds in Connecticut (n=65), Massachusetts (n=130), New Hampshire (n=60) and Vermont (n=62). The sampling design randomly selected ten percent of the available crossings in seven targeted watersheds where extensive surveys had been previously conducted. Within each watershed sites were stratified by crossing type (bridge, open bottom arch, single-culvert, multiple-culvert). Additional sites with open bottom arches and multiple culvert crossings were included (above the 10 percent target) because these crossing types were uncommon in study area.

At each of the 317 crossings, trained technicians conducted crossing assessments using the same protocols as had been used previously (Appendix A). Data from these assessments were used to evaluate the accuracy and repeatability of the protocols. In addition, at 116 of these sites (in MA, VT and NH) more detailed surveys were conducted to collect data needed to run FishXing and implement other fish passage assessment methodologies. Results from these other models were used to evaluate the scoring algorithm used by the Crossings Database.

Evaluation of the Survey Protocols

The protocols were developed to serve as a rapid assessment methodology that could be used by trained volunteers or technicians during a single visit to a crossing site. At each crossing, information about road and stream characteristics was collected as well as specific information needed to run the scoring algorithm (See Appendix A for the field data form). In New Hampshire a variation on this data form was used. The New Hampshire form included additional data fields and different wording or formatting for four of the data fields used in this analysis (inlet drop, outlet drop, crossing condition, and crossing substrate). Our analysis focused only on those data fields that were evaluated in all four states.

It is specified in the protocols that crossing assessments should be done during typical low-flow conditions. However, many of the previous evaluations had been conducted during flow conditions that were either higher or lower than typical low-flow. To further help evaluate the effect of flow conditions on survey results, fifteen crossings were evaluated by the same technician during different flow conditions.

Data from the 2008 assessments were entered into the online Crossings Database where information from previous surveys was already stored. Data were then extracted from the Crossings Database and analyzed in Excel.

At crossing sites where multiple resurvey assessments were conducted (either at different flows or by different people) only one site was used for comparison with previous surveys. The resurvey assessment selected for analysis was the one for which flow conditions were most similar. For sites where more than one previous survey had been conducted, each of the previous surveys was independently evaluated against the appropriate resurvey assessment.

Using Excel the scoring algorithm (Appendix B) was used to calculate scores for each crossing record. We knew that many of the previous surveys were conducted by people who were trained to evaluate Flow Contraction in a way that was inconsistent with the protocols. Because Flow Contraction has a strong influence on crossing score we modified the scoring algorithm to eliminate Flow Contraction for this evaluation of survey protocols. Although the algorithm scores crossings on a scale ranging from 0 (worst) to 10 (best), the range of score was truncated for this study because it was primarily focused on aquatic organism passage (scores 0-6; scores 7-10 are associated with different levels of passability for terrestrial wildlife). For purposes of comparing previous surveys with resurveys all scores of seven or greater were treated as sevens. This yielded two derived variables, “Crossing Score” and “Points” (a component of crossing score) that could be compared between previous surveys and resurveys.

Information from the previous surveys and the resurveys were carefully compared to ensure that both surveys were done at the same crossings. Data fields used to determine whether surveys were mismatched included road name, stream name, town, road type (paved/unpaved), number of travel lanes, crossing type, and crossing dimensions. Survey data from crossings with characteristics that did not match the original crossing were not used in the analysis. Most of questions included on the field data form are formatted with check box options for recording data. These were the data fields used to compare results of previous surveys and resurveys. Fill-in-the-blank data fields were not used in these analyses. Comparisons were made to determine for each crossing whether the data collected from previous surveys and resurveys were the same or different for each of these data fields. The percentage of differences (Percent Differences) was calculated for each crossing. From these data we also calculated separately for each state, the percentage of sites for each data field that contained different responses between previous surveys and resurveys.

We used ANOVA to analyze for differences among states for three derived variables: Percent Differences, percent differences in Points and percent differences in Crossing Scores. To investigate the influence of flow conditions on data collection and crossing scores these same three variables were analyzed using t-tests for sites that were resurveyed at flows similar to the previous surveys (similar flow) compared to sites where resurvey flow conditions were different from those of the previous survey (different flow). Summary statistics were used to compare the percent of sites that yielded different results for each of the data fields analyzed. ANOVA was used for comparison of road and crossing characteristics by state that might help explain differences in rate of discrepancies for data fields.

Evaluation of the Scoring Algorithm

The scoring algorithm for the Crossings Database (Appendix B) was developed to assign scores to road-stream crossings as an index of passability. The algorithm is based on factors that either are responsible for blocking upstream movement of aquatic organisms (e.g. outlet drops) or serve as indictors of conditions that might impede aquatic organism passage (e.g. constriction of flow, scour pool size). A point system is used for most characteristics with crossings with more favorable characteristics receiving a higher point total (up to 90 points). Certain characteristics, if present, will result in a crossing score of zero regardless of the point total. Otherwise, the point total is used to determine scores ranging from zero to five. Other factors are used to assign scores between six and ten.

Crossing scores between zero and six indicate relative passability for aquatic organisms. The scoring is not based on empirical data but rather on how closely a crossing compares with the Massachusetts River and Stream Crossing Standards (for more information go to www.streamcontinuity.org). A crossing score of zero is meant to represent a severe barrier affecting most if not all organisms in that portion of the stream or river. Crossings that fully comply with the Crossing Standards receive a score of six. Scores one through five represent combinations of characteristics according to how closely they match those specified in the Standards.

Because the scoring algorithm is not empirically based some have found it difficult to interpret the scores. By comparing the scores yielded by the Crossings Database with those derived from other fish passage assessments we hoped to better understand the relationship between crossing scores and fish passability.

We chose three fish passage assessment methodologies for comparison with the Crossings Database scoring algorithm: FishXing, three coarse screens developed by Seth Coffman (Coffman Coarse Screen; 2005), and the coarse screen for salmonid fish contained in the California Salmonid Stream Fish Habitat Restoration Manual (Taylor & Love 2003).

FishXing is a sophisticated model that requires inputs in the form of field data from the crossing site as well as stream low and high flow discharge rates and information about the swimming requirements of target fish. Rather than focus on particular species of fish we used species groups: A (Salmonidae), B (large Cyprinidae and Catostomidae), C (small Cyprinidae) and D (benthic non-minnows) as identified by Nedeau (2006). Because of the lack of research on swimming capability and requirements of New England fish we used two sets of swim parameters in an effort to model both the lower and upper limits of swimming ability for each species group. Information on the swimming requirements of target fish (Table 1) came from a variety of sources.

	Fish	Ave. Length	Min. Swim Depth	Prolonged High	Burst high	Max. Drop
Group A1	Salmonidae	9 in	0.2 ft	4.1 ft/s	14.1 ft/s	2.0 ft
Group A2	Salmonidae	9 in	0.2 ft	2.4 ft/s	6.2 ft/s	1.5 ft
Group B1	Catostomidae	12 in	0.3 ft	3.3 ft/s	10.2 ft/s	1.2 ft
Group B2	Catostomidae	12 in	0.3 ft	1.7 ft/s	5.2 ft/s	0.7 ft
Group C1	Cyprinidae	3 in	0.1 ft	2.0 ft/s	2.7 ft/s	0.8 ft
Group C2	Cyprinidae	3 in	0.1 ft	0.8 ft/s	2.2 ft/s	0.4 ft
Group D1	Percidae	3 in	0.1 ft	1.1 ft/s	1.3 ft/s	0.5 ft
Group D2	Percidae	3 in	0.1 ft	0.13 ft/s	0.9 ft/s	0.1 ft

Table 1. Swimming ability input variables used in FishXing.

Prolonged High and Max Drop (Perch Height) were based on Figures 2 & 3 in Nedeau (2006). Burst high speeds came from Broadfoot and Murphy (2002) and from Ministry of Transportation of Ontario (2009).

Low and high discharge rates were obtained from StreamStats models maintained by the U.S. Geological Survey for Vermont (Olson 2002) and Massachusetts (Ries and Friesz 2000). Low flow for Massachusetts came from AUGD50 (August stream flow exceeded 50 percent of the time). No comparable low flow statistic was available from the Vermont StreamStats so low flow for Vermont was derived by plotting low flows for Massachusetts against watershed area and using linear regression analysis. The equation was used for the largest areas in Vermont (2.77 sq. miles and above). For smaller areas interpolation was used, matching Vermont watershed areas with Massachusetts watershed areas and their low flow discharge rates.

High flow discharge rates in Vermont were based on the PK2 (maximum instantaneous flow that occurs on average once in 2 years). Nothing comparable was available from Massachusetts StreamStats and so high discharge flows were again derived based on linear regression analysis of watershed area versus Vermont PK2 discharge. The equation worked best for larger watershed areas (> 2.5 sq. mi.) and interpolation was used for smaller areas.

In order to get high and low flows for New Hampshire, which had not yet implemented in StreamStats, we chose the Miller's River watershed as a model because of the similarities in topography to the Ashuelot River where all our New Hampshire sites were located. Plotting watershed area and average active stream margin width, another straight line equation was determined through regression analysis by using the first 10 points in the plot. Once watershed areas were determined for the Ashuelot sites, the low and high flows were determined by interpolation and for watershed areas above 2.1 sq. miles, using the appropriate straight line equation for highs and lows for Vermont and Massachusetts.

FishXing results were given as percent passable for each species group in the range of discharge rates from low to high flows.

The Californian Salmonid Coarse Screen and Coffman Coarse Screens require collection of a handful of field parameters and the use of simple flow charts to characterize each crossing as passable, impassable or indeterminate. Results for the Californian Salmonid Coarse Screen were not particularly useful and were not used for analyses because the methodology yielded indeterminate results for most of the crossings in our study.

Crossing scores calculated using the Crossings Database scoring algorithm were truncated to use only those scores that were relevant for aquatic organism passage (zero through six). For comparison with FishXing and the Coffman Coarse Screens all sites with crossing scores above six were treated as sixes.

Results from FishXing and Coffman Coarse Screens were converted to scores on a scale of 0-6 using the following simple conceptual model:

- 0 = impassable or largely impassable for all species
- 1 = passable for Group A for part of the year
- 2 = full passage for Group A
- 3 = full passage for Group B; partial passage for Group C
- 4 = full passage for Group C; partial passage for Group D
- 5 = full passage for all species groups
- 6 = full fish passage plus all structural elements (fully embedded, appropriate substrate, no channel constriction) in place

This was implemented for FishXing using the scheme in Table 2. The Coffman Coarse Screen results were converted using the scheme in Table 3. Having converted all assessment results to scores on a 0-6 scale the scores for these three methods were then compared for each crossing site. Comparisons yielded three useful statistics: average difference in scores (based on absolute values), percent agreement (score difference = 0), and net shift in crossing scores (shift in mean score either up or down).

Desire Score	Range of FishXing Passage Values (Percent)
0	A1=0
1	A1=1-59 A1 >0 and B1=0
2	A1≥60 and B1>0 A1≥60 and B1≥60 and A2<10
3	A1≥60 and B1≥60 and A2≥10
4	A1≥60 and B1≥60 and C1≥60
5	A1≥60 and B1≥60 and C1≥60 and D1≥60, but CDB score < 6
6	A1≥60 and B1≥60 and C1≥60 and D1≥60, and CDB score ≥ 6

Table 2. Desired scores derived from FishXing percent passable values.

Desire Score	Coffman Passability Classifications
0	A= Impassable
1	A= Indeterminate
2	A= Passable, B= Impassable, C= Impassable
3	A= Passable, B= Indeterminate, C≠ Passable
4	A= Passable, B= Passable, C≠ Passable
5	A= Passable, B= Passable, C= Passable, but CDB score < 6
6	A= Passable Yes, B= Passable, C= Passable, and CDB score ≥ 6

Table 3. Desired Scores derived from Coffman passabilty classifications. (Note: Coffman species group A is comparable to Nedeau group A; Coffman group B is comparable to Nedeau group C; and Coffman group C is comparable to Nedeau group D).

Results

Evaluation of the Survey Protocols

It was determined that for 51 of the 317 sites (16.1%) it was likely that the surveys were not conducted on the same crossings. This was based on combinations of discrepancies in a number of key fields such as road name, stream name, town, road type (paved/unpaved), number of travel lanes, crossing type, and crossing dimensions. It seems likely that at some of these sites crossings had been repaired or replaced between surveys. However, for most of the crossings the most likely explanation is that the surveys had been conducted at entirely different locations. At an additional 19 sites (6.0%) there were substantial differences in the crossing dimensions between the previous survey and resurvey assessments. However, other data fields were similar enough that we decided to include these crossings in the analyses.

The number of differences (expressed as a percentage) between previous surveys and resurveys for the data fields evaluated ranged from a low of 3.8 percent for High Traffic Volume to a high of 56.0 percent for Crossing Condition (Table 4). Percent differences for two derived variables (Points and Crossing Score) were relatively high reflecting the fact that these two variables are influenced by differences in several other data fields used to calculate the variables. Some of the differences among data fields are likely due to the fact that certain characteristics (High Traffic Volume, Jersey Barriers) are present at a minority of sites while others (Crossing Span, Flow Conditions) are evaluated for all crossings. Table 5 provides information for each state about the prevalence of various road and crossing characteristics that might influence the frequency of discrepancies between previous and resurvey data as well as differences among the states in percent difference values.

Table 5 reveals that there is considerable variation in the prevalence of certain road and crossing characteristics with significant differences ($p<0.05$) among the states in 11 of 15 characteristics. It is important to note that the crossing sites surveyed were in priority watersheds for The Nature Conservancy. They are most likely watersheds with less development than would be found elsewhere in the four states. The prevalence of characteristics listed in Table 5 is not likely to be representative of the roads and crossings in those states.

Percent Difference is a derived variable that was calculated for each crossing as the number of data fields for which previous survey and resurvey assessments differed, divided by the total number of data fields evaluated ($n=22$). An ANOVA comparing Percent Differences among the states indicated significant differences ($p<0.01$) with New Hampshire having the highest rate (31.8%) and Vermont the lowest (19.4%) (Table 6).

Crossing Score is derived from a number of data fields according to the algorithm in Appendix B, but adapted to eliminate Flow Contraction. Data on comparison of scores is presented in Table 7. Overall, 46.2 percent of crossings had the same score for the previous survey as for the resurvey and 73.7 percent of previous survey scores fell within one unit of those for corresponding resurveys. Significant differences were found among states ($p<0.05$) with Connecticut showing the lowest rate of agreement among scores (32.7%) and Vermont the highest (55.0%).

Overall there was little shift in crossing scores when going from previous surveys to resurveys (+0.05), although the shift for New Hampshire was much larger (+1.02) than for other states (Table 7). Figure 1 shows the distribution of differences in score for crossings in all four states.

Flow Conditions was one data field that shows a substantial number of differences (60.2%) between previous surveys and resurveys (Table 4). Despite the fact that more than half of the crossing surveys were not conducted under similar flow conditions as the previous surveys we found little evidence that this affected the three derived variables: Percent Differences, Points and Crossing Score. One-tailed t-tests failed to indicate any significant difference for each state independently or all states combined.

Looking specifically at data fields most likely to be affected by flow conditions some of the data fields did show higher rates of discrepancies when surveys were conducted at different flows as compared to similar flow conditions (Table 9). These included Inlet Drop, Scour Pool, Water Depth, Water Velocity and Flow Contraction. Yet, rate of discrepancies for other variables that might conceivably be influenced by flow conditions (Structure Height, Outlet Drop, Crossing Embedment, Crossing Substrate and Crossing Span) were either comparable or were lower for surveys that were conducted under different flows. Results of surveys conducted by the same trained technician at different flows suggests that the variables most likely to be affected by flow conditions are Water Depth, Scour Pool, Crossing Embedment, Crossing Substrate, and Crossing Span (Table 9).

	Percent of Differences All States	Percent of Differences CT	Percent of Differences MA	Percent of Differences NH	Percent of Differences VT
High traffic volume	3.8	4.1	3.8	7.7	0.0
Road surface	4.1	0.0	3.8	7.7	5.0
Jersey barriers	4.1	16.3	1.9	1.9	0.0
Crossing type	6.4	14.3	8.6	1.9	0.0
Shoulder	10.2	10.2	9.5	9.6	11.7
Fencing	14.3	14.3	18.1	5.8	15.0
Inlet drop	14.7	2.0	18.1	13.5	20.0
Structure height	15.8	8.2	22.9	19.2	6.7
Travel lanes	16.2	4.1	7.6	36.5	23.3
Outlet drop	19.2	6.1	21.9	26.9	18.3
Crossing embedment	24.1	38.8	18.1	36.5	11.7
Tailwater armoring	24.4	18.4	31.4	23.1	18.3
Water velocity	28.9	32.7	21.9	34.6	33.3
Scour pool	31.2	32.7	25.7	32.7	38.3
Water depth	31.2	30.6	27.6	42.3	28.3
Physical barriers	32.0	22.4	34.3	25.0	41.7
Crossing substrate	33.1	36.7	22.9	73.1	13.3
Steep embankments	39.5	32.7	61.0	46.2	1.7
Flow contraction	43.2	46.9	34.3	46.2	53.3
Retaining walls	45.9	30.6	68.6	61.5	5.0
Crossing span	47.4	36.7	55.2	48.1	41.7
Crossing Score	53.8	67.3	52.4	53.8	45.0
Crossing condition	56.0	55.1	43.8	100.0	40.0
Flow conditions	60.2	36.7	63.8	59.6	73.3
Points	77.1	81.6	74.3	84.6	71.7

Table 4. Prevalence of discrepancies between previous surveys and resurvey assessments for 25 data fields.

	CT (%)	MA (%)	NH (%)	VT (%)	P-Value
High traffic volume	8.5	2.0	4.2	0.0	0.001
Paved road	86.1	68.1	63.3	27.4	< 0.001
Jersey barriers	6.2	1.2	0.8	0.0	0.001
Bridge or open bottom arch	34.6	34.3	15.8	32.3	0.002
Road shoulder	13.1	11.0	11.7	7.3	0.492
Fencing along road	12.3	11.4	2.5	7.3	0.017
Inlet drop	2.3	13.8	13.3	13.7	0.004
Outlet drop	22.3	33.5	45.0	48.4	< 0.001
Crossing fully embedded	40.8	35.4	31.7	37.1	0.504
Tailwater armoring	11.5	22.0	15.0	12.1	0.019
Large scour pool	16.2	26.4	23.3	29.0	0.076
Substrate in crossing comparable to stream	45.4	37.8	36.7	38.7	0.455
Steep embankments	20.0	32.7	28.3	2.4	< 0.001
Retaining walls	15.4	35.0	31.7	2.4	< 0.001
Crossing spans bankfull width	12.3	18.5	5.8	12.1	0.008

Table 5. ANOVA comparison among states for select road and crossing characteristics derived from data fields. Characteristics with significant differences (P<0.05) among states are in bold.

	Mean Percent Differences	Median Percent differences	Std Dev	Min Percent Differences	Max Percent Differences
CT	22.4	22.7	10.3	4.5	54.5
MA	25.5	27.3	11.7	4.5	63.6
NH	31.8	31.8	11.5	13.6	54.5
VT	19.4	18.2	9.4	0.0	40.9
All States	24.8	22.7	11.7	0.0	63.6

Table 6. Comparison of Percent Differences between previous surveys and resurvey assessments for 22 data fields. These included all the data fields listed in Table 4 except for Flow Condition, Points, and Crossing Score.

	Same Score (%)	Within 1 Score (%)	Within 2 Scores (%)	Mean Net Score Shift*	Max Score Difference
CT	32.7	65.3	87.8	-0.29	5
MA	47.6	76.2	86.7	-0.41	7
NH	46.2	69.2	75.0	+1.02	6
VT	55.0	80.0	90.0	+0.30	6
All States	46.2	73.7	85.3	+0.05	7

*Previous survey minus resurvey scores

Table 7. Comparison of crossing scores between previous surveys and resurvey assessments.

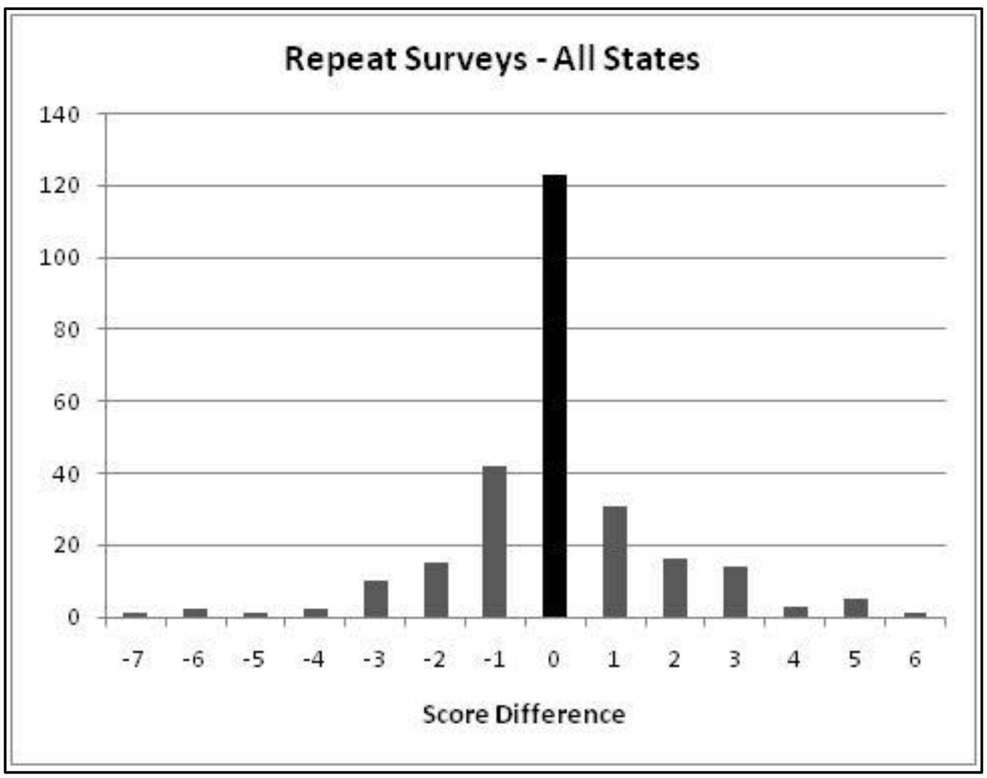

Figure 1. Differences in scores between previous surveys and resurvey assessments for all states combined (previous survey score minus resurvey score).

	Mean Percent Differences		Mean Change in Points		Mean Change in Score	
	Similar Flow	Different Flow	Similar Flow	Different Flow	Similar Flow	Different Flow
CT	22.0	23.2	-5.23	-11.28	0.00	-0.78
MA	25.2	27.9	-3.11	0.43	-0.84	-0.18
NH	35.3	29.5	11.43	8.29	1.05	1.00
VT	19.3	19.4	-0.12	-2.11	0.62	0.18
All States	24.7	24.8	-0.73	0.18	-0.02	0.10

Table 8. Affect of flow conditions on Percent Differences, change in Points and change in Crossing Score. Analyses using one-tailed t-tests indicated no significant differences between previous survey and resurvey data collected at similar flows as compared to data collected at different flows.

	Similar Flow (%)	Different Flow (%)	Different Flow Technician Check (%)
Crossing type	6.6	6.3	10
Inlet drop	12.3	16.3	10
Structure height	16.0	15.6	0
Outlet drop	23.6	16.3	0
Tailwater armoring	24.5	24.4	0
Scour pool	26.4	34.4	20
Water depth	27.4	33.8	30
Water velocity	27.4	30.0	10
Flow contraction	33.0	50.0	0
Crossing embedment	34.0	17.5	20
Crossing substrate	37.7	30.0	20
Crossing span	51.9	44.4	20
Crossing condition	52.8	58.1	20
Score	58.5	50.6	30
Points	78.3	76.3	40

Table 9. Comparison of Percent Differences for data fields most likely to be affected by difference in flow. The column Different Flow Technician Check contains Percent Differences from 15 crossings that were surveyed twice in 2008 by the same technician but during different flow conditions.

Evaluation of the Scoring Algorithm

One Hundred eleven (111) crossings were evaluated by all three methodologies (FishXing, Coffman Coarse Screens, Continuity Crossings Database) and scores generated on a scale of 0-6. A comparison of the scores generated by these three methods is presented in Table 10.

The two methods that yielded the most similar results were Coffman's Coarse Screens and the Crossings Database (Table 10 and Fig. 2). Scores for these two methods were in agreement for 39.6 percent of crossings, with 68.5 percent falling within one unit and 83.8 percent within two units of each other. On average crossing scores using these two methods differed by a little over one unit (1.15 units) with a small net shift moving from Coffman's to the Crossings Database score of 0.29 units.

Comparison of the Crossings Database scores with those derived from FishXing did not show strong agreement (Table 10 and Fig. 3). The two methods yielded the same scores at only 20.7 percent of crossings and at only two-thirds of sites did scores fall with two units of each other. The average difference in scores was 1.73 units with a mean net shift in scores of -0.74 (moving from FishXing score to Crossings Database score).

There also was little agreement between scores derived from FishXing and those from the Coffman Coarse Screens (Table 10 and Fig. 4). The scores from these methods were the same for 23.4 percent of crossings with little over half

(52.3 %) falling with one unit and 70.3 percent within two units of each other. The mean difference in scores (1.70 units) was similar to the difference between FishXing and Crossings Database (1.73 units), but the mean net shift in the score was even higher (-1.20 vs. -0.74) between FishXing and Coffman.

	SAME SCORE (%)	WITHIN 1 SCORE (%)	WITHIN 2 SCORES (%)	MEAN DIFFERENCE IN SCORE	MEAN NET SCORE SHIFT
FishXing vs. Coffman[1]	23.4	52.3	70.3	1.70	-1.20
FishXing vs. Crossings Database[2]	20.7	53.2	67.6	1.73	-0.74
Coffman vs. Crossings Database[3]	39.6	68.5	83.8	1.15	0.29

[1] FishXing score minus Coffman score
[2] FishXing score minus Crossings Database score
[3] Coffman score minus Crossings Database score

Table 10. Comparison of scores from the Crossings Database Algorithm and those derived from FishXing and Coffman Coarse Screen assessments using only those crossings for which we were able to derive scores using all three methods (n=111).

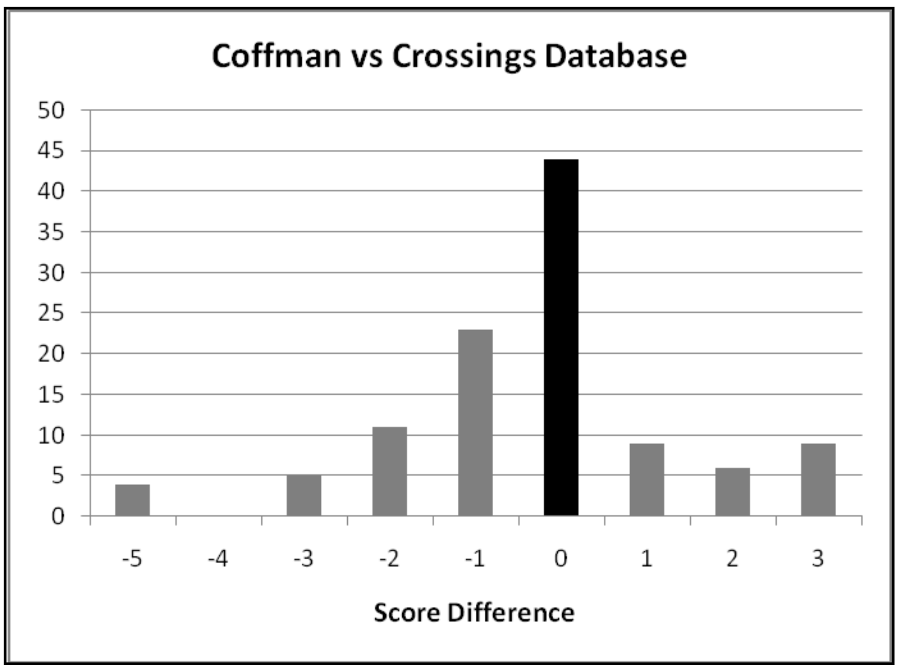

Figure 2. Differences between scores derived from Coffman Coarse Screen assessments with those from the Crossings Database (Coffman score minus Crossings Database score).

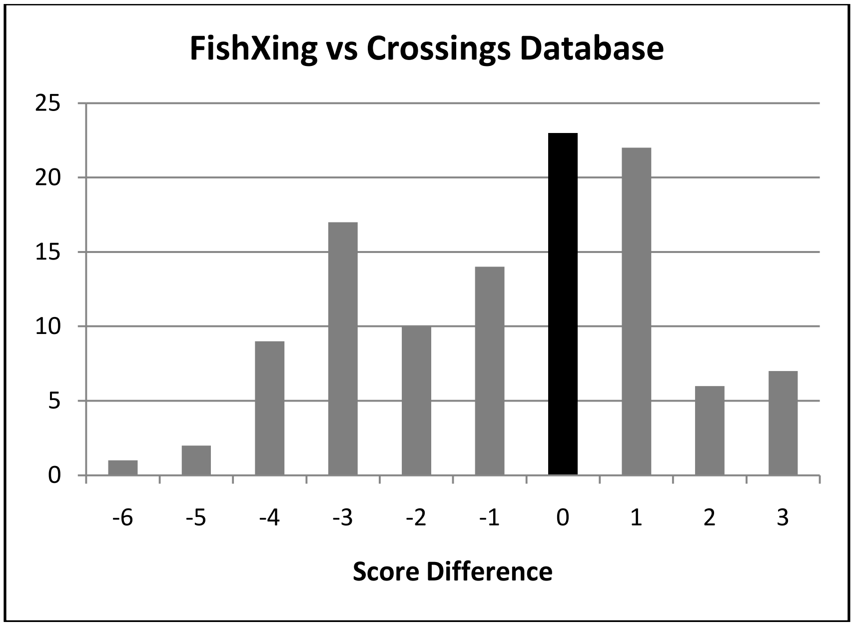

Figure 3. Differences between scores derived from FishXing assessments with those from the Crossings Database (FishXing score minus Crossings Database score).

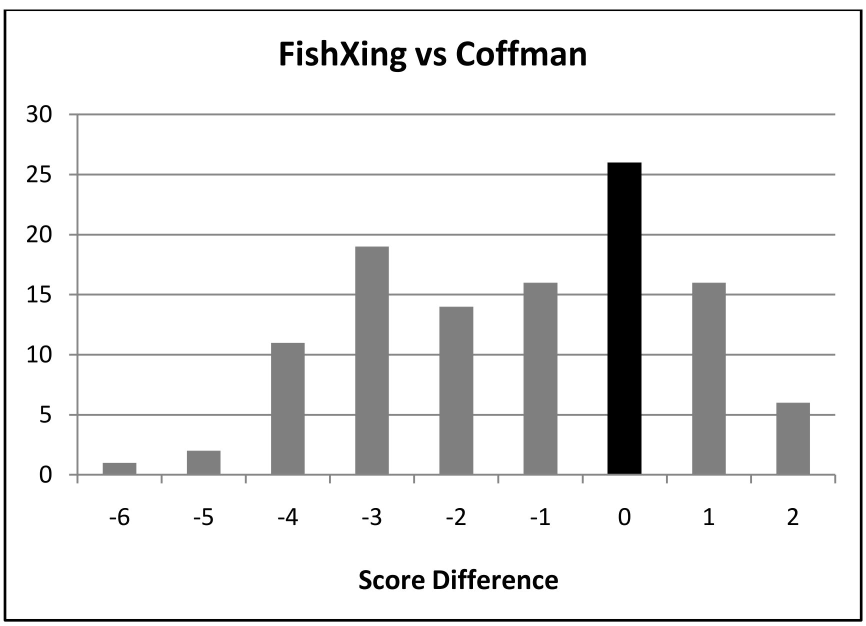

Figure 4. Differences between scores derived from FishXing assessment with those from the Coffman Coarse Screen assessments (FishXing score minus Coffman score).

Discussion

Evaluation of the Survey Protocols

The River and Stream Continuity crossings survey protocol was developed in Massachusetts and has been used or adapted for use in four other New England states. Crossing surveys have been conducted by various organizations using either trained volunteer observers or technicians to collect the data. To evaluate the accuracy and repeatability of these protocols we resurveyed 317 crossings in four states (CT, MA, NH and VT) and compared the results of previous surveys with resurvey assessments.

We excluded from analyses 51 crossings (16.1 %) because it appeared likely that the resurvey assessments were not conducted on the same crossings evaluated in the previous surveys. Some of these crossings appear to have been repaired or replaced between the previous survey and the resurvey. However, most of these probably represent mismatched locations. These results emphasize the need for the collection of good location data, preferably GPS coordinates, to ensure proper correspondence between data in the database and the correction location of the crossing in the field. Another 19 crossings (6.0 %) were viewed with skepticism because of discrepancies in data on the crossing's dimensions. We suspect that large discrepancies occur in the recording of crossing length when those crossings are not configured at right angles to the roadway.

We were surprised at the large number of discrepancies between previous survey and resurvey data for a number of data fields (Table 4). Even the low rates of differences for some fields are probably, in part, a result of the fact that these characteristics (High Traffic Volume, Jersey Barriers, Fencing) were not common in the areas surveyed (Table 5). Results in Table 5 also help explain differences among states for some of these data fields (Road Surface, Jersey Barriers, Fencing, Inlet Drop, Outlet Drop, Tailwater Armoring, Steep Embankments and Retaining Walls).

The large differences among states for two of the data fields (Crossing Substrate and Crossing Condition) appear to be related to different wording of the survey questions on the New Hampshire data sheet. The percentage of New Hampshire crossings with discrepancies for Crossing Substrate (73.1 %) is substantially higher than the average for all states combined (33.1 %). The rate of discrepancies for Crossing Condition in New Hampshire was 100 percent.

Despite the large number of discrepancies within individual data fields we were encouraged to find reasonably strong correspondence between previous surveys and resurvey crossing scores (Table 7). Looking at data from all four states combined, the scores were the same for 46.2 percent of crossings. Resurvey crossing scores for 73.7 percent of sites fell within one unit and 85.3 within two units of those from previous surveys. We believe that the distribution of changes in crossing score in Figure 1 indicates a reasonably good correspondence between previous survey and resurvey crossing scores.

In developing a rapid assessment protocol for assessing road-stream crossings we have always been concerned about how different flow conditions might affect survey results. Results of this study indicate that, although some data fields may be affected by flow conditions, Percent Differences, differences in Points and difference in Crossing Score were not significantly higher for crossings that were resurveyed at different flow conditions compared to those surveyed at similar flow conditions.

Evaluation of the Scoring Algorithm

It was more difficult than we had anticipated implementing FishXing as part of our study. The first challenge was deciding what swimming parameters to enter into the model given how little data exist on swimming and leaping ability of New England fish. Of more importance were difficulties encountered in coming up with high and low flow discharge rates for 111 crossings that had not been monitored for hydrology. We used projections from available StreamStats models where we could and then did the best we could to extrapolate and interpolate from these projections to come up with discharge rates for other sites. Given the uncertainties associated with our inputs for fish swimming and leaping ability and hydrology, along with the errors and uncertainties inherent to any model, it is not clear how much confidence we can put in the passability values derived from FishXing.

The Coffman Coarse Screens were relatively easy to implement and the outputs easy to use. These models are attractive because of their ease of use and the fact that they are based on empirical data using fish found in the Eastern U.S. However, the data from which these models were derived came from only 26 sites and are based on fish movements monitored for two 30-day periods within the same year (Coffman 2005). Not only are the coarse screen models based on limited movement data, the final models (revisions of the draft models tested by Coffman) were fit to the data and, as far as we know, have not yet been tested.

Empirical data on fish and other aquatic organism passage at road-stream crossings of varying characteristics are very limited for New England. In the absence of empirical data we attempted to validate our scoring algorithm by testing it against two other crossing assessment models. Given the inherent problems and weaknesses of these other models the results are hard to interpret.

Given the stronger correspondence between the Crossings Database scores and those from the Coffman Coarse Screens, as well as the weaker correspondence between FishXing scores and those from either of the two other methods (Table 10), it is tempting to believe that the Coffman approach represents the best benchmark against which to evaluate the Crossing Database scoring algorithm. However, it is not clear which of these methods yields the most credible results.

The approach used in the Continuity surveys and scoring algorithm reflects an effort to assess how closely crossings compare to a suite of favorable conditions for fish and aquatic organism passage expressed as the Massachusetts River and Stream Crossing Standards. Given the absence of empirical data that can be used to test any of the methodologies used in this study or develop a better one, the next best option for the River and Stream Continuity Partnership may be to further refine the scoring algorithm based on expert opinion from people knowledgeable about aquatic organism passage in New England.

Conclusions

Based on the results of this study we offer the following conclusions and recommendations.

1. Repeat surveys of crossing structures indicate relatively high rates of discrepancies for particular data fields but small overall effects on crossing scores. Efforts to improve the wording of questions on field data forms, the instruction manual and training programs should be used in an effort to lower data field discrepancy rates.
2. It is important to collect sufficient data to accurately document crossing locations. GPS coordinates should be collected for all surveyed crossings.
3. Flow conditions may not be a critical factor in timing field surveys. However, it is still recommended to avoid extreme high or low flow conditions.
4. FishXing is difficult to implement unless detailed hydrological data are available for target sites. This will likely limit its use in New England.
5. It will continue to be difficult to implement FishXing or develop models such as Coffman's Coarse Screens or the Continuity Scoring Algorithm without significantly more research on swimming and leaping ability of New England fish and data from field studies on passability of culverts for a broad range of species.
6. The Crossings Database Scoring Algorithm is currently an expert opinion model that seeks to compare crossings against an idealized standard based on a number of characteristics that can affect passability for fish and other aquatic organisms. In the absence of empirical data or other credible models to evaluate or calibrate the algorithm, efforts should be made to better ground the algorithm using the professional judgment of experts in aquatic organism passage.

The River and Stream Continuity crossings survey protocol is a rapid assessment protocol designed to give a rough assessment of the degree to which a crossing might present a barrier to aquatic organism passage. A reliable and accurate rapid field assessment protocol with an efficient process for scoring, storing and retrieving information from those assessments will provide an important tool for evaluating opportunities and establishing priorities for culvert replacement and the restoration of river and stream continuity.

The Crossings Database now contains information for over 3000 crossing structures in five states and offers an excellent opportunity to learn about the conditions that are associated with various structure types and the extent to which they serve as impediments or barriers to fish and other aquatic organism passage. Continued improvement of the survey protocols and scoring algorithm will increase the credibility of information contained in the database.

Acknowledgements

Funding for this project was provided by The Nature Conservancy. The Nature Conservancy also participated in the data collection including coordination of all of the resurvey and most of the previous survey assessments. Special thanks go to Marie-Françoise Walk, Amy Singler, Alison Bowden, Kim Lutz, Hanh Chu and Ayala Ben-Chaim. This project is part of ongoing work of the River and Stream Continuity Partnership that includes The Nature Conservancy, Massachusetts Riverways Program and University of Massachusetts Amherst.

Biographical Sketch

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Field Data Form: Road-Stream Crossing Inventory

Coordinator	Crossing ID#

Date: ________ **Stream/River:** ________________ **Road:** __________________________ **Town:** ________________

Location: __________________________________ **GPS Coordinates (lat/long):** ______________________________

Observer: _____________________ **Phone #:** _____________ **Email address:** ______________________________

Photo IDs: ____

Road/Railway Characteristics

1. # of Travel Lanes: ____ **Shoulder/ Breakdown lanes:** ☐Yes ☐No **Road Surface:** ☐Paved ☐Unpaved ☐RR

2. Are any of the following conditions present that would significantly inhibit wildlife crossing over the road?

High traffic volume (> 50 cars per minute)	☐ Yes	☐ No
Steep embankments	☐ Yes	☐ No
Retaining walls	☐ Yes	☐ No
Jersey barriers	☐ Yes	☐ No
Fencing	☐ Yes	☐ No

Other (specify) ____

____

Crossing/Stream Characteristics (during generally low-flow conditions)

3. Crossing Type: ☐ Ford ☐ Bridge ☐ Open Bottom Arch ☐ Single Culvert ☐ Multiple culverts (# of culverts) _____

4. Condition of crossing: ☐ Good ☐ Fair ☐ Collapsing ☐ Eroding ☐ Rusted through ☐ Broken

5. Does the stream at the crossing contain fish? ☐ Yes ☐ No ☐ Don't know

6. Is the stream flowing (in the natural channel)? ☐ Yes ☐ No

7. Flow conditions during the survey are:

☐ unusually low ☐ typical low-flow ☐ average flow ☐ higher than average

8. Are any of the following problems present?

Inlet drop	☐ No	☐ <6"	☐ **= 6”**
Outlet perch	☐ No	☐ <6"	☐ **= 6”**
Flow contraction	☐ Yes	☐ No	

9. Tailwater armoring: ☐ Extensive ☐ Not Extensive ☐ None

10. Tailwater scour pool: ☐ Large ☐ Small ☐ None

11. Physical barriers to fish and wildlife passage: ☐ Permanent ☐ Temporary ☐ None

Describe any barriers: ____

____

12. Crossing Embedded? ☐ Not embedded ☐ Partially embedded ☐ Fully embedded < 1' ☐ Fully embedded > 1'

13. Crossing substrate: ☐ None ☐ Inappropriate (large rip rap, concrete) ☐ Contrasting ☐ Comparable

14. Water depth matches that of the stream? ☐ Yes (comparable) ☐ No (significantly different)

15. Water velocity matches that of the stream? ☐ Yes (comparable) ☐ No (significantly different)

16. Crossing span: ☐ Constricts channel ☐ Spans active channel ☐ Spans bankfull width ☐ Spans channel & banks

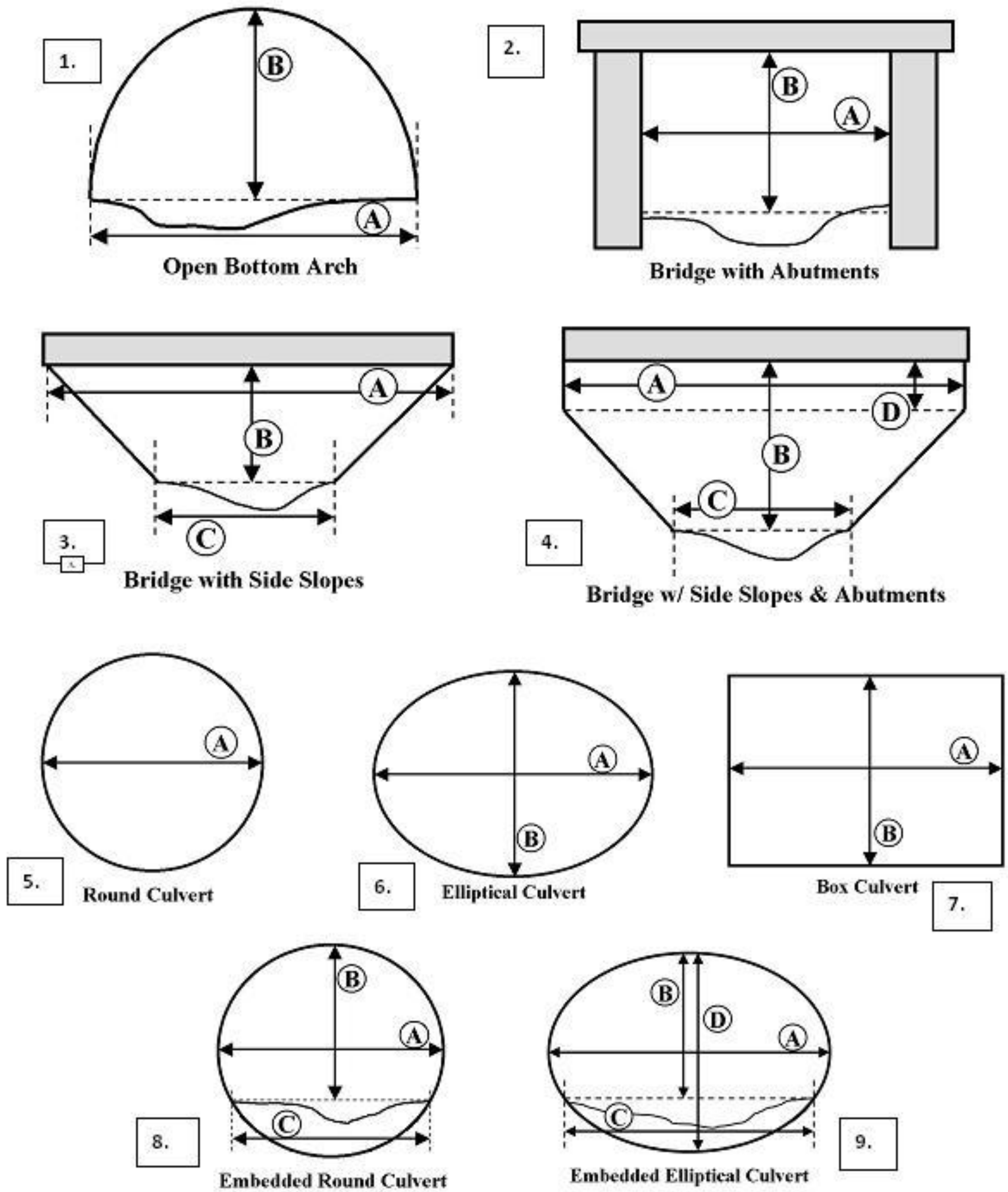
17. Minimum structure height at low water (from water level to the roof inside the structure) ☐ > 6 ft. ☐ 4-6 ft. ☐ < 4 ft.

18. Comments ____

____

____

CROSSING DIMENSIONS

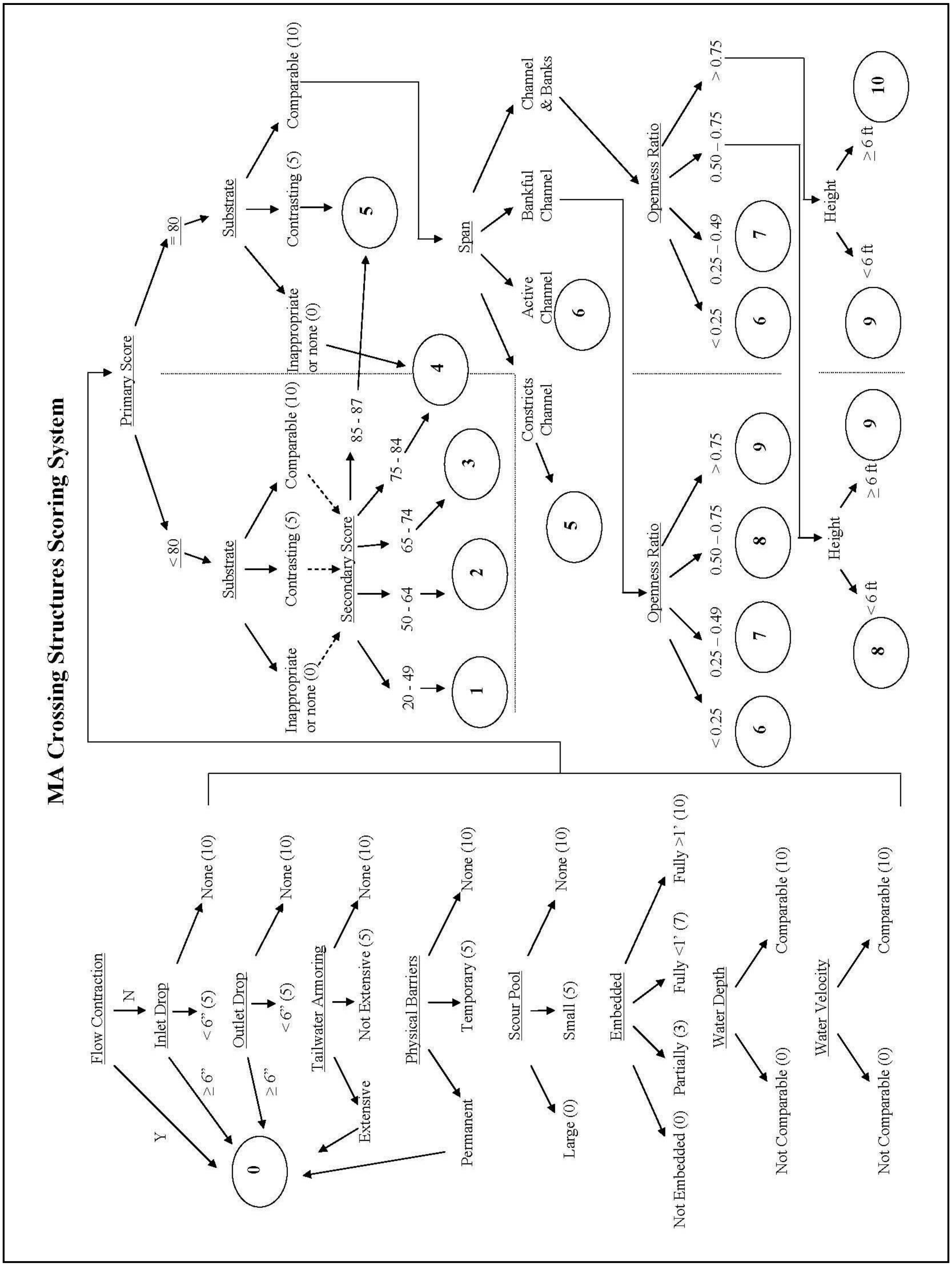


Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft or m): A) __________ B) __________ C) __________ D) __________

Downstream Dimensions (ft or m): A) __________ B) __________ C) __________ D)__________

Length of stream through crossing (ft or m): __________


MA Crossing Structures Scoring System
Flow Contraction
Y
N
Inlet Drop
≥ 6"
< 6" (5)
None (10)
Outlet Drop
≥ 6"
< 6" (5)
None (10)
Tailwater Armoring
Extensive
Not Extensive (5)
None (10)
Physical Barriers
Permanent
Temporary (5)
None (10)
Scour Pool
Large (0)
Small (5)
None (10)
Embedded
Not Embedded (0)
Partially (3)
Fully <1' (7)
Fully >1' (10)
Water Depth
Not Comparable (0)
Comparable (10)
Water Velocity
Not Comparable (0)
Comparable (10)
0
Primary Score
< 80
Substrate
Inappropriate or none (0)
Contrasting (5)
Comparable (10)
Secondary Score
20 - 49
50 - 64
65 - 74
75 - 84
85 - 87
1
2
3
4
≥ 80
Substrate
Inappropriate or none (0)
Contrasting (5)
Comparable (10)
5
Span
Constricts Channel
5
Active Channel
6
Bankful Channel
Channel & Banks
Openness Ratio
< 0.25
0.25 – 0.49
0.50 – 0.75
> 0.75
6
7
8
9
Height
< 6 ft
≥ 6 ft
8
9
Openness Ratio
< 0.25
0.25 – 0.49
0.50 – 0.75
> 0.75
6
7
Height
< 6 ft
≥ 6 ft
9
10

Where the River Meets the Road: How Washington State is Providing Habitat While Protecting Highways

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Abstract

The configuration of today's road system owes more to historic travel routes, and transportation needs than to regard for ecological and fluvial processes. Roads are often located along rivers where they are subject to periodic damage from seasonal high flows and severe storms. The traditional response is to protect the roadway with rock armoring to stabilize eroding banks and fend off the water's force. This work, as maintenance or emergency response, may need repeating if it only addresses a symptom. Threats to the roadway and risk of road closures may continue. This approach can also result in significant loss of aquatic habitat in the ongoing cycle of damage and repair. Severe weather, high flows and flooding exhibit increasing frequency and intensity Washington State and elsewhere. Projections for climate change show this trend continuing. How can we reduce the problems with repetitive maintenance while improving aquatic habitat?

Washington State Department of Transportation (WSDOT), working closely with Washington Department of Fish & Wildlife (WDFW) established the Chronic Environmental Deficiency (CED) program, where projects are developed and implemented with the goal of optimizing habitat improvement. This allows specialized focus on long-term solutions beyond the scope of maintenance or emergency response. Sites with repetitive maintenance concerns are nominated by WSDOT, WDFW, Tribes or others and evaluated against program criteria. WSDOT conducts a reach assessment, reach analysis, or corridor analysis that identifies the hydrologic mechanisms for failure and develops a conceptual design solution. A scientifically based prioritization methodology provides ranking based on ecological gain and effectiveness of the correction.

Since 2004, WSDOT has successfully completed seven CED projects with an investment in excess of $10 million. Engineered logjams have worked both as bank stabilization and as mid-channel flow diffusion structures on the Hoh, Nooksack and Clallam Rivers. Bridges that were replaced Nolan Creek have restored channel migration. Buried woody groins on the Snoqualmie and Newaukum rivers have protected shorelines as predicted. The Hoh River project, WSDOT's largest CED project to date, involves some of the world's largest engineered log jams. Monitoring for ongoing assessment of structural integrity, geomorphic changes, and biological performance is in development. There are currently 13 CED projects funded for $50 million to be constructed by 2010. About 30 additional projects are currently included in the CED process. During recent winters these projects held up very well to historic floods.

Defining road projects based on environmental as well transportation needs is a path to more comprehensive, long term solutions. This approach demonstrates the importance of detailed reach analysis and effectiveness of bioengineering technique, and has wide application for transportation professionals adapting to change.

Geographic Context and Problem Description

The Terrain of Washington State Reflects the Shaping Influence of Moving Water

With its high mountain ranges crowned with active, glacier clad volcanoes that feed mighty rivers which flow to marine waters, Washington State is a highly dynamic environment—and a difficult place to maintain roads. Rivers and streams support fish and wildlife including the iconic pacific salmon species. These constitute important, commercial and recreational resources, indicators for ecosystem health and a cultural symbol of region identity.

Many highways share mountain valley corridors with the rivers that formed them. These rivers formed the original "highway system" from time immemorial. The growth of trails, rails, and finally highways along them is an artifact of history and a reflection of the dramatic topography. Many of the roads along our rivers are thus a predictable outgrowth of historic travel routes.

There are over 7000 miles of state highway in Washington State, and some 3995 miles of highway (57%) lie within 500 feet of a stream or river. This poses unique challenges for maintaining static highway infrastructure amidst an inherently dynamic and constantly changing environment. These challenges are perhaps most marked along our numerous mountain river/highway corridors where topography, geology, channel migration, forest practices, and reduction of glacial ice storage conspire to push our rivers into disequilibrium as a result of both anthropogenic and natural disturbance regimes.

When a stream is in equilibrium its inputs and outputs (water, sediment, vegetation etc.) are in relative balance and it provides complex and diverse habitat. When land use impacts, weather climate change or other factors throw the system out of balance the resultant geomorphic disruptions can be rapid and dramatic. This often manifests as either vertical or lateral instability. Results of vertical instability include bed aggradation or degradation. Lateral instability results in channel migration and river avulsions.

Stream disequilibrium can have negative effects on both habitat and human infrastructure. Culverts, bridges and road beds become inundated or undermined and can be structurally threatened. Habitat features such as vegetated shorelines, in-stream woody material, salmon spawning gravels and protected off channel rearing areas can impacted by accelerated erosion and sedimentation.

Both anthropogenic and natural disturbance regimes tend to reduce channel complexity in the short term. Simplified stream channels are more vulnerable to instability and are thus more likely to cause damage to highway infrastructure. Likewise they are more vulnerable to habitat degradation. Understanding this, it is perhaps ironic that the usual response to infrastructure damage stemming from stream instability is to harden the banks and bed with rock armor in a manner that furthers channel simplification, thus reinforcing trends toward stream instability.

Regional Climate Change Anticipated to Lead to More Destructive Flows

Projections for climate change for the Pacific Northwest generally indicate a shift in precipitation patterns toward wetter autumns and winters, drier summers, and small overall increases in annual precipitation Annual runoff (water into streams) across the state of Washington is projected to increase 0% to 2% by the 2020s, 2% to 3% by the 2040s, and 4% to 6% by the 2080s and these changes are mainly driven by projected increases in winter precipitation. (Littell et al, 2009). Regional climate model simulations generally predict increases in extreme high precipitation over the next half-century, particularly around Puget Sound. In that region, existing drainage infrastructure designed using mid-20th century rainfall records may be subject to rainfall regimes that differ from current design standards (Mote, 2009).

Guiding Principles

As the age of the transportation infrastructure increases, so do the visible impacts to both habitat and roads from stream instability. This stems from increases in disturbance regimes that have both natural and anthropogenic causes. These trends, aging infrastructure in the context of increased stream instability mean the difficult job of maintaining highway infrastructure in dynamic mountain river environments is getting even tougher. This is also an opportunity for innovative approaches.

Simplified channels and protective systems like bank armoring function mainly through deflection of kinetic energy. Complex natural channels on the other hand tend to diffuse energy and as a result are not only more stable, but more productive from a habitat standpoint as well. A central guiding principle of the approach to infrastructure protection discussed here hinges upon this fact. If more complex infrastructure protection structures can be developed that mimic natural processes of energy diffusion, greater success is likely to be achieved not only in terms of protecting our highways, but in reducing the environmental impacts on aquatic habitat as well.

Consciously mimicking natural processes in the development of infrastructure protection also holds benefits with regard to permitting and mitigation requirements. Erosion repair which relies largely on placing rock can lead to a loss of habitat and can require some form of compensatory mitigation to offset the impacts of the project, and potentially at a separate mitigation site might need to be designed and constructed. If complex elements such as large woody debris can be incorporated into the protective structure, then the structure can mitigate itself.

Program Description

New Approach to an Old Problem

Very often, the approach to protecting road infrastructure from migrating rivers has been placing and replacing rock, sometimes repeatedly, excavating sediment or removing debris, essentially responding to the symptoms of the problem with the potential for ongoing maintenance needs at the site (Figure 1). The maintenance can have negative impacts on fish habitat and fish life that can result from smoothing stream banks which contribute to higher velocities, simplifying channels, removing sediment sometimes including spawning gravels, and removing large woody debris that provides cover and a food source for fish. This situation often is the result of the limited scope of response available through a maintenance or emergency action. To start to avoid these problems, a change in the approach at the programmatic level is needed.

Figure 1: A usual approach to protecting road infrastructure is placing large rip-rap, such as this temporary revetment along SR20 on the Skagit River.

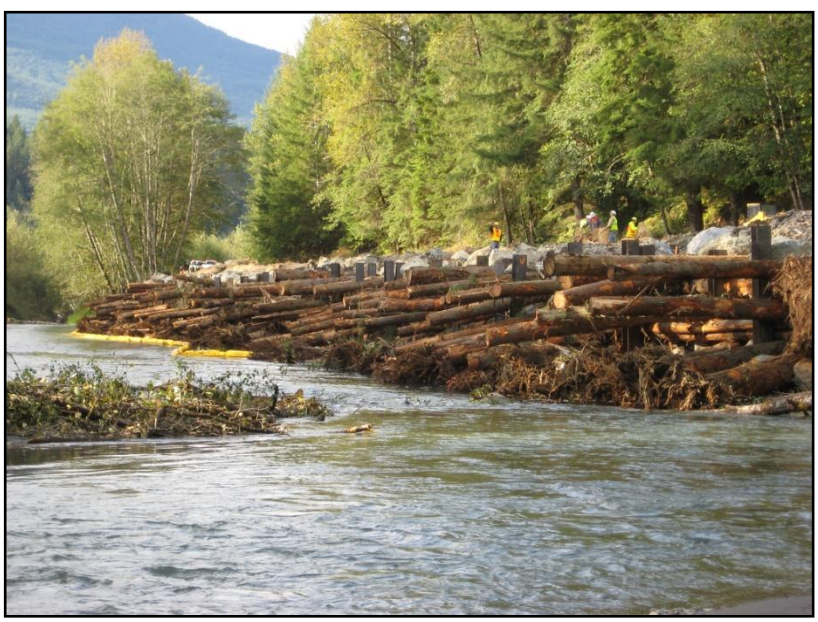

Figure 2: A change in approach is needed to address the habitat loss by continued rip-rap, the Sauk River wood cribwall is an example of the CED programs change in approach.

To help reduce the need for repetitive maintenance activities and resulting effects of on the aquatic environment, Washington State Department of Transportation (WSDOT) established the Chronic Environmental Deficiencies (CED) program in 2001. WSDOT coordinates closely with the Washington Department of Fish and Wildlife (WDFW) to find long-term solutions that optimize improvements for fish and fish habitat, while also addressing transportation needs.

The goal of the CED program is to:

- Reduce maintenance costs
- Reduce the loss of commerce due to road closures
- Reduce or remove damaging material and other material that is potentially damaging to aquatic habitat, such as rip-rap.
- Reduce or replace riprap with rough woody structures and other bio-engineered designs to enhance fish habitat.

Innovative Concepts of the CED Program

The CED program is designed to reduce the need for maintenance and reduce or eliminate the negative impact to fish. A CED project is a location adjacent to the state highway system where recent, frequent, and chronic maintenance repairs to the state transportation system are causing impacts to fish and fish habitat.

We use the following criteria for projects to be entered into the program:

- Adverse habitat conditions related to fish or fish habitat are associated with repetitive repairs to WSDOT infrastructure.
- The infrastructure at the site has a history of maintenance actions within the last ten years
- The infrastructure has been repaired and/or maintained at least three times within the last 10 years.
- The project does not fit into another WSDOT funding category.

Stand Alone Funding for Environmentally Defined Work

Traditionally, this type of correction would have to wait to be included as part of a larger transportation project, Often the timing and the scope of maintenance or emergency work will not accommodate a project that does more than treat the symptoms. To enable a more comprehensive approach, a separate 'stand alone" funding category was established for the CED program allowing the legislature to review CED projects separate from other projects such as safety, unstable slopes, or fish passage. The stand alone funding category also allowed for project specific funding instead of a pool of funds that could be divided up between projects.

Collaborative project development

WSDOT and WDFW work together to develop each CED project. WSDOT develops a scope of work for each site by working with a hydrologist conducting the site and reach analysis. The scope includes the timing of deliverables which is agreed to by both agencies. When data has been collected and formulated into the draft analysis it is sent to the WDFW local area engineer and habitat biologist for review and a site concurrence meeting is held to agree on a conceptual design between both agencies. The agencies work together to resolve disputes when a solution cannot be agreed upon and work together through design and construction to ensure the outcome meets both agencies goals and missions.

Based on stream reach analysis

Reach analysis is at the core of the CED project development process. WSDOT has developed an interdisciplinary team of hydrologists, geomorphologists, geologists and engineers within its Environmental Services Office Hydrology Program that has performed more reach analysis work than any other entity in the state. A stream assessment or analysis is conducted for each CED project site, however there are different forms. A corridor analysis addresses a larger scope and often multiple sites along the highway river interface. A site and reach assessment addresses one site and assesses the contributing factors of the reach to the problem at that site. A technical memorandum for those sites that WDFW and WSDOT agree are straight forward and do not require in-depth analysis. All forms of analysis use the multi agency created Integrated Streambank Protection Guidelines (Washington State Aquatic Habitat Guidelines Program, 2002) and the Hydraulic and Engineering Circular Manual 18, 20 & 23

Habitat conditions improved

Contained within the analysis documents is a habitat component that addresses the habitat features of the site and reach including fish presence and use. Also included are the habitat features essential to the reach including the project site such as large woody debris spawning gravels or areas of quiescence for migrating salmon to rest. These are included as part of the project design process, so that the resulting solution provides habitat benefits as well as protection of the roadway.

Overview of the CED process

Coordination – nomination of sites

The CED coordinator attends training and meetings that occur between WDFW and WSDOT giving presentations on the program, and educating stakeholders on the benefits of the program designed to proactively address habitat needs and protect the highway. This coordination effort results in Area Habitat Biologists, Tribal Natural Resource Managers, and other governmental agency staff, in addition to WSDOT staff, nominating sites for the program. The CED coordinator and technical lead make a determination on site whether the site is eligible for the program.

Site and Reach analysis

An analysis is conducted by WSDOT hydrology staff or consultants for some larger projects, which addresses the mechanism for failure at the site and within the reach. The analysis also recommends a solution. The solution is based on a Hydraulics and Engineering Circular and a multiagency developed guidelines for stream bank protection. The draft reach assessment is sent to WDFW for comments.

Pre-Scoping

After review of the analysis a pre-scoping meeting is held onsite with WDFW and WSDOT to discuss the alternatives and select a conceptual solution. With a selected solution WSDOT engineers can assess constructability and feasibility of the solution resulting in a cost estimate. This cost estimate is what is taken forward to the state legislature for funding.

Prioritization

Projects are prioritized using a Priority Index (PI) model which takes into account the potential benefits of the project as well as factors that affect a project's feasibility. Using quantity and quality of habitat for anadromous and resident salmonids as the base parameter, the PI indicates each project's relative priority. Site-specific modifiers are used to adjust this base parameter.

Design

When the chosen alternative identified in the site reach assessment is funded the project is assigned to a WSDOT project office. The CED coordinator arranges a meeting to discuss the CED goals and objectives and make sure the project office has the support it needs. Often, the lead hydrologist for the reach assessment will be a member of the design team. WDFW is involved throughout the process with design review. Once the conceptual design is agreed on by resource agencies appropriate permits are obtained.

Construction

During construction the CED program staff verifies that the CED goals and design criteria are being met.

Monitoring

Certain monitoring such as plant establishment is required through permitting. Also, WSDOT is directing research monies to assess fish usage in and around ELJ's and compare that with habitat use in and around a rip-rap placement. Our goal is to continue that type of monitoring for more CED sites around the state.

Project Examples

Engineered Logjams

Engineered logjams are designed to stabilize stream banks by arresting erosion and to diffuse the energy the stream has. The Hoh River project used both types of ELJ's 4 mid-channel and 6 bank stabilizing structures, the mid-channel ELJ's are the largest in the world (Figure 3). The Nooksack and Clallam River have much smaller ELJ's protecting road infrastructure from erosion. WSDOT designs ELJ's at sites only where appropriate. Considerations include: good sight distance for recreational users, ability to dewater the channel or construct a bypass and use of a double anchoring system usually consisting of steel piles and rock overburden. WSDOT is developing guidance on how to install LWD in river systems.

Figure 3: Damage to US 101 adjacent the Hoh River, left, resulted in one of the first CED projects including bank stabilization structures, center, and large mid-channel ELJ's, right.

Stream Crossing Replacement

Older stream crossings are often undersized, the creek has meandered resulting in the culver being misaligned or debris becomes entangled in by the design of the crossing. Culverts that clog with excess sediment from upslope land use changes are replaced with larger taller culverts or bridges. Bridges such as that on Nolan Creek (Figure 4) are replaced to restore channel migration and, like the Moclips River, replaced to remove the excess pilings within the river which accumulate large woody debris.

Figure 4: The old US101 bridge over Nolan Creek, left, was a safety hazard and constricting the creek. The CED program replaced the bridge with a clear span bridge to allow channel migration, right.

Woody Groins

When roads cannot be moved out of the channel migration zone a softer environmentally conscious solution is to install buried woody groins (structures that project into the water body to deflect flows and are not meant to be overtopped; a barb is intended to be overtopped) in the dry. Buried groins require adequate space between the river and the road, however knowing the river will migrate in that direction work very proactively. Two projects the Snoqualmie River project constructed in 2002 (Figure 5) and the Sauk River project constructed in 2007 which faced a flood event four weeks later have protected the highway.

Figure 5: Channel migration threatens the right bridge abutment and a future project on the Snoqualmie river, left. The CED program designed a project with buried groins to arrest erosion as it came closer to SR202, right.

Program Summary Outcomes, Benefits, Challenges

Since its inception in 2001, the CED program has expanded as its benefits have been recognized by stakeholders around the state. Fourteen projects were completed by the end of 2008, ten more have been funded and are scheduled to be constructed by 2011, and two are funded for design. About 60 additional projects currently reside at various stages in the CED process.

Projects in the CED process face challenges similar to other highway projects, and site-specific constraints beyond the typical highway project. These include logistical problems such as limited rights-of-way and traffic control; engineering challenges such as steep, unstable slopes that interface with dynamic river systems. The program has been successful in navigating these constraints through multi-agency, multi-discipline coordination and collaborative project development.

The CED program was created to address not only site-specific chronic problems in the Washington State highway system, but also to improve and foster collaborative relationships with resource agencies and tribes with the intent of creating successful projects that meet the needs of highways and resources. To date, the CED process has been successful in meeting its goals. A few CED highlights include the Sauk River side-channel project, recognized for environmental design excellence for its innovative approach to bank stabilization while providing long-term habitat benefits within a limited project footprint. Another highly-visible and successful project is the Naches River project, where riparian benches were used to push the force of the river away from the highway, while providing long-term habitat functions.

Benefits of the CED program go beyond providing habitat for fish. CED projects contribute to a safe and reliable state highway system while reducing spending on repetitive maintenance and loss of commerce due to road closures. Further, the collaborative process allows multiple stakeholders to engage in the process from initial scoping through construction. This involvement creates trust and minimizes disagreements, saving time and money.   The CED process is a successful example of adaptation from the old way of approaching transportation problems to a new paradigm that focuses not only on what's best for the road, but what's best for the resource as well.

Acknowledgements

This program and therefore this summary is only possible through the ongoing coordination between WSDOT and WDFW staff at the region and headquarters offices and especially with the WSDOT regional maintenance staff.

Biographical Sketches

Paul Wagner is a wildlife biologist with over 20 yrs experience in the field. He is currently the Biology Branch Manager for the Washington State Department of Transportation. He chairs the Steering Committee of the International Conference on Ecology and Transportation.

Scott E. Anderson is a salmon habitat biologist with over 12 years of experience in habitat science and regulation. Mr. Anderson holds a master's degree in Environmental Science and has worked as an ESA biologist with NOAA Fisheries, as an area habitat biologist with Washington Department of Fish and Wildlife, and is currently the manager of WSDOT's Stream Restoration Program.

Jim Park is the Senior Hydrologist, Hydrology Program Manager, and CED Program Technical Lead for the Washington Department of Transportation. He holds a Master's Degree in Environmental Sciences and has over 16 years experience in conducting hydrologic and geomorphic analysis of riverine systems and floodplains, specializing in transportation infrastructure protection and habitat restoration. Mr. Park has authored or co-authored over 50 hydrologic and geomorphic reports, river reach analyses, and floodplain hazard analyses, making him one of the most prolific researchers on river dynamics and infrastructure impacts in the Pacific Northwest.

Karen Zirkle is a conservation biologist with a degree from the University of Washington and 9 years experience in the field. Currently, she is the CED coordinator for Washington State Department of Transportation contributing to the habitat analysis of each site and reach assessment, managing consultant contracts and overseeing project delivery.

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For additional information refer to the CED website: http://www.wsdot.wa.gov/Environment/Biology/FP/CEDretrofits.htm

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EFFECTIVE MITIGATION: THE CUMULATIVE IMPACT OF CLIMATE CHANGE ON TRANSPORTATION NETWORK AND ITS IMPLICATIONS ON AQUATIC BIODIVERSITY OF GANGES HEADWATERS, GARHWAL HIMALAYAS

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Abstract

Integrated approach to planning, building, maintaining and monitoring the health of the transportation system and natural ecosystem of Ganges headwaters, Garhwal Himalayas need to be addressed in the context of global climate change. It is a cause of concern that the poorly designed network of roads and trails in the mountain area are expanding, without giving due consideration to natural process of ecosystem function and climate change. These cumulative effects have been quantified for a period of five years (January 2004 – December 2008) of climate change on transportation network and its implications on aquatic biodiversity of rapids and riffles of Ganges headwaters (Latitude 29^0 61'- 30^{o}28' N; Longitude 77^{o}49' – 80^o 6' E). Transportation network of 573 km long passing along the glacier-fed Ganges headwaters, a project of US $ 290 million, is one of the most important networks in the mountain region of Garhwal Himalayas. Monitoring of meteorological data revealed an erratic behaviour of rainfall, temperature, humidity, sunshine, changes in the frequency of snowmelt, snow falls, floods, drought, in addition to increased CO_2 emission (370-403 µmol. mol^{-1}) in the valley of Ganges. It has cumulative impacts on transportation network in terms of massive landslides, submergence of roads at few places, thawing, and slope failures in monsoon and winter seasons, which have direct or indirect implications on transparency, dissolved oxygen, conductivity, bottom substrate composition and aquatic organisms of Ganges. A decline of 49% in annual mean density, 49% in alpha diversity and 17% in Shannon Weiner index ($\overline{H}$) of periphyton was recorded during a five–year period. Periphyton of Ganges were represented by genera of Bacillariophyceae (25), Chlorophyceae (11) and Myxophyceae (4). A decline of 15% in mean annual density, 22% in alpha diversity and 17% in Shannon Weiner index ($\overline{H}$) of zooplankton was estimated. Zooplankton were represented by the genera of Cladocera (2), Protozoa (2), Copepoda (2) and Rotifera (3). A depletion of 80% in annual mean diversity, 67% in alpha diversity and 28% in Shannon Weiner index ($\overline{H}$) of macrozoobenthos was computed. Macrozoobenthos of Ganges headwaters were reported by the genera of Ephemeroptera (11), Trichoptera (3), Diptera (4), Coleoptera (5), Hemiptera (2), Plecotera (2), Odonata (1) and Molusca (1). A shrinking of 24% in annual density, 18% in alpha diversity and 30% in Shannon Weiner index ($\overline{H}$) of fish was also calculated. Fish of Ganges headwaters were represented by 39 species belonging to 15 genera and five families. We have recommended the following mitigation measures: regular maintenance and monitoring of roads, raising the height of the roads from the river bed, natural recovery of functional habitats and effective management of landslides and slope failures through bioengineering methods and construction of retaining walls and toe walls, close watch on erratic behaviour of meteorological parameters and the strong co-ordination among transport planners, geologists, civil engineers, environmental biologists and climatologists. The suggestion to address climate change by providing alternative fuels, increasing vehicular efficiency and changes to travel behaviour has also been recommended.

Introduction

Mountain regions, covering about one-fifth of the Earth's land surface, are an important source of water, energy, minerals, forests, agricultural products as well as the area of recreation. They are the storehouse of biological diversity, home to endangered species and also the vital part of the global ecosystem (Beniston 2003). Mountains are unique ecosystems covering all the Earth's climatic zones such as tropical, sub-tropical, temperate and alpine. They are widely recognized areas containing highly diverse and rich ecosystem and thus key element of the global geo-space biosphere system. They also represent unique areas for the detection of climate change and the assessment of climate related aspects. Mountain regions are characterized by substantial gradients in environmental characteristics due to rapid and sharp altitudinal gradients leading to distinct altitude specific pattern (zonation) of vegetation structure, composition , functioning and specific dynamics of hydrological processes with important positive and negative consequences (IGBP 1996). Series of changes in the Himalayan geomorphology, climate and biota occur since its origin (Vishnu-Mittre 1984). These changes coupled with more recent human activities have given rise to present day biodiversity (Mani 1974).

There is now a general consensus within the scientific community that the global climate and its regional components, including mountain climates - is likely to change over coming decades, at rates unprecedented in human history. It means that, at any point on Earth, over the next few decades, significant changes in long-term averages (*e.g.* floods, droughts, storms) may occur. Over the past decade, the issue of climate change has risen rapidly to an important position on scientific and political agendas. Mountains occupy a considerable part of the world's land surface and are directly or indirectly vital for significant proportion of the global population. Little explicit attention has been given to the impact of climate change on transportation network and its implications on aquatic ecosystem of mountains.

The Garhwal Himalayas is one of the most important parts of the Himalayas, which is the repository of rich biodiversity due to its physiographic and climatic variability. The Ganges is the Holy River, which has been declared as a National River of India. A very long stretch of headwaters of Ganges passes through Garhwal Himalayas in addition to its origin from the glaciers. A strong transportation network is the necessity for human mobility and fast development of mountain areas. It is a cause of concern that the poorly designed network of roads and trails in mountain areas are expanding, without giving due consideration to natural process of ecosystem function and climatic severity in the Himalayas. The effects of climatic change on transportation network and its implications on aquatic biodiversity of rapids and riffles of headwaters of Ganges River have been quantified for a period of five- year (January 2004 – December 2008). This is for the first time that such type of work has been undertaken in India.

The present paper attempts to provide manifestation of adverse impact of erratic behaviour of meteorological parameters (rainfall, temperature, humidity, sunshine, changes in the frequency of snowmelt, snowfalls, floods, droughts, *etc.*) in addition to increased concentration of atmospheric carbon dioxide on transportation network in terms of massive landslides, submergence of roads at few places, thawing, and slope failures in monsoon and winter seasons, which have direct implications on quality of aquatic environment, functioning of ecosystem and depletion of density and diversity of aquatic organisms dwelling rapids and riffles of Ganges headwaters.

Materials and Methods

Physiography of the Study Area

The study area is located in the Garhwal Himalayas, an important zone of the Himalayas and a part of the new state of Uttarakhand of north India (Latitude: 29^{o} 26' -31^{0} 28' N; Longitude: 77^{0} 49' – 80^{0}6' E). It encompasses six districts (Dehradun, Tehri, Pauri, Uttarakashi, Chamoli and Rudraprayag) and covers an area of 30,029 km^2. The area is very rich in terms of terrestrial and aquatic biodiversity. The entire region is bestowed with tremendous freshwater resources in terms of major fluvial systems of holy rivers of Ganges, Yamuna and their tributaries. Two major parent streams – Alaknanda and Bhagirathi form the Ganges after the confluence at Deoprayag. All four world famous Indian Shrines (Badrinath, Kedarnath, Yamunotri and Gangotri) are located in this region. To cater the needs of heavy influx of pilgrims, a thick network of roads and national highways has been launched. Most of the roads and highways in Garhwal Himalayas have been constructed in the river valleys along the major rivers including the Holy River Ganges.

Geology of the Study Area

The study area encompasses the watersheds of two parent streams of Ganges-Alaknanda and Bhagirathi. The watershed of Alaknanda is characterized by the flat-topped ridge, steep slopes and wide valley. The area is covered by three types of rocks of the Proterozoic ages (Valdiya 1984). The area is represented by huge thinly foliated, highly folded, fractured and joined phyllite rock traversed by quartz veins and few basic intrusive in the form of sill and dykes. The phyllite is called Pauri phyllite (Kumar and Aggarwal 1975). Vertically folded, highly fractured, pinkish ripple and current bended quartzite rocks and intercalated with massive intrusive of meta volcanic rocks are under Garhwal group of rocks. The tectonic features generally control the landform of an area; slopes of a drainage pattern are more sensitive to recent neotectonic activities. Wide valley of Alaknanda is characterized by the set of terrace formed by the river sifting and reducing the water discharge. The river flowing in the area was assumed to have heavy water discharge with laminar flow that reduced to its present level. Therefore, the sediments and load are deposited along the riverside in the form of terraced. Most of the lowest terraces are in contact of the river. The stretch of the Bhagirathi of upper Ganges (Gangotri to Rishikesh) falls under four major stratigraphic units; the Central Crystalline, the Garhwal Group, the Kumaun Group, Krol Formation and Tal-Quartzite. The Central Crystalline thrusts upon the Garhwal Group along the Main Central Thrust (MCT), while the North Almora Thrust delineates the Garhwal Group for the Kumaun Group. The Central Crystalline extends from Gomukh to Sanj, the Garhwal Group from Sanj to Dharasu, and the Kumaun Group from Dharasu to Sanknidhar. The Krol Formation extends from Sankanidhar to Byasi and the Tal –Quartzite extends from Byasi to Rishikesh. A tremendous increase in the gradient (10.3 -30.0 km^{-1}) of the river channel was observed upstream of Uttarkashi. The gradient decreases to an average of 3.7 m km^{-1} between Uttarkashi to Deoprayg and about 1.0 km^{-1} up to Rishikesh. The tributaries of Bhagirtahi have a much steeper gradient. The upper most stretch of Bhagirathi (up to Harsil and adjoining areas) has cliff type slopes. Downstream at Dabrani, the cliff type slope has taken the form of repose slope at certain places, implying the remnant of old landslides. The repose type of slope was seen from Uttarkashi to Deoprayag. However, the cliff slope was again observed between Tehri and Deoprayag.

Salient Features of Transportation Network Project in Garhwal Himalayas

The transportation network of 573 km long passing along the glacier-fed Ganges headwaters, a project of US$ 290 million is one of the most important networks in the mountain region of Garhwal Himalayas. It is 230 km long passing along the Alaknanda River, 195 km long passing along the Bhagirathi River, 78 km along other tributaries and 70 km long passing along the Ganges. This transportation network caters the need of heavy traffic (1.25 million people per year), as it is used by the pilgrims for visiting the world famous Indian shrines of Gangotri, Yamunotri, Badrinath, Kedarnath and Hemkund Sahib.

Methodology

Monthly sampling was conducted for a period of five-year (January 2004 to December 2008) at 0800-10.00 hrs at all the sampling sites; (three sampling sites each on Alaknanda and Bhagirathi, two on Ganges and two on other tributaries). Meteorological data were also collected from these sites. Physico-chemical parameters were analyzed following the methods outlined in Wetzel and Likens (1991) and APHA (1998).

Various components of aquatic biodiversity dwelling rapids and riffles of Ganges headwaters included periphyton, zooplankton, macrozoobenthos and fish. The collected organisms were identified in the laboratory following Ward and Whipple (1992) and several keys of Freshwater Biological Association, UK along with the help of several experts. For the study of density of the fish dwelling Ganges headwaters, the three small seine nets (TSSN) methods of Penczak and O'Hara (1983) and Chapman (1978) were employed.

Concentration of atmospheric CO_2 was recorded with the help of hand held CO_2 monitor (Telaive 7000 series, USA) at all the sampling sites. Annual mean and standard deviation of all the limnological, meteorological parameters and CO_2 were also calculated.

Results and Discussion

Meteorological Data

The recorded data on average global temperature recorded for a period of 1880-2007 (Table 1) revealed that decadal mean temperature of the Earth has increased considerably.

Decade	Average Air Temperature (^oC)
1880-1889	13.81
1890-1899	13.69
1900-1909	13.74
1910-1919	13.79
1920-1929	13.90
1930-1939	14.02
1940-1949	14.06
1950-1959	13.99
1960-1969	13.96
1970-1979	14.02
1980-1989	14.26
1990-1999	14.40
2000-2007*	14.64

Source: Goddard Institute for Space Studies, NASA *Eight year period

Table 1. Average global temperature by decade, 1880-2007

Under the present study, meteorological data were collected for a period of five years (January 2004 –December 2008). Monitoring of meteorological data in the Valley of Ganges headwaters, Garhwal Himalayas, revealed an erratic behaviour of rainfall, temperature humidity and sunshine (Table 2).

Meteorological Parameter	**2004** ($\overline{X}$ ± S.D.)	**2005** ($\overline{X}$ ± S.D.)	**2006** ($\overline{X}$ ± S.D.)	**2007** ($\overline{X}$ ± S.D.)	**2008** ($\overline{X}$ ± S.D.)
Air temperature (^{0}C)	23.88±2.79	24.90±3.0	26.82±4.3	27.47±4.2	27.01±4.1
Humidity (%)	75.79±10.38	79.85±12.90	82.98±12.99	84.04±11.72	83.86±11.65
Rainfall (mm)	21.38±7.86	24.08±7.74	21.67±7.44	26.42±8.36	32.42±7.36
Conc. of CO_2 (μ mol.mol^{-1})	370±6.20	374±5.59	380±4.90	395±3.45	403±3.68

Table 2. Meteorological data recorded over a period of five-year (January 2004 –December 2008) in the valley of Upper Ganges, Garhwal Himalayas

Atmospheric temperature was recorded 23.88±2.79 ^{o}C in 2004 and reached a maximum of annual mean of 27.47±4.2 ^{0}C in the year 2007 and slightly decreased in 2008.. Humidity fluctuated from 75.79±10.38 % to 84.04±11.72 % during a span of five-year. Rainfall also fluctuated erratically. It was recorded minimum (21.38±7.86mm) in 2004 and maximum in (32.42±7.36 mm) in the year 2008. Snowfall on the higher reaches of the valley also reflected erratic pattern. Irregular changes in the frequency of snowmelt, snowfalls, thawing, floods, and droughts were also recorded in the valley.

Atmospheric Concentration of CO_2

Atmospheric concentration of carbon dioxide was also recorded at all the sampling sites for a period of five-year (January 2004 –December 2008). A steady increase in the annual mean of concentration of CO_2 from 2004 (370.0±6.20 μ mol.mol^{-1}) to 2008 (403.0±3.68 μ mol.mol^{-1}) was recorded (Table 2).

Direct / Indirect Primary Impact of Climate Change on Transportation Network

Cumulative impacts of erratic behaviour of meteorological parameter were manifested on transportation network in terms of massive landslides (Figure 1), submergence of roads at few places, thawing, and slope failures in monsoon and winter seasons. These environmental disturbances have affected the entire transportation network of 573 km long in the valley of upper Ganges.

Figure 1. Cumulative impact of climate change on transportation network and its Implications in terms of massive landslide in Garhwal Himalayas

Physico-chemical Environmental Degradation of Ganges Headwaters

The cumulative impact of climate change on transportation network and its implications on aquatic environment of rapids and riffles of Ganges headwaters in terms of degradation of water quality has been observed (Table 3). Analysis of data revealed that a considerable change in the water temperature in the year 2008 (15.6±2.8 ^oC) was recorded in comparison to the temperature recorded in the year 2004 (15.0 ±3.1 ^oC). A minor change in the conductivity was also recorded from 0.13±0.01 to 0.16± 0.06 μ S cm^{-1} over a five-year period. The drastic change in the annual mean of turbidity and total dissolved solids was recorded over a period of five-year. A slight change in the pH was also noticed. It increased from 7.51± 0.18 to 7.63±0.17. A considerable reduction in the dissolved oxygen from 10.55±0.84 to 9.79±0.50 was recorded in the Ganges headwaters during a span of five-year. A minor change in other physico-chemical parameters (hydromedian depth, transparency, free CO_2, chlorides, nitrates and phosphates) was also recorded.

Environmental Variables	2004 ($\bar{X}$ ± S.D.)	2008 ($\bar{X}$ ± S.D.)
Water temperature (^0C)	15.0 ± 3.1	15.6 ± 2.8
Hydromedian depth (m)	1.21 ± 0.72	1.16 ± 0.70
Turbidity (NTU)	138.13 ± 244.75	160.61 ± 239.09
Transparency (m)	0.35 ± 0.29	0.21 ± 0.17
Conductivity (μ S cm^{-1})	0.13 ± 0.01	0.16±0.06
TDS (mg . l^{-1})	34.0 ± 33.39	45.14± 30.13
Dissolved Oxygen ((mg . l^{-1})	10.55 ± 0.84	9.79 ± 0.50
Free CO_2 (mg . l^{-1})	1.90 ± 0.42	2.79±0.60
pH	7.51 ± 0.18	7.63±0.17
Hardness (mg . l^{-1})	59.88 ± 16.16	64.92± 17.28
Alkalinity (mg . l^{-1})	49.67 ± 6.08	53.67 ± 6.03
Chlorides (mg . l^{-1})	2.61 ± 0.56	3.18 ± 0.70
Nitrates (mg . l^{-1})	0.41 ± 0.24	0.48 ± 0.25
Phosphates (mg . l^{-1})	0.25 ± 0.34	0.43 ± 0.45

Table 3. Cumulative impact of climate change on transportation network and its implications on annual mean ($\bar{X}$ ± S.D.) of physico-chemical environmental variables of rapids and riffles of Ganges headwaters, Garhwal Himalayas during a span of five- year (January 2004- December 2008)

Shrinking of Population of Aquatic Organisms

The aquatic biodiversity of Ganges headwaters is characterized by the presence of periphyton, zooplankton, and macrozoobnethos. As a consequence of climate change on transportation network and its implications on annual mean density of periphyton, a sharp reduction of 49% was recorded over a period of five year (Table 4). Periphyton of Ganges headwaters were represented by 25 genera (*Tabellaria, Diatoma, Diatomella, Meridion, Fragilaria, Synedra, Denticula, Tetracyclus, Nitzschia, Navicula, Coconeis, Cymbella, Gomphonema, Gomphoneis, Cyclotella, Stauroneis, Ceratoneis, Pinnularia, Acanthes, Amphora, Caloneis, Gyrosigma, Hantzschia, Opephora*) of Bacillariophyceae, 11 genera (*Closterium, Cosmerium, Desmidium, Ulothrix, Microspora, Zygnema, Stigeoclonium, Cladophora, Oedogonium, Hydrodictyon, Chlorococcum*) of Chlorophyceae and 4 genera (*Coccochloris, Anabaena, Phormidium, Oscillitoria*) of Myxophyceae.

A decline of 15% in mean annual mean density of zooplankton was also recorded over a period of five-year (Table 4). Zooplankton were represented by two genera (*Daphnia, Ceriodaphnia)* of Cladocera, two genera (*Vorticella*, *Zoothamnium*) of Protozoa, two genera (*Cyclops, Diaptomus*) of Copepoda and three genera (*Trichocera, Asplanchna, Keratella*) of Roifera.

A sharp depletion of 80% of annual mean density of macrozoobenthos over a period of five- year was recorded in the Ganges headwaters as a consequence of an adverse impact on transportation network due to cumulative impact of climatic change (Table 4). It reduced from 895.23±623.70 to 179.17± 171.45 ind.m^{-2}. Macrozoobenthos of Ganges headwaters were represented by 11 genera of Ephemeroptera (*Heptagenia, Leptophlebia, Caenis, Cloeon, Baetis, Centroptilum, Ephemerella, Ecdynurus, Siphlonurid*), 3 genera (*Hydropsyche, Rhyacophila, Glossoma*) of Trichoptera, 4 genera (*Tendipes, Tabanus, Antocha, Psychoda*) of Diptera, 5 genera (*Ochthebius, Dineutus, Amphizoa, Agabinus, Peltodytes*) of Coleoptera, two genera (*Corexia, Hesperocorixa*) of Hemiptera, two genera (*Brachyptera, Acroneuria*) of Plecoptera , one genus (*Hagenius*) of Odonata and one genus *(Cymnaea*) of Mollusca.

Biotic Component	2004 ($\bar{X} \pm$ S.D.)	2008 ($\bar{X} \pm$ S.D.)
Periphyton (ind.m^{-2})		
Bacillariophyceae	366.79 ± 183.88	211.07 ± 88.18
Chlorophyceae	110.92 ± 66.85	41.0 ±25.56
Myxophyceae	52.83 ±35.07	18.50 ± 12.64
Total	**530.54 ± 285.80**	**270.57±126.38**
Zooplankton (ind.l^{-1})		
Cladocera	11.50 ± 3.54	10.43 ± 2.12
Protozoa	21.0 ± 1.41	19.50±0.70
Copepoda	8.0 ± 0.00	6.50± 0.71
Rotifera	10.0± 2.83	6.50 ±0.71
Total	**50.50 ±7.78**	**42.93 ±4.24**
Macrozoobenthos (ind.m^{-2})		
Ephemeroptera	456.63 ± 331.85	102.91 ± 71.82
Trichoptera	146.88 ± 96.49	23.13 ± 28.79
Diptera	148.96 ± 85.64	41.25 ± 44.49
Coleoptera	62.50 ±31.79	2.50 ± 9.73
Hemiptera	34.38 ±28.78	2.92 ± 1.86
Plecoptera	20.83 ± 17.37	2.50 ±3.61
Odonata	7.29 ± 15.57	1.04 ± 3.61
Mollusca	9.38 ± 16.28	2.92 ± 7.53
Total	**895.83±623.70**	**179.17± 171.45**
Total Fish (g.m^{-2})	**2.889±0.752**	**2.189±0.4428**

Table 4. Cumulative impact of climate change on transportation network and its implications on annual mean density of aquatic biodiversity of Ganges headwaters, Garhwal Himalayas over a period of five- year (January 2004- December 2008)

A shrinking of 24% in annual density of fish communities was calculated as a cumulative impact of climate change on transportation network and its implications on fish life of Ganges headwaters (Table 4). Fish community of the Ganges headwaters was represented by 39 species belonging to 15 genera and five families. The most important fish were Schizothorax richardsonii, Schizothorax plagiostomus, Schizthoraichthys progastus, Tor tor and Tor putitora.

Depletion of Alpha Diversity

A sharp depletion in the annual mean of alpha diversity of periphyton (49% reduction) and macrozoobenthos (67% reduction) and macrozoobenthos (67% reduction) was recorded as a cumulative impact of climate change on transportation network and its implications on aquatic biodiversity of Ganges headwaters over a period of five-year (Table 5). A considerable decline of 22% and 18% was estimated in the alpha diversity of zooplankton and fish respectively dwelling the Ganges headwaters due to cumulative impact of climate change.

Biotic Component	2004	2008	Decline %
Periphyton	38.0	19.38	49%
Zooplankton	7.0	5.46	22%
Macrozoobenthos	31.0	10.23	67%
Fish	39.0	31.98	18%

Table 5. Cumulative impact of climate change on transportation network and its implications on annual mean of alpha diversity of various components of biodiversity of Ganges headwaters, Garhwal Himalayas during a span of five year (January 2004- December 2008)

Reduction in Shannon Weiner Index ($\overline{H}$)

A considerable reduction in the annual mean of Shannon Weiner Index ($\overline{H}$) of all the components of aquatic biodiversity (periphyton, zooplankton, macrozoobnethos, fish) was recorded over a period of five-year as a consequence of cumulative impact of climate change on the transportation network and its implications on the aquatic biodiversity of Ganges headwaters of Garhwal Himalayas (Table 6).

A decline of 17% in the Shannon Weiner Index was recorded in both periphyton and zooplankton. However, a decline of 28% in the Shannon Weiner Index was recorded in macrozoobnethos and 30% in fish (Table 6).

Biotic Component	**2004** ($\overline{H}$)	**2008** ($\overline{H}$)	**Decline %**
Periphyton	2.710±0.85	2.249±0.74	17.0
Zooplankton	1.260±0.62	1.046±0.54	17.0
Macrozoobenthos	3.770±0.97	2.941±0.81	28.0
Fish	2.265±0.71	1.586±0.68	30.0

Table 6. Cumulative impact of climate change on transportation network and its implications on the annual mean of Shannon Weiner index ($\overline{H}$) of various biodiversity components of Ganges headwaters, Garhwal Himalayas during a span of five- year (January 2004- December 2008)

Cumulative and Synergistic Impacts

Cumulative and synergistic impacts are generally the consequences of single impact, multiple interrelated impacts or multiple unrelated direct and indirect impacts. In all cases, individual impacts cannot be considered in isolation, but rather must be seen as components of the more serious cumulative or synergistic effects. Prediction of cumulative and synergistic impacts is difficult, because of uncertainties regarding the interrelationships of individual impacts (Spaling and Smith 1993; Lawrence 1994; Bedford and Preston 1996; CEAA 1998). The cumulative and synergistic impacts of climate change on transportation network and its implication on aquatic biodiversity and the physico-chemical environment of sensitive ecosystem of Gangs headwaters was seen in the form of impairment of ecosystem function and loss of biodiversity under ecosystem stress. The causes, effects (primary and secondary) and the cumulative impacts of climate change on the Himalayan aquatic ecosystem of Ganges headwaters have been depicted in Figure 2.

The environmental degradation of Ganges headwaters and decline in quantity and missing of sensitive aquatic organisms are believed to have been caused by increase in water temperature, turbidity, total dissolved solids and depletion of dissolved oxygen.

The sensitivity of water resources and climate variability has been recognized since the ancient times, the issue of impeding crisis due to climate change threats was raised at the International Forum on Climate and Water held in Helsinski in 1989. The recent IPCC report expresses concerns about observed decrease in mountain glaciers and snow cover globally, but has concluded that no consistent pattern in snow cover and snow depth has been established. It adds that Himalayan glaciers have generally shrunk at varying rates though on regional basis, pattern of glacier regime is quite complex. The Ganges headwaters are glacier-fed. Therefore, the climate change has indirect /direct impact on these headwaters. Upadhyay (1995) has carried out extensive studies on hydrology in India. Impact of climate change on water resources and run-off in the Himalayas are discussed by Singh *et al.* (2006). Hengeveld (1990), Harte (1992), Peters and Lovejoy (1992) and Price and Haslett (1995) have summarized the impact of climate change on biological diversity.

Meyer *et al*. (1988) and Cathy (1990) summarized recent literature on elemental cycle in stream ecosystems and concluded that nutrients regulate ecosystem processes (e.g., decomposition, primary production, etc.) and links atmosphere sub-system constitutes nutrient cycle. The cycling of nutrients, the source of additional nutrients and the pathways of losses are of great importance in attempting the analysis and to understand the functional aspects of an ecosystem (Chapman 1976).

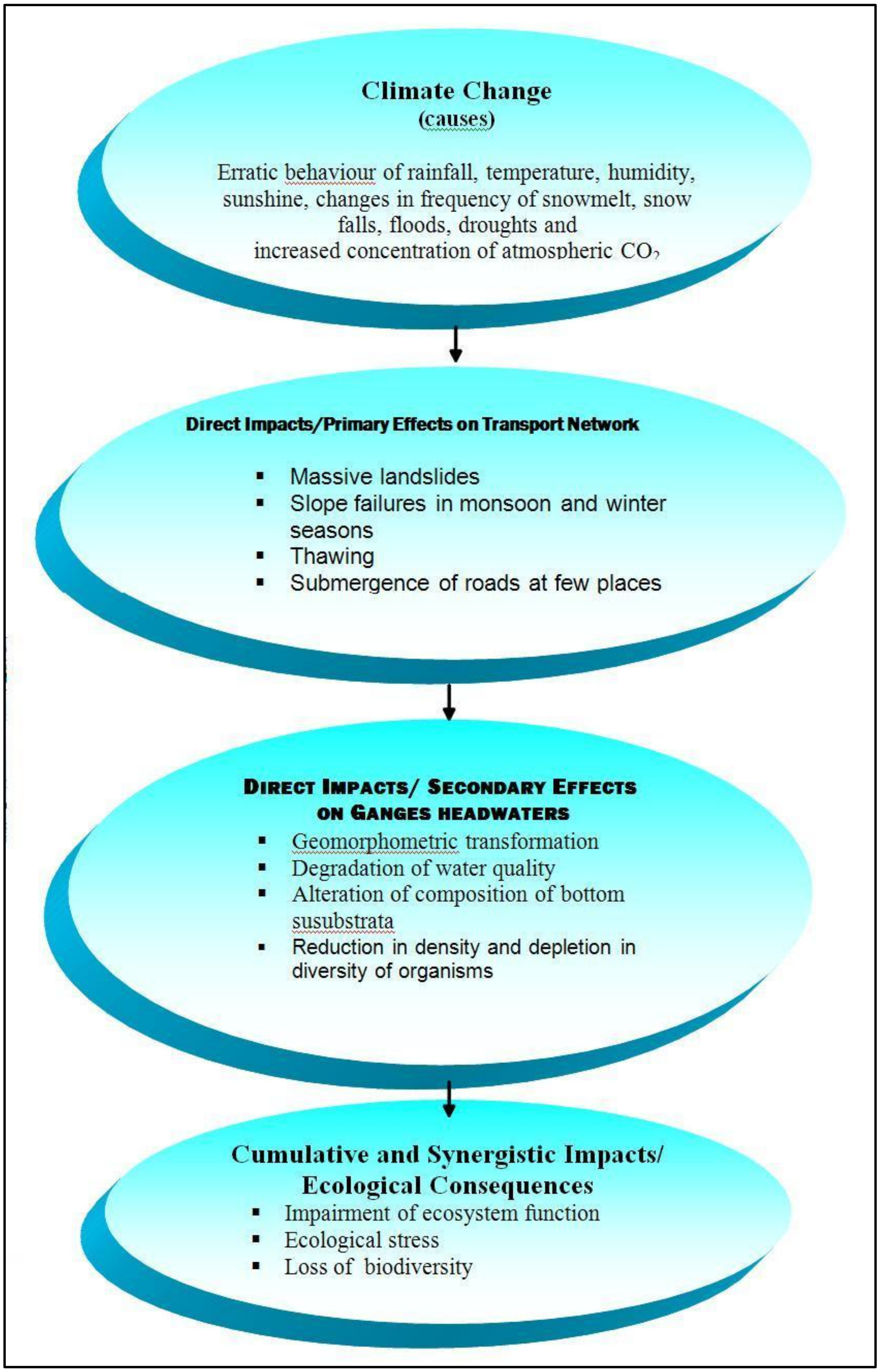

Figure 2. Cumulative impact of climate change on transportation network and implications on aquatic biodiversity of Ganges headwaters, Garhwal Himalayas

The dominant connections that most strongly affect stream health are between streams and their catchments. Most of the water sediment, organic particles and dissolved material that leaves a catchment are carried by the streams. The amount of sediment and other materials in a stream are determined by climate geology and the way the catchment is used by humans. The "openness" of stream ecosystems makes vulnerable to changes in their catchments. Some land uses including construction of roads can cause degradation of rivers. The cumulative impact of climate change has also an important role to play in the degradation of aquatic ecosystem through impairment of transportation network in the Himalayas.

Aquatic ecosystems are dynamic assemblages supported by the interaction of physical, chemical and biological features within the environment biota within these ecosystems exhibit specific tolerances and limitations to various physico-chemical conditions of the environment they inhabit (Brookens *et al.* 2003). According to Armantrout (2001) anthropogenic pressure on river in turn affect the biological communities which disturb the ecological balance of nature. Thus, it is very much clear that there is an adverse cumulative impact of climate change on transportation network and its implications on the depletion of aquatic biodiversity of Ganges headwaters, Garhwal Himalayas

Mitigation Measures

Effective mitigation measures for habitat restoration of Ganges headwaters is very important for addressing the problem of environmental degradation and depletion of aquatic biodiversity caused by the cumulative impact of climate change in terms of erratic behaviour of meteorological parameters in the valley of Ganges. We have recommended the following measures for addressing these problems.

Regular Maintenance and Monitoring of Roads

Regular maintenance of the slope failures, massive landslides, and landslips is very important in the Garhwal Himalayas. The maintenance of the roads and trails in the valley of upper Ganges can be undertaken through the construction of protection walls, toe walls, securing steep cut slopes by use of reinforcing structure at their bases, netting exposed slopes with coir/jute or synthetic geotextile, followed promptly by revegetation by fast growing nonpalatable species suitable to the climatic conditions of the site. Regular maintenance of the roadbed after heavy precipitation during monsoon and winter seasons should be undertaken at the earliest. This maintenance should be monitored effectively by the Border Road Organization (BRO) which is solely responsible for construction and maintenance of roads in the border areas of the valley of upper Ganges.

Raising the Height of the Road from River Bed

There are overall seven places where there are possibilities of submergence of roads. There are three places on the Alaknanda River where there is a problem of submergence of the road during heavy flood. There are three more places on Bhagirathi and one on Mandakini where the level of road is almost parallel to the water level of the river during heavy precipitation. Therefore, there is a dire need for raising the heights of the road from the river bed at these places.

Natural Recovery of Functional Habitat

River restoration is a complex science, combining hydrology, geomorphology and ecology. It has so far been applied in such integrated fashion to a few sites in Europe (Brookes 1995). Functional habitat is a tool for evaluating the heterogeneity of the existing rivers. Impairment of 'functional habitats' may lead to collapse of the entire ecosystem. Therefore, the natural recovery of the 'functional habitat' of Ganges headwaters is very important. It is possible by minor manipulation in the morphology of the river in terms of widths, depth, velocities and channel edges based on geomorphological principles. After this manipulation, there will be a natural recovery of 'functional habitat' for providing efficient functioning of the ecosystem.

Close Watch on Erratic Behaviour of Meteorological Parameters

The Department of Science and Technology, Government of India in coordination with the Government of Uttarakahnd, Indian Meteorological Department (IMD) and the universities has established 125 meteorological labs in the colleges/schools in the entire Uttarakhand including the area of valley of Ganges. There is a need to strengthen the capacity, effectiveness of these metrological labs for providing real time meteorological data so that a close watch on the erratic behaviour of these meteorological parameters can be undertaken. The prediction can be made and the precautionary measures can be undertaken.

Strong Coordination among Stakeholders

The strong coordination among transport planners, geologists, civil engineers, environmental biologists and climatologists is very much essential for addressing the problem of transportation system and the degradation of aquatic ecosystems of Ganges headwaters in the context of global climate change. The planning, execution and monitoring of transportation system should be undertaken by efficient flow of information among all these stakeholders.

Suggestions to Address Climate Change

There is a little doubt any more that the risk emanating from climate, resulting from anthropogenic green house gas emissions, in particular CO_2 emission, are no longer a matter of speculation. Unless, addressed with a sense of compelling urgency, there could be catastrophic consequence for the world as a whole in general and Himalayan region in particular. The worst suffering would be fall precisely in the developing countries which are least equipped to cope with such adverse consequences. The need for cooperative global actions to meet the challenge of climate change was recognized as early as in December 1988 when, the UN General Assembly adapted to the resolution and endorsed the proposal for the setting up of Intergovernmental Panel on Climate Change (IPCC). With in just four years of this landmark event, the historic UN Summit Conference on Environment and Development, popularly known as Earth Summit adopted the very first multilateral legal instrument on climate change, the UNFCCC. All subsequent multilateral negotiations on different aspects of climate change, including both adaptation and mitigation are being held based on principles and objectives set out by the UNFCCC.

For addressing the specific problems of cumulative impact of climate change on transportation network and its implementation on Ganges headwaters in Garhwal Himalayas, following suggestions are given:

- Alternative fuels (hydrogen, solar, biofuel, *etc.*) to fossil fuel should be promoted for the vehicles plying on the route of Garhwal Himalayas.
- There should be a close watch on the vehicular efficiency and their maintenance. Old vehicles should be discarded and new one with more efficient engines should be allowed on roads.
- Public transport should be encouraged and promoted in place of use of individual vehicles. Use of bicycles, mules, horses should be encouraged in the mountain areas in place of automobiles.
- Trekking and walking should be encouraged for short distances.

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Biographical Sketch

Professor Ramesh C. Sharma has a distinguished academic career. He passed his graduation with Zoology Honours and obtained a masters degree in Zoology with Freshwater Fishery Biology. He obtained his doctorate (D.Phil.) and Doctor of Science (D. Sc.) in Environmental Biology. He has a wide experience of teaching and research for more than thirty four years on environmental monitoring, bioenergetics, biodiversity and transportation ecology in the Himalayas. More than 16 research projects have been completed on these aspects. Twenty five doctoral research students have been conferred to doctoral degrees and seven more students are engaged in research under his supervision. He has sufficient professional experience and exposure by way of visiting and working at different research laboratories in India and abroad (USA, Sweden, Poland, Czech Republic and Canada). He has published more than 122 research articles in the journals of international repute. He has been conferred several awards and gold medal (NATCON Gold Medal 2001, Zoological Society of India Gold Medal 2001, Environmentalist of the year Award 2003, Recognition Award Gold Medal 2004, Indira Gandhi National Environment Award 2005). He is a fellow of many national and international societies. He has been nominated as Environmental expert of the Environmental and Social Panel (ESP) constituted by the World Bank for rendering expert advice on various issues pertaining to environment of hydroelectric projects in India for five years. He is also an Environmental Expert, EIA Authority, Govt. of Uttarakhand, nominated by MoEF, Govt. of India. Currently, he is Professor and Chairman, Department of Environmental Sciences, H.N.B. Garhwal Central University, Srinagar – Garhwal, Uttarakhand, India.

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ADAPTING RELATIONSHIPS FOR AGENCIES AND INSTITUTIONS: THE I-90 SNOQUALMIE PASS EAST PROJECT'S COLLABORATIVE APPROACH TO IDENTIFYING A PREFERRED ALTERNATIVE AND MITIGATION STRATEGY

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Abstract

Since 1999, the Washington State Department of Transportation (WSDOT) I-90 Snoqualmie Pass East Project (I-90 Project) team has worked with dozens of government agencies and non-governmental groups to develop a range of potential solutions to meet project needs. Project needs include addressing traditional and nontraditional transportation improvements as they relate to the physical and natural environment. As part of the National Environmental Policy Act (NEPA), the underlying challenge for WSDOT and project partners was to design this interstate improvement project around an unforgiving environment and incorporate meaningful ways to mitigate the project's potential adverse impacts on the Central Cascades' ecosystem and the state's economy.

Early in the NEPA and State Environmental Policy Act (SEPA) scoping phase of the project, WSDOT needed to consider landscape-scale efforts by the US Forest Service (USFS) and conservation groups. These agencies and groups were working to improve ecological connectivity by acquiring conservation lands through land exchange(s) and purchasing public land along the I-90 corridor. To ensure that the I-90 Project's objectives aligned with the actions of these groups, WSDOT created a multi-agency Interdisciplinary Team (IDT) as an advisory body to recommend a Preferred Alternative for WSDOT that incorporated relevant science and the concerns of agency stakeholders. The project's original IDT included eight primary and advisory agencies; advisory members included Washington State Department of Ecology, Washington State Parks and Recreation Commission, US Environmental Protection Agency, and US Army Corps of Engineers.

The IDT determined that there was insufficient information to make an informed recommendation on how the project would be designed to meet ecological connectivity needs. Therefore, the IDT formed the Mitigation Development Team (MDT), a technical advisory sub-committee consisting of hydrologists and biologists from different agencies, to identify locations and develop performance criteria for investments in ecological connectivity. The MDT's strategy considered landscape-, watershed-, and habitat-specific variables to identify connectivity emphasis areas (CEAs) along the project. The MDT and the design team used these recommendations to also develop a comprehensive list of connectivity objectives and performance standards for the evaluation of design options.

In addition to the IDT and MDT, the project continues to use partnerships to help resolve environmental and design challenges. The IDT, now consisting of 12 different agencies, was reformed as a communication forum during regulatory permitting and construction processes. Formal technical committees have been formed to assist in planning and permitting challenges for final designs on wetlands mitigation, wildlife monitoring, and stormwater.

WSDOT has also established innovative partnerships with university researchers and conservation groups to help establish citizen awareness, wildlife monitoring, and targeted habitat acquisitions. Relationships with transportation-based organizations, associations, and businesses were formed in order to gain insight into the requirements of interstate users.

In August 2008, the I-90 Project's Final Environmental Impact Statement was published highlighting the Preferred Alternative – an accomplishment made possible by the recommendations of the IDT, MDT, and other collaborative partnerships. FHWA signed a Record of Decision on October 6, 2008, clearing the way for construction to begin in summer 2009. The unique components of the I-90 Project, as well as the project team's innovative approach to developing partnerships to understand and meet landscape-scale, watershed-based objectives, provides a scalable model for the integration of context sensitive solutions for future WSDOT and other state DOT projects.

Introduction

In 1999, WSDOT began evaluating a 15-mile section of Interstate 90 between the community of Hyak to the town of Easton. Initially, this evaluation focused on reducing winter closures of the interstate, but the aim quickly expanded to include other needs, including reducing the risk of rock and debris falling on the roadway from unstable slopes, fixing structural deficiencies, providing for increases in traffic volumes, and connecting habitat across I-90 for fish and wildlife.

During the public scoping process, complex issues arose for designing and constructing this project. Land ownership and management objectives along the corridor were changing, and the project was being scoped without understanding that context. WSDOT immediately understood that a diverse set of project stakeholders including state and federal agencies, cities, counties, and community groups were needed to collect input from in order to develop consensus for a long-term vision for the I-90 corridor.

By 2000, interdisciplinary teams were formed and preliminary engineering and environmental analysis began. When the Transportation Partnership Account (TPA) finance package was passed in 2005 by the Washington State Legislature, WSDOT finally received funding to ramp up the design effort, finish National Environmental Policy Act compliance (NEPA), and prepare construction documents for the first five miles of the project area from Hyak to the Keechelus Dam vicinity (NEPA 2009, 66).

By involving stakeholders early in the environmental and design processes, WSDOT was able to respond to their diverse needs by incorporating a landscape-level, watershed-based mitigation strategy. This strategy allowed the department to consider multiple ecological needs in the project design, including connecting habitat, streams, and groundwater across I-90 at various Connectivity Emphasis Areas (CEAs). These CEAs are mostly located at existing bridge and culvert locations and include water crossings as part of the design strategy.

WSDOT published the I-90 Snoqualmie Pass East Project Draft Environmental Impact Statement (Draft EIS) for public review and comment in summer 2005. The landscape-level, watershed-based approach helped WSDOT secure the necessary agency and citizen approval for the Draft EIS. Over the next two years, WSDOT continued using existing partnerships and formed new teams, including specialized technical committees, to identify a preferred design alternative for the I-90 Project. These collaborative efforts culminated with the release of the Final EIS in August 2008 that identified WSDOT's preferred design alternative for the I-90 Project. The Federal Highway Administration (FHWA) issued its Record of Decision (ROD) in October 2008 that adopted the preferred alternative within the ROD for construction.

Through the I-90 Project, WSDOT will ensure the continued availability of I-90 as a primary statewide corridor by improving the safety and reliability of a 15-mile stretch of the interstate east of Snoqualmie Pass. WSDOT will reduce avalanche risks to the traveling public, minimize road closures required for avalanche control work, and reduce the risk of rock and debris falling onto the interstate from unstable slopes. WSDOT will also fix structural deficiencies, provide for the recent and predicted increases in traffic volume, and work to reduce wildlife / vehicle collisions by re-connecting habitat across I-90 for improved mobility of fish and wildlife. Plans for the project include widening the existing four lane interstate to six lanes, replacing deteriorated concrete pavement, straightening sharp roadway curves, stabilizing unstable rock slopes, building new bridges and culverts - including the construction of wildlife under- and over-crossings, and building a new, more efficient snowshed.

Construction of the first phase of the project from Hyak to Keechelus Dam consists of five miles of construction that are broken into multiple construction contracts. WSDOT started work on the first construction contract in July 2009 by building a long-term detour bridge and excavating materials from Keechelus Lake – an irrigation reservoir – to mitigate for project impacts to reservoir storage during future construction activities. In October 2009, WSDOT will advertise the next contract to begin replacing the old lanes and adding a new lane in each direction, rebuilding bridges, and extending chain up / off areas along the first three miles of the project. This contract is expected to begin construction in 2010. In fall 2010, WSDOT will advertise the third contract to continue adding a lane in each direction, replace the snowshed, address unstable slopes, build new bridges, and construct new chain up / off areas for the next two project miles. This contract is scheduled to begin construction in 2011. Several smaller projects are planned to start after 2011. These projects will consist of specialty work, including stormwater retrofit, wetland and roadside mitigation, and the installation of wildlife fence.

The first five miles of the I-90 Project from Hyak to Keechelus Dam is funded at $595 million. The remaining portion of the project (10 miles) from Keechelus Dam to Easton remains unfunded.

Understanding the I-90 Project Corridor

To better understand WSDOT's use of partnerships and how a preferred alternative was identified, it is necessary to first discuss the I-90 Project's geographic landscape.

I-90 spans 300 miles in Washington state from the Port of Seattle to the Idaho State line, and then continues east across the United States to Boston, MA. I-90 is the major east-west transportation corridor across Washington and is vital to the state's economy (Washington State Department of Transportation Final EIS 2008, 1-1). The I-90 Project improves a 15-mile portion of I-90, beginning on the eastern side of Snoqualmie Pass at milepost 55.1, just east of the Hyak Interchange, where the existing highway narrows from six lanes to four lanes. The project end point is at milepost 70.3 at the West Easton Interchange, where the terrain becomes flatter and the highway is straighter. This 15-mile stretch of I-90 is in Kittitas County, WA, and passes through the Okanogan-Wenatchee National Forest.

Figure 1. Map of Washington State, highlighting Interstate 90 and the I-90 Snoqualmie Pass East Project

I-90 is a critical link connecting Puget Sound's large population and business centers with the farmlands, diverse industries, and extensive recreational areas of eastern Washington. The uninterrupted movement of people, freight, and business over Snoqualmie Pass is essential to our quality of life and the economic vitality of Washington State (WSDOT Final EIS 2008, ES-1).

The I-90 Project presents many unique environmental and design challenges due to its location along a high mountain pass in the Central Cascades. The general topography is one of mountainous peaks and valleys. For the first six miles of the project area, I-90 runs along a narrow corridor between the shores of Keechelus Lake, a deep-water agricultural reservoir of glacial origin, and steep mountain slopes. These steep mountain slopes contain volcanic bedrock at varying depths that are subject to deep fissures and stress cracks with weakened slip planes, which when combined with high annual precipitation and freeze-thaw conditions, makes them susceptible to landslides, debris flow, and avalanche. Geotechnical studies indicate that certain portions of the project area contain stable rock and favorable sediment, while other areas contain soft frangible rock and liquefiable soil conditions. These conditions, combined with short construction windows and a planned annual winter shutdown, require a unique set of plans for designing bridges, improving ground conditions for foundations, and stabilizing rock slope cuts before and during construction.

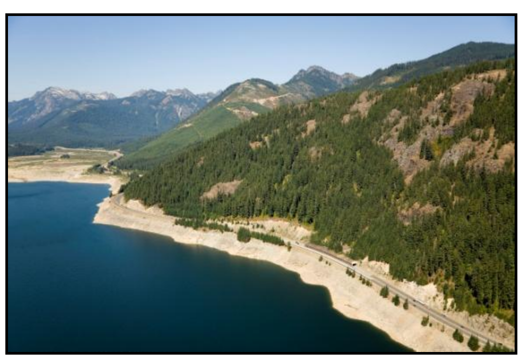

Figure 2. The I-90 Hyak to Keechelus Dam project corridor. This section of I-90 rests between Keechelus Lake and steep cliffs

I-90 is built primarily on National Forest land. The large areas of protected state, federal, and conservation land north and south of I-90 support a broad range of habitats and a diverse array of plants and wildlife. Since the late 1990s, the area has been managed according to the Snoqualmie Pass Adaptive Management Area Plan. This plan requires protection of old-growth habitat, removal of portions of existing U.S. Forest Service roads, and management of recreation to facilitate species movement. In recent years, through the acquisition of private land, there have been substantial private and public land conservation efforts to protect old-growth forest, provide larger contiguous blocks of forested habitat, and facilitate habitat connectivity across the I-90 corridor. The Cascades Conservation Partnership, the Mountains-to-Sound Greenway Trust, the U.S. Fish and Wildlife Service (USFWS), and the U.S. Forest Service (USFS) have invested over $100 million in these efforts during the last five years. These land purchases, along with the I-90 Land Exchange, have added 75,000 acres (approximately 117 square miles) of land to the National Forest system adjacent to and within the I-90 Snoqualmie Pass East project area. The land management by USFS and conservation groups has given WSDOT confidence that ecological connectivity investments will be protected in perpetuity.

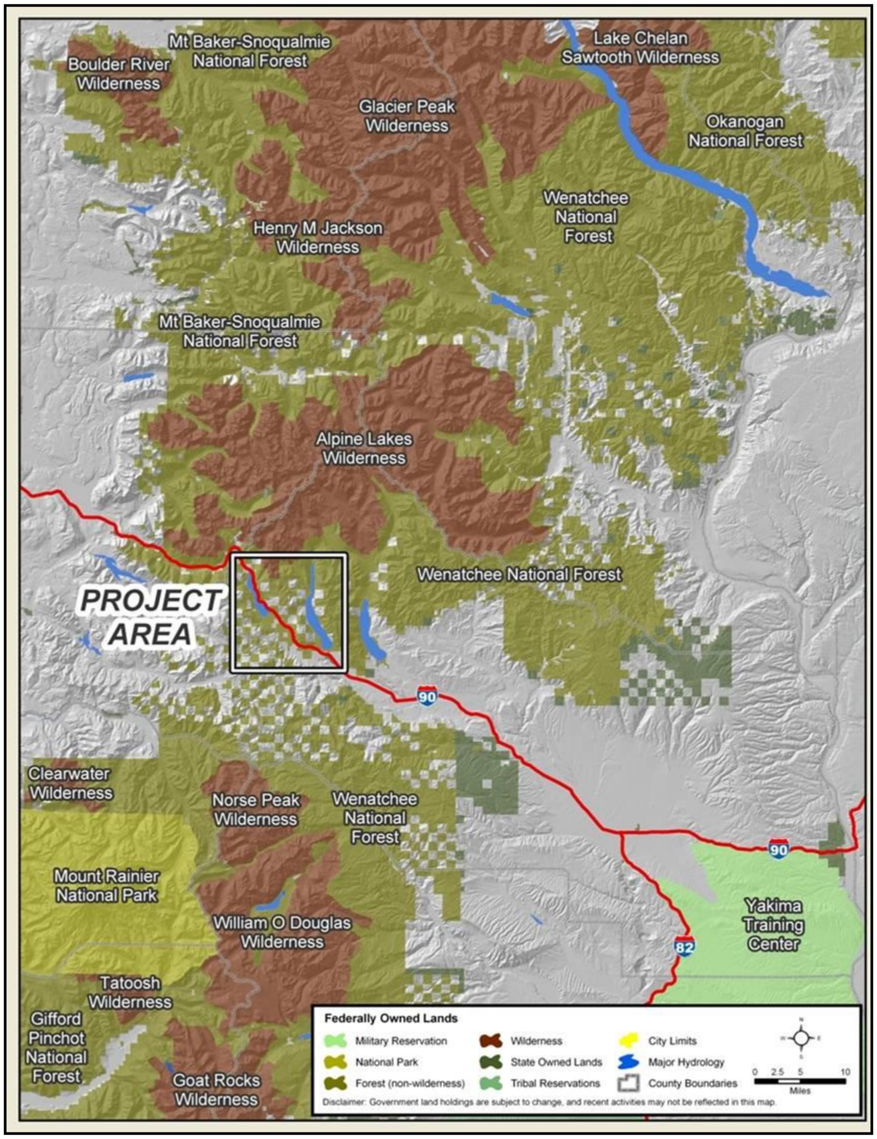

Figure 3. The blocks of state, federal, and conservation lands north and south of I-90

Even with conservation efforts, I-90's presence limits wildlife movement and forms a physical barrier between upstream and downstream terrestrial and aquatic environments. Existing culverts and narrow bridges limit aquatic species movement, and in many cases, the highway embankment has filled in habitat that once made up channels, floodplains, and associated wetlands. Adequate connections between habitats and hydrologic features on either side of I-90 are necessary for the continued health of the project area's diverse ecosystems.

Identifying Project Partners with a Vested Interest

The I-90 Project corridor's complex engineering and environmental design issues led WSDOT to look outside of the agency for partners with a vested interest in helping solve challenges and focus on a landscape-level, watershed-based design and mitigation strategy.

In 2000, WSDOT formed an interdisciplinary team (IDT) to provide effective and efficient interagency advice to the I-90 Project team, develop a project purpose and need statement, help meet NEPA / State Environmental Policy Act (SEPA) guidance during the environmental analysis phase, and move quickly through the permitting actions.

WSDOT and FHWA were the lead agencies on the IDT. The original IDT consisted of five agency members, but by 2005, had expanded to include 12 agencies. Partnership agencies included: USFS, U.S. Bureau of Reclamation (USBR), U.S. Fish and Wildlife Service (USFWS), U.S. Army Corps of Engineers (USACE), Environmental Protection Agency (EPA), National Marine Fishery Service (NMFS), Washington Department of Fish and Wildlife (WDFW), Washington Department of Ecology, Washington State Parks, and Kittitas County.

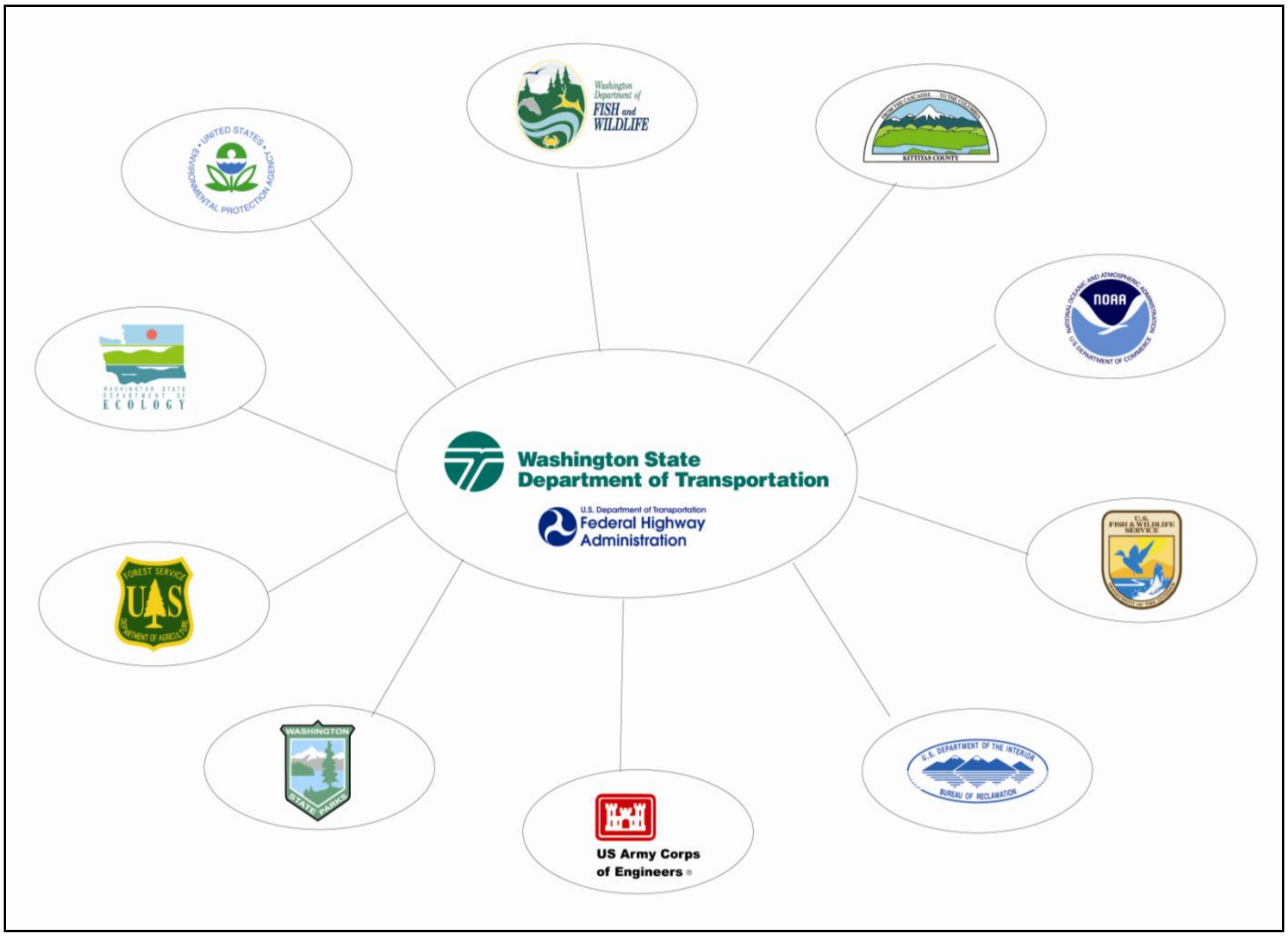

Figure 4. An IDT partnership wheel

WSDOT and FHWA often required multiple participants in the IDT. In addition to WSDOT, each non-lead agency provided one primary and one or more alternate representatives to participate in monthly or bi-monthly IDT meetings. IDT meetings allowed WSDOT and the IDT to talk openly about project descriptions based on information learned from recent field work. Frequent agenda topics included the existing and proposed project conditions, the project's impacts and benefit opportunities - as well as risks and management strategies, a Value Engineering Study, Cost Evaluation Validation Procedures, analysis of ecological connectivity information / design features, and review of design engineering data such as geotechnical, structural investigations, alignment data, advanced stormwater design, and avalanche modeling (Inter-Disciplinary Team 2000, 1). Between meetings, IDT members worked proactively to identify and assist in developing management strategies for project risks associated with engineering design and environmental impacts. IDT members conducted, coordinated, and group reviewed the project designs and permit application materials and arranged physical and virtual field reviews focusing on water resources and watershed context.

With guidance from the IDT, WSDOT and FHWA developed the purpose and need for the I-90 Project. It was determined that the I-90 Project, regardless of the build alternative, must:

- Reduce the risks of avalanche to the traveling public and reduce the frequency and duration of road closures required for avalanche control work,
- Reduce the risk of rock and debris falling onto the roadway from unstable slopes,
- Fix structural deficiencies by replacing damaged pavement,
- Provide for the growth-related increases in traffic volume, and
- Connect habitat across I-90 for fish and wildlife (WSDOT Draft EIS 2005, ES-1).

To identify a preferred alternative and complete the Final EIS, WSDOT and the IDT had to resolve issues with integrating ecological connectivity objectives with other project objectives. Specifically, WSDOT and the IDT needed to identify solutions to issues regarding the location of crossing structures within CEAs, wetlands mitigation, wildlife monitoring, stormwater treatment, and best management practices (BMPs) within the I-90 Project area. Therefore, specialized teams were identified to make project recommendations to WSDOT and / or the IDT.

The first specialized team WSDOT and the IDT formed was the Mitigation Development Team (MDT) to provide technical support regarding ecological connectivity and the development of an environmental design / mitigation strategy. The MDT worked closely with the project team to prepare and publish the MDT Recommendation Package.

Establishing the Mitigation Development Team

To integrate ecological connectivity into the project design, the IDT convened a multi-agency team of biologists and hydrologists to form the MDT. Partnership agencies included WSDOT, USFS, USFW, and WDFW. (See Figure 5).

Figure 5. The MDT partnership agencies

The MDT was tasked to make recommendations that responded to the following central question: Given what we know about wildlife movement, habitat fragmentation, and ecological connectivity needs, and framing this knowledge within the context of a limited design / construction budget, where are the locations within the project area that provide the highest benefit-to-cost ratio and long-term solutions to the issue of ecological connectivity? (Mitigation Development Team 2006, 1-5).

The MDT's first order of business was to review the existing scientific information and site-specific technical report data to determine the existing ecological conditions within the project area. Among other topics, the MDT considered high-mobility species, low-mobility species, roadkill data, fish passage, landscape permeability, existing habitat conditions, aquatic habitat connectivity, and hydrologic function. At the project-wide scale, the MDT identified three generalized north-south linkage zones—the Gold Creek Valley, Keechelus Lake to Amabalis Mountain, and the Easton Hill area. Within these zones, they also identified 14 CEAs across the project area. Each CEA provides an opportunity to improve connectivity for a unique assemblage of species. CEAs range in complexity from single stream crossings to multiple stream crossings with associated wetlands and areas of diffuse surface flow, to upland areas that are important movement routes for wildlife (MDT 2006, ES-7).

The I-90 Project design team collaborated with the MDT to develop alternative conceptual designs for the highway at each CEA. The design team also developed some designs independently so that a range of alternatives could be evaluated. The IDT requested that the MDT evaluate the likely performance of the resulting array of different design options to determine which design options would meet ecological connectivity objectives.

After evaluating design options and developing specific performance standards and CEA-specific connectivity objectives, the MDT found that crossing structures would be more effective for some species if they contain habitat, rather than simply being physical connections between habitat on opposite sides of the highway. For instance, lower mobility animals will feel more secure crossing a structure if it contains hiding cover. Different animals show different preferences for crossing structures, whether the structures are small, medium, or large (MDT 2006, ES-8).

The MDT also noted that project-wide wildlife connectivity objectives were likely to be met and would profoundly improve ecological connectivity relative to the existing condition by (1) combining design options at CEAs that meet CEA-specific objectives, (2) installing small or medium crossing structures at upland sites, and (3) implementing recommended performance standards outside of CEAs. The MDT also recommended a combination of structure types (i.e., over-crossing and under-crossing) that would be most beneficial for the variety of species to be served. They recommended additional small or medium crossings at intervals of approximately every 820 feet throughout the corridor to further support the linkage of upland habitats and the movement of smaller animals. From a hydrologic perspective, project-wide connectivity needs are predominantly met by design options that meet objectives within CEAs (MDT 2006, ES-11). These recommendations were presented to the IDT, who integrated them into the overall recommendations for the preferred alternative and forwarded them to FHWA and WSDOT decision makers.

After these recommendations were adopted by the decision makers, the I-90 Project design team used these recommendations to move conceptual design plans to plans at each CEA.

While working with the MDT, WSDOT identified further challenging areas where the I-90 Project design team could use the help of inter-agency collaboration. These areas included responding to the challenges associated with wildlife monitoring, stormwater treatment, and wetland mitigation. Therefore, technical committees were created to provide direction to WSDOT designs. The Wetlands Mitigation Technical Committee was created to assess wetlands and other jurisdictional waters within the project area and analyze the project's mitigation designs. The Wildlife Monitoring Technical Committee was established to oversee and review information gathered from pre-construction, and later post-construction, wildlife monitoring efforts. The Stormwater Technical Committee (STC) was created to help WSDOT develop solutions to stormwater and hydraulic challenges.

Establishing a Wetlands Mitigation Technical Committee

The Wetland Mitigation Technical Committee consisted of interagency personnel with expertise in wetland, hydrology, horticulture, and related scientific fields. The committee was established to advise WSDOT design and environmental teams on challenges facing the specific wetland mitigation designs related to meeting wetland replacement requirements. The wetlands team reviewed preliminary designs, provided guidance and support for habitat acquisitions, and worked with other agencies to help resolve conflicts associated with the unique mitigation proposed on the project.

Figure 6. The Wetlands Mitigation Technical Committee member agencies

Mitigation for the I-90 Project focuses on improvements to CEAs and consists of mitigation underneath and adjacent to bridge and culvert structures, identification and connection of habitat types and aquatic features, and preservation / restoration that is consistent with project and partnership objectives.

Developing a Wildlife Monitoring Program

Ecological connectivity objectives, specifically wildlife connectivity, focus on improving motorists' safety by reducing wildlife / vehicle collisions and improving the ecological permeability of the highway for fish and wildlife. In order to understand how WSDOT's investments perform over time, and to incorporate lessons learned into future phases of design and construction, baseline and post-construction wildlife monitoring programs were needed. Because of the broad landscape context of road systems, ecological connectivity objectives, and surrounding land management agencies, wildlife monitoring and assessment needed to address the broader landscape, ecological processes, and restoration of important linkages for a multiple-species ecosystem. Implementing a wildlife monitoring plan of this spatial and ecological scale was beyond WSDOT's capacity however. Therefore, WSDOT, other agencies, and interested groups came together to launch a multi-tiered monitoring program.

WSDOT first formed a Wildlife Monitoring Technical Committee (WMTC) to assist with developing a wildlife monitoring program and help with solving problems associated with the implementation of a program. The committee concentrated their efforts on working with WSDOT project team members, partner agencies, and non-governmental organizations to review and add value to a wildlife monitoring plan that would be used for baseline and long-term monitoring in the project area. The WMTC provided a venue where experts in wildlife biology and road ecology could develop guidance on how to perform baseline and post-construction wildlife monitoring for WSDOT (WSDOT WMTC Memo, 1). Members of the WMTC included WSDOT, USFS, USFWS, EPA, WDFW, Central Washington University (CWU), and Western Transportation Institute (WTI) at Montana State University.

WSDOT contracted with WTI to help develop the multi-tiered Wildlife Monitoring Plan. Under the plan, WTI would provide services during the pre-construction monitoring as the lead role in coordinating research efforts with all active WMTC participants, support the development of new partnerships, and help to identify and seek funding for joint efforts. In addition, WTI would work with WSDOT to lead education, outreach, and communications with partners and stakeholders. Other participating organizations include federal land management and wildlife agencies, including USFS, USFWS, WDFW and related state agencies; CWU and other academic institutions; non-governmental organizations; private foundations; and other stakeholders that were interested in understanding and evaluating the effects of engineered connectivity measures on this segment of I-90. These agencies and organizations provided a variety of skills and experience to further the goals of the project's Wildlife Monitoring Plan (WSDOT / Western Transportation Institute 2008, 1-8).

Figure 7. Agency members of the Wildlife Monitoring Technical Committee

In order to assess the many aspects of meeting ecological connectivity objectives on the I-90 Project, the I-90 Wildlife Monitoring Plan focuses on a two-tiered approach to wildlife monitoring. Tier 1 evaluates basic transportation management questions regarding the performance of crossing structures and fencing (such as changes in wildlife / vehicle collisions and use of new crossing structures). Tier 2 builds on the results of Tier 1 to address more complex questions about the effects of the project on wildlife populations (such as genetic and demographic structure, viability, and dispersal) (WSDOT / WTI 2008, viii).

Wildlife monitoring focuses on a select group of species (focal species) and occurs on multiple spatial scales, over time. Both high- and low-mobility focal species are used based on the assumption that they will provide an indication of the generalized response to a given stimulus by a larger assemblage of species. Ecological attributes are used to determine which species serve as the best indicators of change. Some examples are: black bear and bobcat (arealimited species); marten, northern flying squirrel, and various amphibians and reptiles (dispersallimited species); elk and mule deer (process-limited species); mountain lion (keystone species); and pika and mountain goat (narrow-endemic species) (WSDOT / WTI 2008, viii).

Tier 1 objectives include: evaluating the locations and rate of wildlife / vehicle collisions; assessing the use and effectiveness of wildlife crossing structures – both existing and planned; characterizing the locations and rate of at-grade highway crossings by wildlife; estimating species occurrence and distribution in the project area; assessing the effectiveness of fencing; and appraising the effectiveness of jump-outs (WSDOT / WTI 2008, ix).

WSDOT and its partners have been conducting both CEA-specific and project-wide monitoring for Tier 1 activities since 2008 to identify baseline conditions. Methods being used to meet Tier 1 objectives include assessing wildlife use of existing culverts and underpasses via remote cameras; documenting crossing rates via snow tracking; evaluating the distribution of various target species via both non-invasive survey methods and live-capture; and documenting wildlife / vehicle collisions. In addition, specific projects to monitor low-mobility species such as fish, amphibians, and pikas have been initiated in partnership with CWU.

Early monitoring results have documented how species are moving through the corridor, and genetic samples collected from various target species will be used for assessments of highway permeability both pre- and post-construction.

Post-construction Tier 2 monitoring activities, research, and objectives will focus on landscape and population-level connectivity and complement Tier 1 monitoring by providing a more comprehensive understanding of how the project connectivity measures perform at a larger scale. Research methods will include: pre- and post-population level benefits (hair collection, scat-detection dogs); pre- and post-regional species occurrence (remote cameras, hair collection, tracking, scat-detection dogs); post population viability analysis (computer-based analysis); and pre- and post-extent of human disturbance (GIS mapping, spatial stats, trail / traffic counters). Tier 2 research will require a continued collaboration and partnering between WSDOT and other entities to be successful (WSDOT / WTI 2008, 1-8).

Integrating Stormwater Treatment Facilities

In addition to integrating ecological connectivity objectives, WSDOT had to specifically look into and develop solutions to stormwater and hydraulic challenges.

The I-90 Project corridor passes through the Wenatchee National Forest and runs adjacent to the north eastern shore of Keechelus Lake for the first six miles, then parallels the Yakima River for the remaining nine miles. The project crosses five tributaries to Keechelus Lake and nine significant tributaries to the Yakima River, including the Kachess River. The project also crosses or is adjacent to numerous wetlands (WSDOT / Otak Stormwater and BMP Report 2007, 1-2).

The nature of the surrounding alpine environment, climatic extremes, and the need to protect water quality made the selection, design, and mitigation process for stormwater management systems challenging. Additionally, portions of the project are located on steep slopes (rock cliffs) where the construction of Stormwater BMPs would be very difficult and require extensive structural support. Other typical freeway BMPs are infeasible because portions of the project are located in narrow corridors where cliffs are on one side of the freeway, and a lake or river is on the other side, with no room for a median. And while not exactly a physical constraint, snow management and snow hydrology play a large role in how space is utilized and what BMPs are most suitable, with open areas in the median or adjacent to the freeway likely doubling as both snow storage areas as well as stormwater BMP locations (WSDOT / Otak Stormwater and BMP Report 2007, 1-2).

The project team relied on additional expertise outside of the current team by establishing a multi-agency Stormwater Technical Committee (STC) to review stormwater design and permitting issues; evaluate analysis and preliminary engineering approaches developed by WSDOT; and recommend appropriate, effective, and efficient mitigation methods to the design team.

Figure 8. The STC partnership wheel)

The STC also provided the stormwater discipline support necessary to meet WSDOT's 2008 Highway Runoff Manual guidance. STC members included WSDOT, USFS, Washington Department of Ecology (Ecology), and consultant staff. These members have permitting approval roles or are partner agencies with a strong interest in helping solve stormwater problems.

The general objectives of the STC were to review WSDOT stormwater analysis and recommendations and provide feedback; help identify areas where stormwater management will be particularly challenging (unconstrained, partially constrained, and fully constrained areas); and help formulate and evaluate innovative stormwater solutions and mitigation alternatives (WSDOT / Otak Stormwater and BMP Report 2007, 2-3). The STC was also charged with reviewing stormwater technical and permitting issues and directly enhancing the clarity and assurance of project stormwater-related design and approvals (WSDOT / Otak Memorandum #3 2007, 2).

WSDOT viewed the need for stormwater BMPs and mitigation as an opportunity to take a holistic approach to protecting, restoring, and improving water quality. WSDOT asked the STC to use creative approaches that maximized environmental benefits, yet still meet permitting obligations (WSDOT / Otak Stormwater and BMP Report 2007, 2-7). WSDOT created "stormwater issue modules" highlighting STC requirements and commitments. The modules also covered other topics for the STC to address, including: site-specific water quality concerns; cold climate considerations; maintenance of the hydrologic cycle; capital costs; maintenance and operations effort / cost; constraints on BMP types; criteria and mapping of project areas partially constrained and fully constrained; optimal versus less than optimal BMP performance; onsite mitigation approaches; offsite mitigation approaches; mitigation alternatives; and evaluation of mitigation alternatives (WSDOT / Otak Memorandum #3 2007, 2).

While recommended stormwater treatment designs are currently underway, the STC has made recommendations to WSDOT on how to resolve these complex issues. WSDOT and the STC have selected permanent stormwater BMPs to maximize the amount of on-site treatment. WSDOT selected the recommendations that were considered most suitable given stormwater standards, space limitations, ecological goals, cold climate concerns, and other criteria. The STC's work allowed WSDOT to receive approval from Ecology for a range of BMPs to apply to the project area.

The physical setting of the project, however, sometimes makes constructing on-site BMPs infeasible. These areas were identified as "constrained areas." WSDOT intends to mitigate for constrained areas by providing off-site equivalent area treatment, as allowed by WSDOT's 2008 Highway Runoff Manual. Equivalent area treatment will be provided by retrofitting stormwater treatment on suitable off-site freeway and WSDOT maintenance facility locations within the Keechelus Lake drainage basin (WSDOT / Otak Progress Report 2008, 3). Recent work has focused on the development of conceptual WSDOT Hyak Maintenance Facility stormwater treatment retrofit options, including bioinfiltration swales, the use of passive, non-structural treatment BMPs preceded by settling vaults, and buffer strips along creeks.

Communicating with Project Stakeholders, Partners, and the Public

Since beginning the public scoping process in 1999, WSDOT has engaged in a continuous process of consultation, collaboration, partnership, and communication with the public, interest groups, the project's cooperating agencies, and other stakeholders. WSDOT has shared information with these groups in an open and transparent manner, which has made the agency credible and qualified to act in the public's best interest. WSDOT has also used these forums to express concerns related to other agency actions. An example would be land use / management and recreation conflicts that could affect the use of wildlife connectivity investments.

In addition to communicating and collaborating with federal, state, tribes, and local agencies on the IDT, MDT, and technical committees, WSDOT formed relationships with transportation-based organizations, associations, and businesses in order to gain insight into the requirements of highway users. This includes relationships with the Ports of Seattle and Tacoma, Washington State Good Roads & Transportation Association, Washington Trucking Association, Freight Mobility Strategic Investment Board, and local importing and exporting freight business. WSDOT also developed partnerships with a variety of agencies, landowners, and citizen groups to reduce conflicts that could affect the project (WSDOT Final EIS 2008, ES-7).

As part of the FHWA commitment for government-to-government consultation, WSDOT has engaged in an extensive and ongoing program with affected Native American Tribes. Tribes have indicated strong support for the project's ecological connectivity goals. Tribal consultation began in 1998 at the beginning of the project, with initial discussion of cultural and natural resources. Consultation with the tribes will continue throughout the completion of the project. Tribes who have interest in the project include the Yakama Nation, Wanapum Tribe, Snoqualmie Tribe, Tulalip Tribe, Muckleshoot Tribe, and Confederated Tribes of the Colville Reservation (WSDOT Final EIS 2008, ES-7 & 8).

WSDOT's I-90 Project team developed an aggressive public outreach campaign to educate the general population and businesses about the project. Washington state citizens should have a vested interest in the I-90 Project due to its far-reaching statewide economic, social, and environmental benefits. However, because of its rural location, WSDOT does not have a ready-made audience to communicate with in its backyard.

In July 2007, WSDOT conducted a baseline survey to determine the public's attitude and awareness of the project. Results indicated that people who knew about the project supported it; however, 84 percent of the individuals surveyed did not know about the project. This helped WSDOT understand that when people knew about the project, they endorsed it, but the agency was having difficulties getting the message out to a larger audience. Clearly, a more innovative communications program was needed.

Specific communications strategies were developed, and education and information campaigns were implemented that supported the overarching goal of earning and maintaining statewide support from the public and interested parties. Strategies included using reader-friendly writing – or plain talk, reaching audiences directly with the WSDOT Web site as a primary way to reach audiences with information unfiltered by other sources, and presenting the project visually with high-tech, 3-Dimensional design visualization videos. Other strategies included making formal and informal presentations to local clubs and organizations, other state agencies, freight associations and businesses, city councils and chambers of commerce, schools, and other interested parties. WSDOT also participates in hundreds of community fairs and festivals, from farmers markets, state fairs, to school fairs.

Using the Collaborative Approach for Identifying the Preferred Alternative

FHWA published the Notice of Availability for the Draft EIS in the Federal Register on June 10, 2005. The Draft EIS presented existing environmental conditions along the I-90 Project corridor, along with a range of six possible alternatives that would potentially meet the project's purpose and need. WSDOT developed alternatives based on comments received during the scoping process. The Draft EIS analyzed the environmental, social, and economic consequences of each alternative, based on technical reports or memoranda prepared for key environmental disciplines. FHWA and WSDOT distributed 2,071 copies of the Draft EIS to tribes, agencies, libraries, and members of the public (WSDOT Final EIS 2008, 1-17).

Working with the IDT, WSDOT and FHWA developed a set of six initial corridor alternatives. The lead agencies and the IDT analyzed these six initial corridor alternatives and determined that the No-Build and Limited Construction Alternatives did not meet the project's purpose and need. The Rampart Ridge, Roaring Ridge, and Split Route Corridor Alternatives presented unacceptable levels of environmental impact and cost, and did not meet the project's purpose and need as well as the Common Route Alternative. The lead agencies advanced this alternative for further study in the Draft EIS, including the development of a range of build alternatives along the Common Route Corridor, along with the No-Build Alternative, which is required under NEPA (WSDOT Final EIS 2008, ES-11).

After publishing the Draft EIS, the lead agencies solicited written and oral comments from the public, agencies, and organizations during the 45-day comment period. Public hearings held in Ellensburg, WA, Hyak, WA, and Seattle, WA, in June and July 2005 gave citizens and agencies the opportunity to comment on the Draft EIS as well as meet project staff.

Figure 9. WSDOT staff educating the public about the I-90 Project and Draft EIS at a public hearing

Approximately 276 people attended these hearings. The lead agencies also maintained a project Web site that provided the public with the opportunity to provide comments via e-mail. FHWA and WSDOT received comments from over 3,300 individuals, groups, and agencies. There were approximately 700 unique comments. Almost without exception, commenters favored making the proposed improvements to I-90, and favored making the largest possible improvements to ecological connectivity. No more than two commenters recommended against construction of the project. Most commenters urged FHWA and WSDOT to use the work of the MDT as the basis for the design of wildlife crossing structures (WSDOT Final EIS 2008, 1-20).

After reviewing comments received during the Draft EIS and gathering final recommendations from the MDT, FHWA, WSDOT and the IDT identified the I-90 Project Preferred Alternative by using the collaborative processes mentioned above. The general process for identifying the preferred alternative included:

- Presenting on individual issues such as tunneling logistics, structural engineering, and considering the MDT's recommendations related to ecological connectivity,
- Reviewing Draft EIS comments,
- Using this information to develop IDT recommendations for the Preferred Alternative,
- Identifying the Preferred Alternative based on the lead agencies'- FHWA and WSDOT - concurrence with the IDT's recommendations,
- Performing additional technical studies and cost estimates to refine the Preferred Alternative before issuing the Final EIS (WSDOT Final EIS 2008, 1-18).

FHWA and WSDOT published the Notice of Availability for the Final EIS on August 29, 2008. WSDOT circulated over 6,500 copies of the Final EIS, mostly in a DVD / CD set.

The Preferred Alternative in the Final EIS met the project's purpose and need in the following ways:

- The highway will be expanded from two to three lanes in each direction. This will accommodate projected traffic volumes for the next 25 years.
- The aging, deteriorated highway surface will be replaced with new concrete pavement. This will provide a smoother ride and reduce maintenance costs.
- Where possible, highway curves will be straightened to increase sight distance, drivability, and safety.
- New chain-up areas will be built, providing additional area for trucks and motorists to move out of the travel lanes.
- Low, narrow bridges at two interchanges will be replaced, making truck travel through the interchanges safer and more efficient.
- Avalanche risks and associated closures will be reduced substantially by replacing the existing Lake Keechelus Snowshed Bridge (snowshed) with an expanded six-lane snowshed covering all highway lanes. This will increase safety and reduce road closures for avalanche control work.
- Slopes will be stabilized to reduce rock fall hazards. This will increase safety and reduce road closures due to rock fall.
- Structures for wildlife passage will be built at the 14 major wildlife crossing areas within the project. This will increase safety by reducing collisions between wildlife and vehicles, and will connect habitat that is currently separated by the highway.
- Wildlife passage will be improved by:
    - Replacing narrow bridges and culverts with longer, wider bridges and culverts
    - Adding wildlife exclusion fences and other features to keep wildlife off the highway
    - Adding wildlife overcrossings at strategic locations (WSDOT Final EIS 2008, ES-3 & ES-4).

After publishing the Notice of Availability, a 30-day review period began for the public, agencies, and other relevant reviewers. WSDOT hosted open houses in Ellensburg, WA, Hyak, WA, Bellevue, WA, and a virtual online open house to give citizens and agencies the opportunity to learn about the preferred alternative, as well as meet project staff. Approximately 227 people attended these open houses. Additionally, to educate the public about the release of the Final EIS and open houses, WSDOT mailed over 4,900 postcards to residents living along the I-90 Project corridor, sent e-mails to those registered on project mailing lists, posted informational flyers, placed advertisements in 15 newspapers, mailed letters, and conducted 12 media interviews.

Figure 10. The postcard WSDOT mailed to citizens inviting them to attend the Final EIS open houses

No comments were received during the 30-day public review period after the Notice of Availability appeared in the Federal Register. The public and agencies expressed overwhelming support for the I-90 Project, as evidenced via surveys taken during the open houses.

The FHWA issued a Record of Decision on Oct. 6, 2008, concurring with WDSOT in its choice to construct the preferred alternative.

Successes and Challenges of Using the Collaborative Approach to Identifying a Preferred Alternative

WSDOT was able to meet I-90 Project design and environmental objectives by using the collaborative approach to identifying a preferred alternative. There are several key factors contributing to the success of this approach, including the early identification of the project's purpose and need, early information sharing, agency role definition, and expectation management.

Even though it took months to complete, clearly defining the project's purpose and need was the critical first step in forming the foundation needed for collaborative success. The project purpose and need ensured that the I-90 Project design team and partners were working to accomplish common goals and outcomes.

After identifying the purpose and need, WSDOT and its partners agreed that the early sharing of information and open communication were critical to shaping the project and identifying issues to investigate. The project team used the philosophy of "no surprises," and information sharing was targeted toward that goal. The no surprises goal was achieved by sharing information with project partners that was preliminary in nature. As the information was refined, each partner could contribute and track its progression. Information sharing and open communication were essential in developing a project that incorporated the concerns of agencies and the public into project designs.

Early information sharing also helped WSDOT identify and manage reasonable and unreasonable expectations of partnership agencies and the project team. Expectation management is an essential component to the collaborative approach. WSDOT identified its partners' expectations early on in order to filter through the realistic and unrealistic ones. WSDOT worked with its group of partners to deliver on the realistic expectations and eliminate or modify the unrealistic. Expectations are equivalent to the scope of the project and of each partner; therefore, management of expectations is critical to keeping a project on scope, on budget, and on schedule.

Identifying and managing agency expectations leads to establishing agency role definitions. Agency role definitions ensure mutually compatible partnerships. For the I-90 Project, it was important that WSDOT's collaborative approach benefit all agencies and organizations involved so that together, we could provide a holistic landscape management plan that considered each agencies mission while meeting project needs and benefiting the natural environment.

The collaborative approach process is scalable. WSDOT's South Central Region manages the I-90 Project and has used this partnership approach on other projects before, albeit not to this scale. Because of the South Central Region's past partnership successes, the approach was automatically deemed the best fit for the I-90 Project. This collaborative approach builds projects that build communities. For the I-90 Project, the support of agency, tribal, and public communities were taken into account, which in turn, allows the project to support Washington State as a whole.

Challenges to the Collaborative Approach

The collaborative approach, although successful, also presents challenges. WSDOT faced many challenges when collaborating on the I-90 Project, including issues with timely negotiations, conflicts and strained relationships, drawbacks to early information sharing, and wavering perseverance.

Federal, state, and local agencies all have unique cultures, and because of these cultures, negotiations take an incredible amount of time to complete. Every agency is its own bureaucracy, and its business practices must be respected and accommodated. Respecting business practices includes recognizing each agency's sensitivity to certain issues. Conflicts can arise that strain the partnership if these factors aren't recognized. WSDOT realizes that it's ok to agree to disagree, as conflicts will occur. Therefore, proactively planning for these conflicts is an important part of inter-agency management. WSDOT has learned that when a conflict arises, it is best to discuss the conflict, identify resolution options, and decide on a course of action as a group. Additionally, it's important to recognize that personal opinions are part of a conflict, so when a conflict arises, extra effort must be made toward respecting the feelings and emotions of invested partners.

Even though the early sharing of information was critical to our no surprises goal, it proved challenging at times. Early information must be presented within the boundaries defined by the project team. When sharing information of a preliminary nature, it is important to clearly explain that the data is in draft form and may not contain certain details. Early information without detail requires vision, but not all individuals have this ability. Therefore, early information can oftentimes blur that natural progression of project design, making it difficult for partnership agencies to formulate a response to the data.

Lastly, perseverance to succeed is critical when using the collaborative approach. It's important to have a group of leaders and facilitators that are dedicated to the project and its outcomes, and are willing to persevere through the challenges and inevitable conflict and see it to the end. There are always solutions to problems, despite how bleak the situation appears.

Final Lessons Learned

Over the last 10 years of designing the I-90 Project, WSDOT has learned that no matter how clearly roles, expectations, and partnerships are defined, open, honest, and respectful interaction between people drives success. Understanding agency cultures, recognizing and managing conflict, and taking the time to nurture and invest in partnerships are equally important to both the project and the collaborative approaches' success.

Next Steps for WSDOT and the I-90 Project

Completion of design plans for the second project within the first phase of the I-90 Project is scheduled for fall 2009, with construction scheduled to begin spring 2010. Design plans and permitting actions for the third project within the first phase are still in process with a scheduled completion date of fall 2010, with construction scheduled for spring 2011. The highway improvements from Hyak to Keechelus Dam will be complete by 2015. Other projects within phase one are still being scheduled for completion thereafter.

Phase two of the I-90 Snoqualmie Pass East Project from Keechelus Dam to Easton is currently unfunded. However, WSDOT and project partners are actively trying to secure funding for these important phases.

WSDOT will continue working with the I-90 Project IDT throughout design and construction of phase one and continue this coordination into future Phase two.

The Stormwater Technical Committee and Wetlands Mitigation Technical Committee will continue to be engaged as designs progress and issues are identified that require technical input from our partners.

WSDOT is committed to working with the Wildlife Monitoring Technical Committee to monitor ecological connectivity structures for the Wildlife Monitoring Plan's Tier 1 objectives and support our partnerships in reaching the plan's Tier 2 objectives. WSDOT's role as the lead on this committee will likely diminish as agencies who manage the land and wildlife resources at the landscape scale move into a lead role.

Open and honest communication, and the desire to establish and engage in partnerships early on, is what inevitably allowed WSDOT to develop consensus for a long-term vision for the I-90 corridor. By sharing ideas, being adaptive in designs, and receptive to compromises, WSDOT and our partners have designed a project that will not only improve the safety and reliability of a vital cross-state corridor, but will also ensure the continued health of the delicate ecosystems of the Central Cascades for generations to come.

WSDOT will continue to collaborate with project partners, stakeholders, and resource agencies to overcome challenges as they arise during construction and in future designs. While the remaining 10 project miles from Keechelus Dam to Easton remain unfunded at this time, WSDOT, along with our project partners, stand ready to deliver.

Biographical Sketches

Jason Smith is the environmental manager for the Washington State Department of Transportation' South Central Region. Before becoming region environmental manager in 2008, Jason was the I-90 Snoqualmie Pass East Project environmental manager from 2005. He still maintains an active leadership role in the I-90 Project. Prior to then, Jason was WSDOT Assistant Environmental Manager and the Project Delivery Manager for the Multi-Agency Permitting Team. He joined WSDOT in 1994, shortly after he graduated from Central Washington University with a degree in Resource Management specializing in Botany and Environmental Studies.

Amanda Sullivan is a communications consultant for the Washington State Department of Transportation's I-90 Snoqualmie Pass East Project. While she is employed by the full-service communications company, PRR, Inc., she is co-located with the I-90 Project team to help manage the extensive communications program. She joined PRR in 2008. Prior to then, Amanda was a senior staff writer at Executive Media Corp. from 2005, where she wrote, edited, and published five trade journals. Before then, Amanda was a media relations director for a county museum and an account executive for an advertising specialty corporation. Amanda holds a bachelor's degree in public relations from Central Washington University and associate's degree from Yakima Valley Community College.

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Reducing Road-Based Habitat Fragmentation: An Eastern Box Turtle (*Terrapene c. carolina*) Pilot Project

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Abstract

Box turtle populations are declining throughout their range, largely as a result of habitat loss and fragmentation. The most serious direct threat to box turtles is road-based mortality. Box turtles must move within their home ranges in response to environmental conditions and to find food and mates. Female turtles must undertake nesting migrations, often travelling relatively long distances in search of suitable areas. Destruction of eggs and hatchlings by predator populations that have flourished alongside human development renders every turtle that survives to reproductive age important to its population, yet it is the adults whose movements increase the likelihood that they will attempt road crossings. Population models indicate that the loss of 3-4 adult females in a population of 200 turtles can initiate a slow but irreversible decline to population extinction.

Identifying areas where mitigation efforts might help to protect box turtle populations is a fundamental challenge. One of us (MJB) identified such an area on a rural road bordering a state park in Maryland, counting up to six dead box turtles in one year over a relatively short road segment. With this knowledge, we were able to test for the first time whether box turtles would use existing culverts if directed to them by fencing. We erected 2.7 km of standard silt fencing during the spring of 2005. The fencing was tied into two narrow culverts (.38 and .53 m at the widest point), which carry water only during heavy storm events. Cameras and motion sensors placed in the culverts recorded use by a wide variety of small and medium-sized wildlife, including box turtles.

During the summer of 2005, MJB spent 181 hours searching the barrier, locating 18 turtles; 16% used the culvert. In 2006, 118 hours were spent searching the barrier. Sixteen turtles were observed along the barrier; 6% used the culvert. In 2007, 205 hours were spent searching the barrier; 20 turtles were observed, of which 10% used the culvert. In each year, one road-killed turtle was found in the vicinity of the barrier.

In 2008, we applied for funds through the Transportation Enhancement Program for permanent fencing and improved culverts. The funding proposal was approved, and construction is scheduled to begin in 2010.

This project underscores the importance of partnerships between federal, state and local transportation authorities, land managers and property owners, volunteers, and non-profit organizations. It also demonstrates the impact that relatively modest alterations to existing transportation structures can have in reducing mortality of vulnerable species and serving to protect a wide variety of animals as well as roadway users. Future efforts should be directed toward obtaining estimates of box turtle population size in the area and monitoring use of a new fence/culvert system to determine the degree to which it is a factor in population persistence.

Introduction

Populations of the eastern box turtle are declining largely as a result of habitat loss and fragmentation (McDougal 2000; Dodd 2001). These factors reduce the size of local populations and increase the distance between them, thereby rendering them vulnerable to demographic and environmental stochasticity and possibly reduced genetic diversity (McDougal 2000).

Range-wide, remaining box turtle habitat increasingly is fragmented by development and the construction and use of roads (McDougal 2000, Dodd 2001). In Eastern North America, many populations exist in isolated fragments of forest habitat located in urban and suburban areas. Across Maryland, forest cover has been declining for decades, with an average loss of more than 2428 ha/yr between 1986 and 1999. For those counties which reported the extent of forest clearing, an average of 1125 ha/yr of forest has been cleared without replacement since 1992 (Maryland Department of Natural Resources 2009). In addition to loss of forested habitat, threats to box turtles throughout their range include logging, removal of individuals from the wild for pets or for commercial purposes, and possibly disease and unsustainable levels of predation, particularly of eggs and hatchlings (Dodd 2001).

As a result of these threats, increasing concern is being expressed about the box turtle's status throughout its range (Williams and Parker 1987; Thorbjarnarson et al. 2000; Dodd 2001), and in Maryland (Stickel 1978; Hallgren-Scaffidi 1986; Hall et al. 1999). Few long-term studies of box turtle populations have been conducted, but those which have are unanimous in their conclusion that populations are declining (Stickel 1978, Schwartz and Schwartz 1991, Hall et al. 1999).

Concern over the status of box turtles has led to the adoption of protective measures by the Conference of the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora. At their 1994 meeting, the Parties voted to add all *Terrapene* species to Appendix II, including the two species native to the United States – the eastern box turtle and the ornate box turtle (*T. ornata*). Appendix II includes species that, although not necessarily threatened with extinction at present, may become so unless trade is strictly controlled. The Parties' action was prompted not only by the substantial increase in box turtle exports that occurred as the availability of certain tortoise species was declining, but also by long-term population declines of native *Terrapene* populations (U.S. Fish and Wildlife Service 1996).

Demographic characteristics render turtles particularly vulnerable to human impacts (Gibbs and Amato 2000). These animals are both long-lived and slow to reach sexual maturity. The first decade of a box turtle's life largely is devoted to growth and the development of the shell that is its primary means of protection from predators. Egg and hatchling mortality is typically high (Ernst et al. 1994; Dodd 2001), increasing the importance of juveniles and adults to the population. Congdon et al. (1993) conclude in part that the suite of life-history traits that co-evolve with longevity results in populations that are severely limited in their ability to respond to increases in neonate mortality and even less so to increased mortality of juveniles or adults.

Habitat fragmentation has been identified as the primary cause of contemporary extinctions (Wilcox and Murphy 1985), although Fahrig (1997) asserts that the effects of habitat loss and fragmentation are often confounded in studies claiming to show fragmentation effects. Though the negative effects of habitat loss outweigh those of habitat fragmentation (Fahrig 1997), fragmentation also reduces population size (Soulé et al. 1988; Mitchell and Klemens 2000), and potentially increases the importance of stochastic demographic and genetic effects and the threat posed by environmental extremes (Forman et al. 2003).

As a source of habitat fragmentation, roads that present a barrier to turtle movement and dispersal may be increasing the likelihood of extinction of local populations by reducing the genetic variability of these populations. Roads also pose the most serious direct threat to box turtle populations (Dodd 2001).

In 1945, Robert McCauley wrote that the eastern box turtle is common in both the coastal plain and mountainous areas of Maryland, but noted even then the threat posed by the automobile. "Throughout Maryland this species is the most commonly seen automobile-killed reptile on the road" (McCauley 1945, 163). Concern about the impact of direct highway mortality on a range of Chelonians, including the box turtle, has only increased in recent decades (see, e.g., Stickel 1978; Gibbons 1987; Ernst et al. 1994; Gibbs and Shriver 2002).

Congdon et al. (1994) concluded that, for adult (>15 years) common snapping turtles (*Chelydra serpentina*), an annual increase in mortality of 1% would halve the number of adults in less than 20 years. Other studies have found that additive adult mortality of 2-3% is inconsistent with population growth (Doroff and Keith 1990, Brooks et al. 1991, Congdon et al. 1993, 1994). Modeling studies of box turtles indicate that the loss of 2% of the adult females in a population to additive causes can result in a long but irreversible decline to extinction (Seigel 2005). Compensatory reproduction that might offset population declines, while noted in at least one study (Germano and Joyner 1988), seems to be the exception rather than the rule (Brooks et al. 1991).

The observation by one of us (MJB) of several adult box turtles killed each year by vehicles in a relatively short road segment in Boonsboro, Maryland raised concerns about the impact of this level of mortality on the local population. It resulted in a call from MJB to a national animal protection organization, The Humane Society of the United States, and an agreement to collaborate in an effort to reduce ongoing mortality.

Study Area

Greenbrier State Park (GSP) is located in the Appalachian Mountains of central Maryland. The park is comprised of 607 ha, and is largely forested. Dominant overstory species include oaks (*Quercus* sp.) and hickories (*Carya* sp.). Understory species include flowering dogwood (*Cornus florida*), mountain laurel (*Kalmia latifolia*), sassafras (*Sassafras albidum*), and serviceberry (*Amelanchier* sp.). The shrub layer includes members of the rose family (e.g., *Rubus* sp., *Rosa multiflora*). Herbaceous species include mayapple (*Podophyllum peltatum*), jack-in-the-pulpit (*Arisaema triphyllum*), partridge berry (*Mitchella repens*), stilt grass (*Microstegium*), and garlic mustard (*Alliaria petiolata*).

Keadle Road, on which this project was conducted, runs through the southern portion of the park. It is bordered on the north by park lands, and on the south by both park and private property. Keadle Road is a narrow, two-lane road. Traffic volume was measured in January of 2008 at 300 vehicles per day. Since then, however, the road has been resurfaced and traffic volume has increased substantially.

Project Description

One of us (MJB) observed dead turtles in the road each year for several years. After six adults were killed in 2004, efforts to alert drivers to their presence with the use of customized signs were undertaken, but were frustrated by thieves shortly after their placement.

After a phone call to The HSUS, the authors agreed to collaborate on an effort to determine whether box turtles would use two existing culverts under Keadle Road if directed to them by fencing. The corrugated metal culverts measured approximately 0.38 and 0.53m in diameter. Except for heavy rain events, both culverts were dry most of the year, a requirement for box turtle use.

Permission to construct the fence was obtained from GSP officials, the Washington County Highway Department, and neighbors whose properties the fence would abut. Maryland State Highway Administration and Washington County Highway Department personnel provided valuable advice on fence construction. Over the course of four weekends in the early spring of 2005, volunteers and community service workers spent approximately 273 person-hours constructing 2.7 km of fencing. We used standard pre-staked plastic erosion control material.

Ideally, we would have buried the bottom 15 cm of the fence fabric to prevent turtles from squeezing under the fence to gain access to the road. Large rocks were common in the project site, however, and burying the fabric was impractical. As a result, we staked the bottom 15 cm of the fabric to the ground with landscape staples, and attempted to further prevent turtles from finding openings by adding soil, small rocks and leaves on top of the fabric. In some locations, the fence was slanted away from the road in an effort to reduce the chance that turtles would successfully climb over.

Private driveways interrupted the fencing at several locations on the south side of Keadle Road. In an effort to prevent turtles from entering the road at these locations, we created a 90 degree angle, and extended the fence about 10 meters up the drive and parallel to it in a manner similar to that used in a project to prevent aquatic turtles and other wildlife from gaining access to Route 29 in Florida's Lake Jackson (M. Aresco, pers. comm., March 25, 2005).

We installed a Canon Sure Shot A1 35 mm camera and passive infrared trail monitor (Trailmaster TM550) in each of the culverts to record use by turtles and other animals.

Results

Turtles were photographed in the culverts during each year that cameras were in place (Table 1). The barriers seem to have reduced box turtle mortality rates along Keadle Road from levels observed prior to barrier construction. One turtle was killed each year in the project area, always in proximity to a driveway.

Numerous other species were photographed in the culverts, including, but not limited to: American toad (*Bufo americanus*); black rat snake (*Elaphe obsoleta*); copperhead snake (*Agkistrodon piscivorus*); garter snake (*Thamnophis sirtalis*); Eastern chipmunk (*Tamias striatus*); Eastern cottontail (*Sylvilagus floridanus*); Eastern gray squirrel (*Sciurus carolinensis*); opossum (*Didelphis virginiana*); raccoon (*Procyon lotor*); striped skunk (*Mephitis mephitis*); white-footed mouse (*Peromyscus leucopus*), and woodchuck (*Marmota monax*).

Season	2005	2006	2007
Observation period	June 9-October 31	May 23-November 16	May 28-November 16
Total hours	181	118	205
Hours per turtle	9.5	6.9	9.8
Turtles observed	18 (4M:14F)	16 (9M:7F)	20 (9M:11F)
Percent in culverts	16	6	10
Turtles killed - ps	1	1	1
Turtles killed – ga	2	0	0

Table 1. Observation period, total number of hours fence inspected for turtles, hours per turtle observed, turtles observed, percent of those observed along fencing that used culverts, and box turtle mortality in project site (ps) and in the general area (ga), by season.

Discussion

Box turtles will use existing culverts if directed to them by fencing. The culverts might be used without fencing, though we could find no reference in the literature to such use. The movement of turtles along the barrier fence suggests that they were heading directly toward the road surface until the barrier was encountered. Therefore, the reduction in observed mortality in the project location may be a result of the barrier/culvert system. It could also reflect changes in population size or in patterns of turtle movement. However, the number of turtles found along the barrier did not decrease over the course of the project. While it is possible that turtles simply moved along the barriers and entered the road once the end was reached, none were killed in the road in the vicinity of the barrier ends.

Each of the turtles killed within the project site was killed in association with a driveway. Clearly, the presence of breaks in the fence undermines the level of protection that might otherwise be conveyed by a barrier/culvert system.

The number of turtles that used the culverts relative to those found along the fence was low. We believe that this may be a reflection of the fact that the culverts are small and dark and provide no clear view of habitat on the other side of the road. It is possible that, as with other species (Reed et al. 1975; Clevenger and Waltho 2000), box turtles may need to learn of the location of passages in their habitats. Box turtles seem capable of remembering the location of favorable sites, such as food or water resources, within their habitats (Dodd 2001). Perhaps they can also remember where and how they can access favorable habitat on the opposite side of a barrier.

In the absence of estimates of population size, we do not know whether the barrier/culvert system contributed to population persistence. Future work should estimate population size for monitoring of passage effectiveness in population persistence.

Project Improvements

The Intermodal Surface Transportation Efficiency Act (ISTEA) (1991) established the Transportation Enhancement Program (TEP) for the purpose of funding non-traditional transportation-related projects. It authorized eligibility in 23 U.S.C. 133(b)(8), established funding in 23 U.S.C. 133(d), and defined the activities in 23 U.S.C. 101(a)(35). Section 1201 of the Transportation Equity Act for the 21st Century (TEA-21) (1998) amended 23 U.S.C. 101(a)(35), to include two additional TEP activities. Section 1122 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) (2005) amended §101(a)(35) to specifically list the eligible TEP activities, with minor modifications. Among the activities now eligible for TEP funding is environmental mitigation to "reduce vehicle-caused wildlife mortality while maintaining habitat connectivity." Having demonstrated that box turtles will use even small culverts if directed to them by fencing, the authors sought to obtain TEP funding to support the installation of an improved fencing/culvert system.

On February 25, 2008, MJB submitted to the Maryland Department of Transportation/Maryland State Highway Administration, an application on behalf of the Maryland Department of Natural Resources: Greenbrier State Park, entitled: "Greenbrier State Park Wildlife Road Mortality Mitigation Project." The application requested $130,000 to support the installation of three to four new and improved culverts, primarily for wildlife use, and the installation of permanent barrier fencing for 1.3 km on the north and south sides of Keadle Road. The application was considered by a committee composed of Maryland State Highway Administration officials. The preliminary selections were then approved and finalized by the Maryland Board of Public Works. The application was approved in May, 2008.

In Maryland, TEP funding can be requested for up to half of a project's total estimated cost. The project sponsor is required to fund the balance, known as the match. Because the TEP is a reimbursable program, the project sponsor must pay for project costs before submitting a request for reimbursement of eligible activities. In order for TEP funding to be approved, the project sponsor (i.e., Greenbrier State Park) also must contribute a soft match, which is equivalent to at least 100% of the grant request as well as 25% of the total construction costs in cash.

The soft match – costs that are non-construction related – was easily met by costs of acquisition of additional property for the park on the south side of Keadle Road. Approximately 20% of the turtles observed along the fencing were on this newly acquired property, thereby demonstrating its importance as habitat for this box turtle population. Volunteer hours in constructing and monitoring the fence and materials used in its construction also contributed to the soft match. Approximately $26,000 must be raised for the required cash match. Letters of commitment have been received as of July, 2009, for $5,000-10,000, primarily from non-profit organizations.

As of July, 2009, project design is nearly complete. Four-sided concrete box culverts, each approximately 0.61 m^2 by 7.62 m, will be used. The culverts will be placed so as to serve as wildlife passages rather than in channeling surface water. Head and wing walls will be incorporated. A maximum slope of 15 degrees over a distance of 4.5 m is planned, which is well within the maximum incline and decline that box turtles voluntarily traverse (Muegel and Claussen 1994). Once the new culverts are in place, the two existing culverts will be modified to exclude wildlife; they will then function only as conduits for road runoff.

Galvanized, plastic-coated 23-guage fencing will be used. Fencing will be approximately 0.61m high. A lip will be constructed along the top edge to prevent turtles from climbing over. As in the pilot project, the bottom 15 cm of the fence will be stapled to the ground, rather than buried, based on the abundance of rocks in the study area. The fence will be constructed so as have a certain amount of give, thereby denying animals a rigid surface for climbing as well as reducing damage to the fence caused by falling tree limbs. If turtles can see through the fence, they tend to continually attempt to get through it rather than move along its length (S. Barnett, pers. comm., April 12, 2007). To eliminate this problem, erosion control fabric will be attached to the galvanized fencing.

Several factors will reduce the overall costs of the project. Four-sided box culverts will be used instead of three-sided culverts. Although the natural substrate provided by three-sided culverts is preferred by some species, upland reptiles are believed to readily use artificial substrates (Arizona Game and Fish Department 2006). Moreover, the bottom of the culvert should gradually accumulate debris that may mimic a natural substrate. While aesthetically and structurally superior, a concrete or rock wall with a smooth surface away from the road would have been prohibitively expensive; the selected fencing materials offer the best combination of durability, effectiveness and cost. Costs of fence installation will be greatly reduced by the use of prison work crews. Installation estimates from commercial firms ranged from $75,000 to $120,000. With the exception of a $300/day cost for a guard, prison work crews are available for the site at no cost, and fence construction can be closely monitored to ensure that fence impermeability is maximized.

As with all fence/passage systems, maintenance of the fence will be critical. Without the willingness of one of us (MJB) to ensure that the fence is checked frequently for breaks and gaps, the effectiveness of the expenditure could be questioned.

An educational component will be incorporated in the project though the Maryland Park Service's Scales and Tales Program. Participants will be informed of the conflict between wildlife and roads, the particular vulnerability of turtles to road mortality, and the steps that they as road users can take to reduce road-based mortality.

Conclusions

Construction of large wildlife crossing structures increasingly is viewed as an important component of road planning and design. Existing structures -- designed and installed for other purposes -- can be used under some circumstances to provide safe passage in fragmented habitats for some species.

This project demonstrates that eastern box turtles will use existing culverts if directed to them by fencing. It requires the identification of crossing "hot spots," and the cooperation of road authorities and landowners in fence construction and maintenance. The project involved the support of federal, state, county and local governments and the active participation of non-profit organizations and volunteers. It could not have succeeded, either as a pilot project or in competition for federal funding, had a local resident not shouldered the burden of day-to-day fence inspection and monitoring of turtle movement.

Future efforts should include estimating the population size of the local box turtle population, monitoring the movement of box turtles along the new barrier and their use of the culverts, and recording box turtle road mortality in and near the project site.

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Biographical Sketches

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RE-EVALUATING THE NEEDS FOR ANIMAL PASSAGES IN ISRAEL: TOWARDS A LONG-TERM MONITORING SCHEME

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Abstract

Centralized planning framework, accelerating habitat fragmentation and growing awareness to animal-transportation issues in Israel have lead to increased demand for ecological considerations during road construction and maintenance. Several governmental bodies have upgraded their requests regarding fauna passages and monitoring, with substantial budget implications.

Planning and management decisions on local and regional scale need to consider changes and adaptations required with time. Current project-oriented planning and budgeting make it difficult to maintain a regional, long-term view.

Most existing fauna passages were not specifically designed for animals. Guidelines for animal passages are derived from European countries, which differ from Israel in climatic-ecological aspects and in some human activity patterns.

Adapting these guidelines to local conditions in order to rationalize and optimize planning, expenditure and results requires more accurate reevaluation of animal needs, testing alternative solutions on small scale before turning to large-scale expensive modifications, and responding to temporal changes.

1. Objectives

This paper presents a project proposed to the Israel National Road Company. The project has 3 objectives: a) Estimate if existing available passages match the connectivity needs of various species; b) Evaluate if, how much and where animal road crossing poses a genuine safety problem to humans; c) Compare various data sources and collection methods and devise a cost-effective long-term monitoring scheme and indicators.

2. Methodology

Several stages are proposed:

I) Identifying "hotspots" or "bottlenecks": using GIS mapping to overlay existing data from various sources in order to locate areas that need attention.

II) Pilot intensive monitoring: intended to assess the efficiency and suitability of existing passages by several criteria and to compare between several monitoring techniques and data sources.
Interim summary of results will lead to further specific monitoring.

III) Devising a long-term monitoring scheme and testing it.

3. Anticipated Results

The initial data collection should point at:

- Specific "hotspots" or "bottlenecks" with high collision rate and/or where connectivity is impaired.
- Species or habitats that need extra attention.
- Locations where safety problems may occur.

Pilot monitoring should:

- Reveal more details on the usage of various passage types and its relation to certain environmental parameters
- Compare different monitoring methods.

4. Implications and Recommendations

The interim summary will recommend on required action: fencing, modifications to existing passages and testing for their effectiveness, additional passages. It will recommend on cost-effective monitoring: techniques, scale, optimal data sources and indices (new or from upgraded existing sources). Further research will be recommended according to results.

The long-term monitoring scheme should detect changes through time deriving from changes in human activity patterns and development, and/or changes in faunal populations, their behaviour and needs. It should enable to point at sensitive areas and at issues that require response.

Introduction

Background

Natural habitats and open landscape in Israel are facing accelerated habitat loss and fragmentation due to high development pressures, particularly at the center of the country. The northern part of the country, with a Mediterranean to semi-arid climate, is densely populated and more fragmented by infrastructure; the southern part of the country, with semi-arid to arid climate, is sparsely populated and infrastructure still leaves relatively large habitat patches.

Regional planning is centralized through the Planning Administration at the Ministry of Interior and its national and regional committees. Numerous master plans address various planning issues including Infrastructure and several categories of protected areas. An increasing awareness to connectivity and transportation issues emerged ca. 10 years ago. The main actors in this scene, apart from the planning authorities, are the Nature and Parks Authority (NPA), the Ministry of Environmental Protection, the National Road Company (NRC) and the Cross-Israel Highway Company (NGOs also play a role).

Tight planning regulations and increasing awareness to animal-transportation issues have lead to increased demand for ecological considerations during road construction and maintenance in the last few years. Several governmental bodies have upgraded their requests regarding fauna passages and monitoring, with substantial financial implications: more passage are required where roads are upgraded, and planners are requested from as general as attention up to a detailed monitoring scheme.

Most of the animal passages available today in Israel are either water conduits in various sizes and shapes or agricultural passages, not specifically designed for animals or their needs. They are not maintained on a regular basis. In the last 5 years, 6 overpasses have been planned. Three are now operational.

Studies and Monitoring

Since 2000, several reviews, studies and short-term specific monitoring on connectivity and wildlife were carried out in Israel, mainly initiated by NPA (e.g. Baki 2000, Gutman *et al*. 2002, Inbar *et al*. 2002, Malichi 2006, Achiron-Frumkin & Frumkin 2007). They were accompanied by a general definition of "Ecological Corridors" and ecological "bottle necks" as guidelines for regional planning (Shkedy & Sadot 2000), and by guidelines for animal passages, recently updated by the NRC (Shkedy & Sadot, 2004, Avnon 2008).

NPA are currently refining their definitions for ecological corridors and test more data sources and monitoring equipment.

There is a notion that animal-vehicle collisions are not a major safety issue. According to the NRC engineers, there are no human-safety problems arising from animal-vehicle collisions, except from collisions with domestic camels and donkeys, mainly along a few roads crossing the Negev desert. Yet, this has not been checked thoroughly, as well as cases where there was no kill, but the driver was startled or the distracted attention eventually caused an accident.

The Fauna: Who Is It For?

Large mammals like elk, moose or bear are absent from the Israeli fauna. The more common large herbivores are two gazelle species and Ibex. Other medium-sized mammals include Wild Boar, Striped Hyena, porcupine, badger and otter, to name few of the large to medium-sized ones.

Several grazing species were re-introduced and are found at specific areas (Onager and Arabian Oryx in desert habitats and Roe Deer and Persian Fallow Deer in Mediterranean habitats)

The Need

The current guidelines and recommendations for animal passages (Avnon 2008) were mainly derived from the experience in European countries (e.g. Iuell *et al*. 2003), where faunal composition, habitats, climate and human activity patterns are different from those in Israel. Moreover, the experience worldwide has led to modifications and improvements that need to be looked at and checked for local suitability.

Adapting the guidelines to local conditions, as several European countries have done (e.g. Rijkswaterstaat 2005, Ministra de Medio Ambiente 2006) is required in order to rationalize and optimize planning, expenditure and results. Choosing between alternative connectivity solutions should be based on hard evidence and on pilot experience before turning to large-scale expensive modifications.

The insights from the preliminary studies mentioned above are insufficient for making more accurate planning and management decisions, such as the number of passages, their design and their maintenance.

Furthermore, planning and management decisions on local and regional scale need to consider changes and adaptations required with time. Current project-oriented planning and budgeting make it difficult to maintain a regional, long-term view. The current procedures are also insufficient to allow for changes and adaptations that are required with time – responding to local animal populations' dynamics and to changes in their movement requirements, as well as to changes in human activities in the surrounding open landscape and to the interaction of both.

This paper presents a project proposed to the Israel National Road Company.

Objectives

The proposed project has three objectives – to find out the magnitude of the animal-road infrastructure problem, both to animals and to people in different regions, to recommend on possible solutions, and to device an optimal monitoring scheme:

a) Evaluate if the existing passages match the connectivity needs of various animal species;
b) Evaluate if, how much and where animal road-crossing poses a genuine safety problem to humans;
c) Compare various data sources and collection methods and devise a cost-effective long-term monitoring scheme and indicators.

Addressing these issues should enable planners, engineers and conservationists to:

1) Locate where connectivity needs do not correspond to existing and planned setup, and therefore:
    - Define priorities to find solutions (for areas or for specific roads of high priority);
    - Recommend on ways to improve connectivity in specific locations;
    - Test for the actual suitability of the applied solutions.
2) Compare between several connectivity options (including costs, maintenance, combined solutions), testing for efficiency and suitability using several criteria (animal movement needs, diversity of species using the passage, the degree of usage, seasonal variations, target species);
3) Decide on the appropriate monitoring scheme and techniques, which are suitable for the physical circumstances and comply with financial and administrative consideration, allowing to detect current and future problems.

Methodology

The proposed project involves several stages. As the whole project is expensive, it was intentionally designed in modules with distinct stopping points allowing to evaluate the results at each point and to decide if, how and when to proceed.

It involves gathering and analyzing existing available data from different sources, and based on this analyzed data – perform a pilot monitoring, gather new data simultaneously, if necessary, and use the conclusions for decision-making and to establish a long-term monitoring program.

The first stage includes collection and analysis of data from various existing sources; a pilot monitoring stage follows, where new data will be collected and compared to the existing available data; the results of the first two stages are summarized towards more detailed recommendations and towards testing the suggested long-term monitoring framework; and finally –an approved long-term monitoring scheme will be operated on the third and last stage.

It is important to note that when we try to assess animal needs and the level of suitability of the currently available passages there are two main issues: a) assessing the animal connectivity/ movement needs based on data from several sources; b) assessing the efficiency of existing passages to answer these needs, using several parameters (such as the diversity of species actually using the passage, the degree of usage, seasonal changes, special focus on species/ groups that were marked as targets).

To support the ability to take knowledgeable decisions and to promote the dialogue between different stakeholders, the proposal also suggests to: a) review the literature for updated monitoring possibilities, their efficiency and costs; b) carry out two professional workshops to present the findings of stage 1 and stage 2 and to discuss the results and recommendations (both are not further mentioned).

Stage 1: Identifying "Hotspots" or "Bottlenecks"

Using GIS mapping enables to gather and overlay existing data relevant to connectivity, on a local, regional and national scale. The data sources include:

- Data from road kills (available data and data to be collected over a defined period);
- Observations on animal movements on or near roads;
- Reports on animal-vehicle collisions;
- Refined mapping of ecological corridors (NPA);
- Species distribution maps (particularly rare or endangered species);
- Habitat distribution maps (particularly aquatic habitats);
- Open landscape along roads, not necessarily included on the ecological corridors);
- Location of existing underpasses and their properties (shape, dimensions).
- Recommendations from current studies on other parameters important to connectivity analysis that need to be considered.

These will be analyzed for the degree of overlap between collision/kill data and ecological and physical data – with distribution maps, with ecological corridors, with other open landscape or with the distributions of certain focal species and habitats and with the availability and properties of passages.

This analysis should point at specific locations that need special attention ("hotspots" or "bottlenecks") – both generally, on a regional or national level, and for particular endangered species. It will also be able to verify or disprove the notion that basically there are hardly any passenger safety problems.

This stage should yield primary recommendations for specific solutions that can be tested later.

Stage 2: Pilot Monitoring

Stage 2 involves intensive monitoring in few selected "hotspot" sites. From the hotspot/bottleneck areas characterized on stage 1, 2-3 areas will be chosen for a pilot study, preferably located at the north, center and south of the country, to allow for different habitats. Monitoring will be conducted during both a rainy and a dry season.

Several monitoring techniques and data sources will be used and compared to examine usage patterns of existing passages and animal movement in their vicinity: recording kills, making direct observations, recording tracks in sand and ink beds, as well as using IR-cameras, that reveal a more comprehensive picture along with important behavioral data not otherwise available.

Additional parameters will be collected for the landscape and for specific passages so as to assess the efficiency and suitability of existing passages by several criteria.

The results will portray the actual usage of different types of passages, and its relation to various parameters. They will also help to compare between monitoring techniques and depict the parameters that should be collected and the costs involved.

Interim Summary of Results

The results of stage 2 will be used for:

1) Recommendations for fencing of problematic road sections;
2) Recommendations to modify and improve passage design and functionality;
3) Recommendations on where to test the effectiveness of the improvement measures before spending more time and money on their wide application
4) Deciding on the most cost-effective future monitoring:
    a. Where and how should it be expanded?
    b. Which data sources can be reliable indicators (for action required or for changes):
        - Which data yielded the most relevant information?
        - Do we need to develop new indicators or is it sufficient to keep collecting data (or upgrade it) from existing sources?

This stage should involve some form of consultation with various stakeholders to reach an accepted framework for long-term monitoring.

Stage 3: Towards a Long-Term Monitoring Scheme

Based on the recommendations from the previous stages, this stage involves devising a long-term monitoring scheme.

The monitoring scheme is intended to track changes emerging from the human side, from development and from changes in human activity patterns on one hand, and changes emerging from the animal side, from changes in animal populations and their needs on the other hand, or from both.

It will recommend on the preferred techniques, define the spatial (where to monitor) and temporal (how often) scale, define responsibilities for different organizations that may collect the data, the organization and analysis responsibilities and the budgets involved.

Anticipated Results

The initial data collection (stage 1) should point at:

- Specific "hotspots" or "bottlenecks" with high collision rate and/or where connectivity is impaired.
- Species or habitats that need extra attention.
- Specific locations where safety problems may occur.

The pilot monitoring (stage 2) should:

- Reveal more details on the usage of various passage types and its relation to certain environmental parameters
- Compare and rate different monitoring methods by several suitability criteria.

Implications and Recommendations

The interim summary will recommend on required action(s): fencing where many road kills or accidents occur; modifications to existing passages to improve their usage and the appropriate testing for the effectiveness of these modifications; planning for additional passages where required.

It will recommend on cost-effective monitoring: techniques, scale, optimal data sources and best predictors/ indicators for the questions of interest: for locations that need attention (change or solution) now or in the future, or for successfully handled problems? Which data sources yielded most relevant data? Should new indices be developed or can we upgrade existing data collection (such as carcass collection and removal by road safety teams)? It will consider if and where should monitoring be extended. Further research will be recommended according to the results.

The long-term monitoring scheme should depict an optimal way to track temporal changes deriving from various reasons (human or fauna related). It should enable to point at sensitive areas and at issues that require response, allowing conservationists and planners to work together towards finding optimal solutions for sustainable development. Such a scheme can be incorporated as part of a larger monitoring scheme which is to be included within the national strategy for biodiversity conservation.

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RESTORING ECOLOGICAL NETWORKS ACROSS TRANSPORT CORRIDORS IN BULGARIA

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Abstract

Bulgaria is currently in a phase of political and socio-economic transition and faces many challenges in balancing economic and environmental interests. One of these challenges is the development of a sustainable road and railroad network that facilitates the needs for efficient transport of goods and people but does not threaten areas that are especially valuable for nature conservation. Currently plans have been developed to substantially upgrade and expand the national road and railroad network. The existing transportation corridors and the proposed extensions pose a threat to wildlife and affect the development and functionality of both a national and Pan-European ecological network. Our objective is to provide the necessary knowledge to help the Bulgarian authorities set up a national program to minimize the fragmentation effects of these expanding transportation corridors so as to preserve biodiversity and develop a coherent and sustainable ecological network across the country. The main research questions we addressed are: (1) What sections of the road and railroad network are expected to significantly affect the viability of wildlife populations? (2) Which of these ecological bottleneck locations need to be addressed most urgently? (3) What measures could be taken to solve the problems? To identify bottleneck locations in the Bulgarian road and railroad network we used a combination of two strategies. First, an expert-based GIS model – LARCH – was used to study the impact of existing and planned human transport corridors on the population viability of twelve indicator species. Second, and independent of the modeling approach, experts for all indicator species were asked to identify bottleneck locations in the road and railroad network in Bulgaria. The bottleneck locations identified by the LARCH model and the experts were mapped and analyzed for potential overlap. In total 283 bottleneck locations were identified in the existing road and railroad network of Bulgaria. About 30% of all bottlenecks are classified as *high priority* locations. Immediate action is recommended at these locations as these have been identified as locations where the impact on population viability is high and/or wildlife is frequently killed in traffic. In total 544 mitigation measures were identified as necessary to restore habitat connectivity and reduce wildlife mortality. A significant number (331) of these proposed mitigation measures involve adapting existing structures, such as road tunnels, viaducts or bridges, to allow for better use of these structures by wildlife. In addition 213 new structures, to be used exclusively by wildlife, are needed. Total costs of the proposed mitigation actions are estimated to be 132 million euro. The implementation of the here proposed road and railroad mitigation is expected to significantly improve the population viability of most threatened wildlife species and, as such, is an indispensable first step in preserving Bulgaria's biodiversity and developing a coherent and sustainable ecological network across the country.

Introduction

Urban, industrial or agricultural areas, transportation corridors, and their continued growth often affect natural areas and the wildlife that depends on these areas. The loss and cutting up of natural areas through these anthropogenic activities is commonly referred to as "habitat fragmentation". Transportation corridors, mostly roads and railroads, are among the main causes of habitat fragmentation. They not only cause the loss of natural habitats but also affect the quality of adjacent habitats, hinder the movement of ground-dwelling animals across the landscape and increase wildlife mortality through vehicle collisions. These impacts can increase the risk of (local) extinction for certain species, especially those that are already vulnerable or endangered.

The total paved road and railroad length in Bulgaria is 18,744 (outside urban areas) and 4,345 km, respectively. A considerable length of these transportation corridors cross valuable natural areas. Furthermore, in Bulgaria plans have been developed to substantially upgrade and expand the national road and railroad networks, including five Pan-European Transport Corridors. The existing transportation corridors and the proposed extensions pose a threat to wildlife and affect the development and functionality of both a national and Pan-European Ecological Network (PEEN), including the designation and protection of NATURA 2000 sites.

This study aims to identify and prioritize sections of the Bulgarian road and railroad network that are expected to significantly affect the viability of wildlife populations and provides recommendations to avoid or mitigate the problems identified (Van der Grift et al. 2008). Our research questions are: (1) What sections of the Bulgarian road and railroad network are bottleneck locations from an ecological point of view? (2) Which of these bottleneck locations need to be addressed most urgently? (3) What measures could be taken to solve the problems? The overall objective is, in these times of extensive expansion of the road and railroad systems, to develop tools to help the Bulgarian authorities set up a national program to minimize the fragmentation effects of these transportation corridors so as to preserve biodiversity and develop a coherent and sustainable ecological network across the country.

Methods

To identify bottleneck locations in the Bulgarian road and railroad network we used a combination of two strategies (Van der Grift et al. 2008). First, an expert-based GIS model was used to study the impact of existing and planned human transport corridors on the viability of wildlife populations. Second, experts were consulted for their opinion of important ecological bottleneck locations. The two methods were included and combined in the study, as the development of a national program for de-fragmentation in the Netherlands has shown that bottleneck locations are best assessed when model analyses of the viability of wildlife populations on a national scale are combined with expert knowledge of the local situation (Van der Grift 2005, Van der Grift & Pouwels 2006).

Selection of Indicator Species

Many wildlife species are affected by roads. Since it would not be feasible to analyze all the species in Bulgaria that might be sensitive to road impacts, twelve key wildlife species were selected and used as indicators to assess bottleneck locations in Bulgaria's transport network. The species were selected so as to represent all the major ecosystem types in the country. Moreover, a range of small, medium and large animal species were selected, as the barrier effect of roads can vary according to the size of the species, the size of their home ranges and their ability to move between habitat patches. The selection consisted of 8 mammal, 3 reptile, and 1 amphibian species (Table 1).

Identification of Bottleneck Locations

Step 1: Population Viability Analysis
A model (LARCH) was used to estimate the viability of the wildlife populations of each indicator species in two situations; with road and railroad barriers present and with mitigated barriers. Any significant changes in population viability between the first and second situation were identified as bottleneck locations, i.e. road or railroad sections where the existing or planned infrastructure limits population viability. These sections can be seen as the best locations for the construction of wildlife passages to restore habitat connectivity. LARCH – an acronym for Landscape ecological Analysis and Rules for Configuring Habitat – is a spatially explicit expert-based GIS model that allows for analysis of the configuration and persistence of habitat networks that can lead to viable wildlife populations. LARCH uses carrying capacity thresholds to determine whether or not these habitat networks can support viable populations. The impact of roads and railroads that form partial, or absolute, barriers to animal movements is included. The model is best used in comparative studies, as is the case here where comparisons are made between the viability levels in situations with and without de-fragmentation measures in the road and railroad networks.

The LARCH study identified sites where de-fragmentation measures may lead to a shift in population viability from non-viable (i.e. population with an extinction probability of >5% in 100 years) to either viable (i.e. population with an extinction probability of 1-5% in 100 years) or highly viable (i.e. population with an extinction probability of <1% in 100 years), and where population viability shifts from viable to highly viable, solely due constructing wildlife crossing structures. Such shifts in population viability can be achieved in different ways, i.e. by restoring habitat connectivity across different roads. In those cases the spot was chosen where habitat connectivity is highest, i.e. the locations with the highest expected exchange rate of animals between habitat patches. No bottleneck locations were identified if >95% of the populations of an indicator species in the current fragmented situation could already be categorized as highly viable. Although in these cases mitigation measures may further improve population viability, it was considered that there is no urgent need for such measures for these species. For a full description of the LARCH-methods used in the present study we refer to Van der Grift & Pouwels (2006).

Step 2: Expert Opinion
Independent of the modeling approach, experts for all indicator species were asked to identify bottleneck locations in the road and railroad network in Bulgaria. The identified spots include locations where animals are known to be killed by traffic, those where animals are known to cross the road, where physical road features inhibit road crossings, where wildlife is often seen in the vicinity of the road and where roads cross pristine areas or areas with high animal densities.

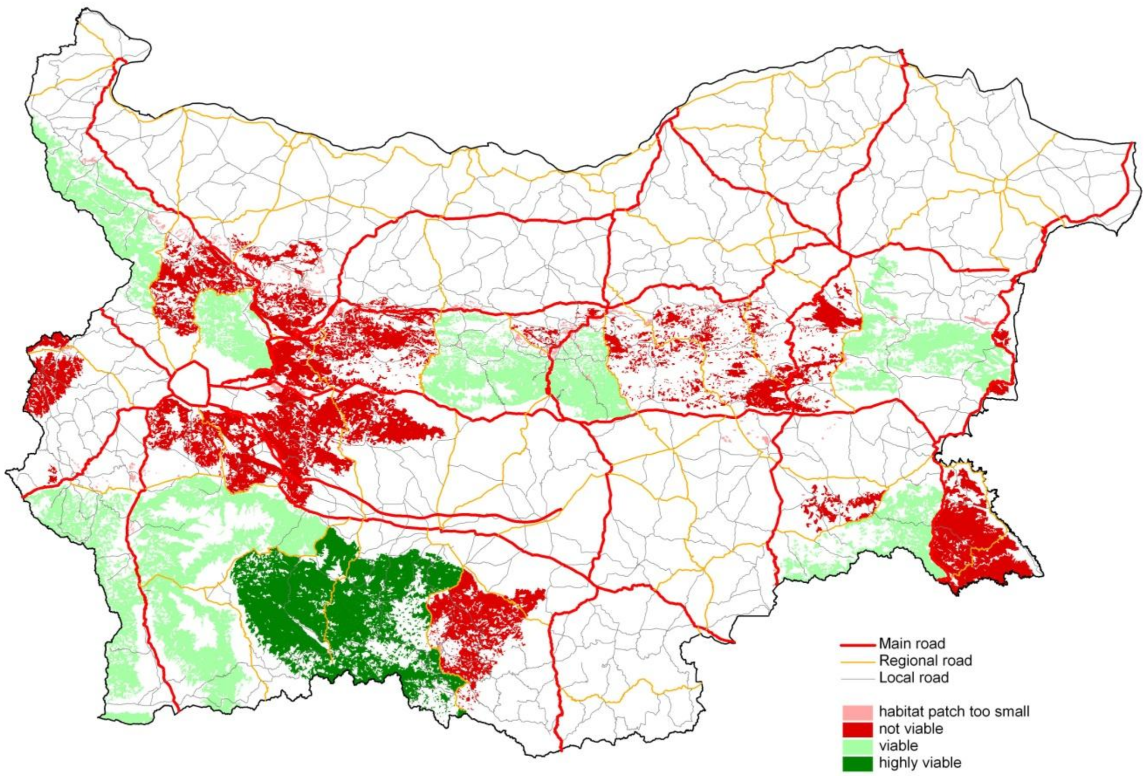
= Forest
= Woodland shrub
= Steppe grassland
= Wetland-River-Pond

Habitat area requirement (km^2)	Dispersal capacity (km)						
	<1	1-3	3-7	7-15	15-25	25-35	>35
0-0.1	Tortoises *Testudo hermanii* and *T. graeca*	Common toad *Bufo bufo*					
	Souslik *Spermophilus citellus*	Aesculapian snake *Zamenis longissimus*					
		Blotched snake *Elaphe sauromates*					
0.1-1			Marbled polecat *Vormela peregusna*				
1-5				Wildcat *Felis silvestris*			
5-10					Pine marten *Martes martes*		
10-50					Otter *Lutra lutra*		Brown bear *Ursus arctos*
>50						Red deer *Cervus elaphus*	Wolf *Canis lupus*

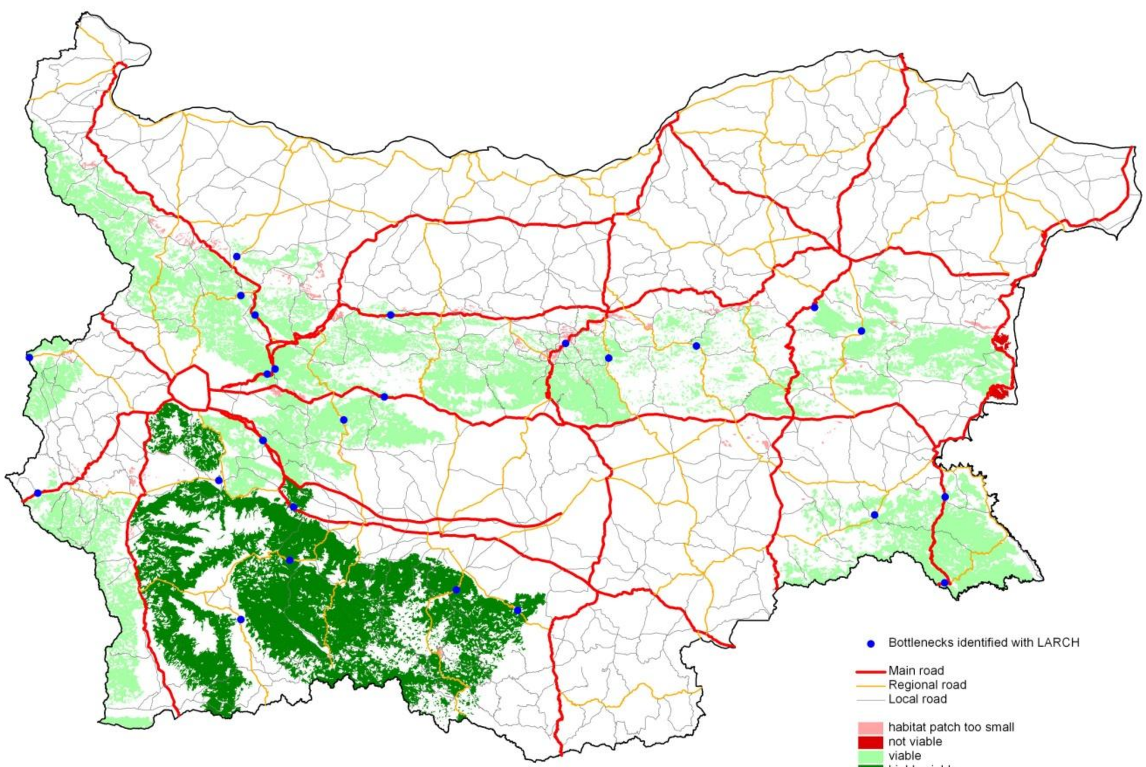
Table 1. Selected indicator species varying in home range size and dispersal capacity, representing a range of ecosystems.

Step 3: Integration
In the third step bottleneck locations identified by the LARCH model and the experts were mapped and analyzed for potential overlap. All of the unique individual bottleneck locations were then evaluated for the potential impact of de-fragmentation measures on the population viability of the indicator species.

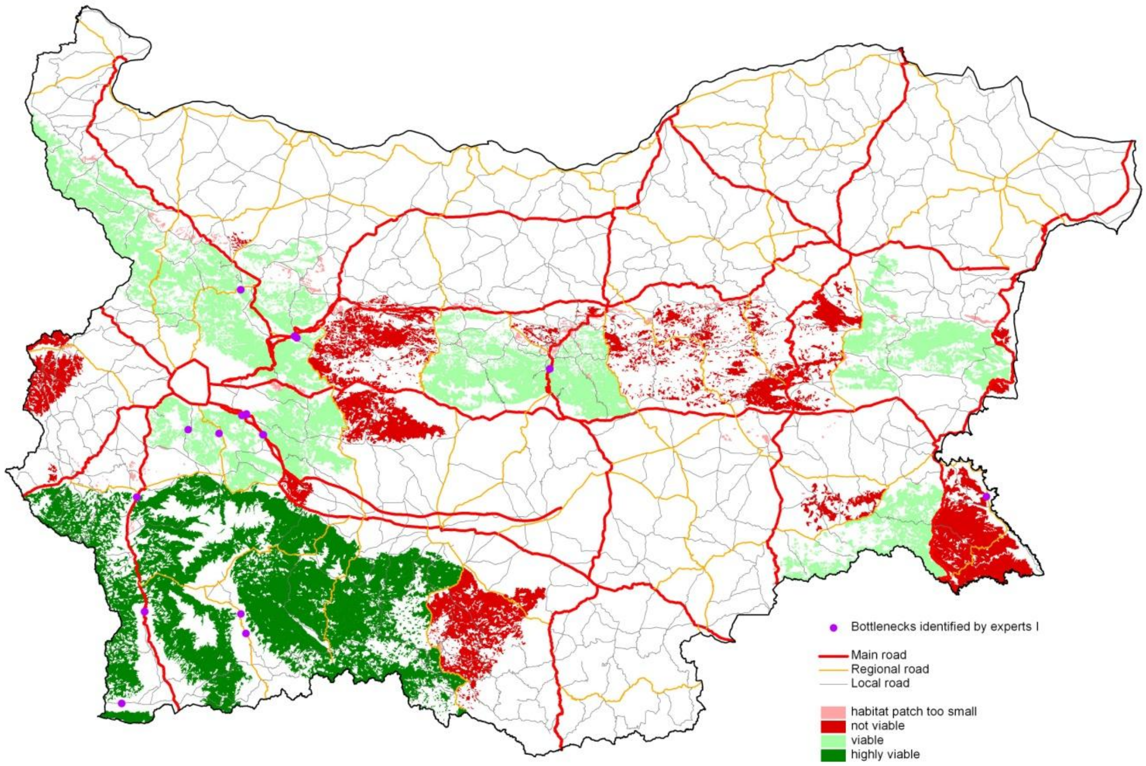
Step 4: Optimization
The LARCH model initially identifies bottleneck locations where mitigation measures are likely to have an immediate effect on population viability. In a second analysis it identifies situations where population viability will change immediately as a result of implementing road mitigation measures if identified bottleneck locations in the first analysis are all mitigated. For most species this two-step approach is sufficient to identify the most important bottleneck locations and improve population viability in most parts of their habitat. However, further improvements may be revealed through a third or fourth ('optimization') analysis, in which mitigation of all previously identified bottleneck locations is assumed. In this study optimization analysis was achieved by a second expert evaluation, in which additional locations for de-fragmentation were identified only if, based on the viability estimations of all initially identified LARCH and expert bottleneck locations together, further significant improvements in population viability could be reached.



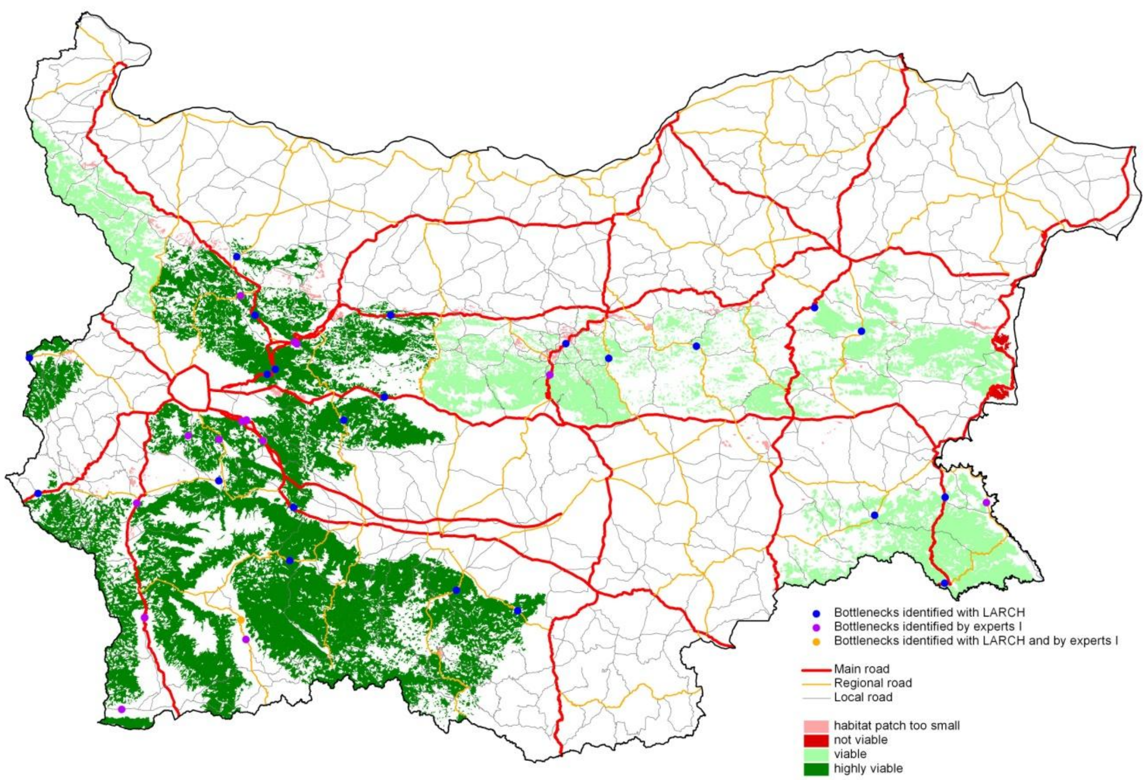
Before: The "before" situation: population viability of pine marten in Bulgaria in the current situation without de-fragmentation measures in the road and railroad network.



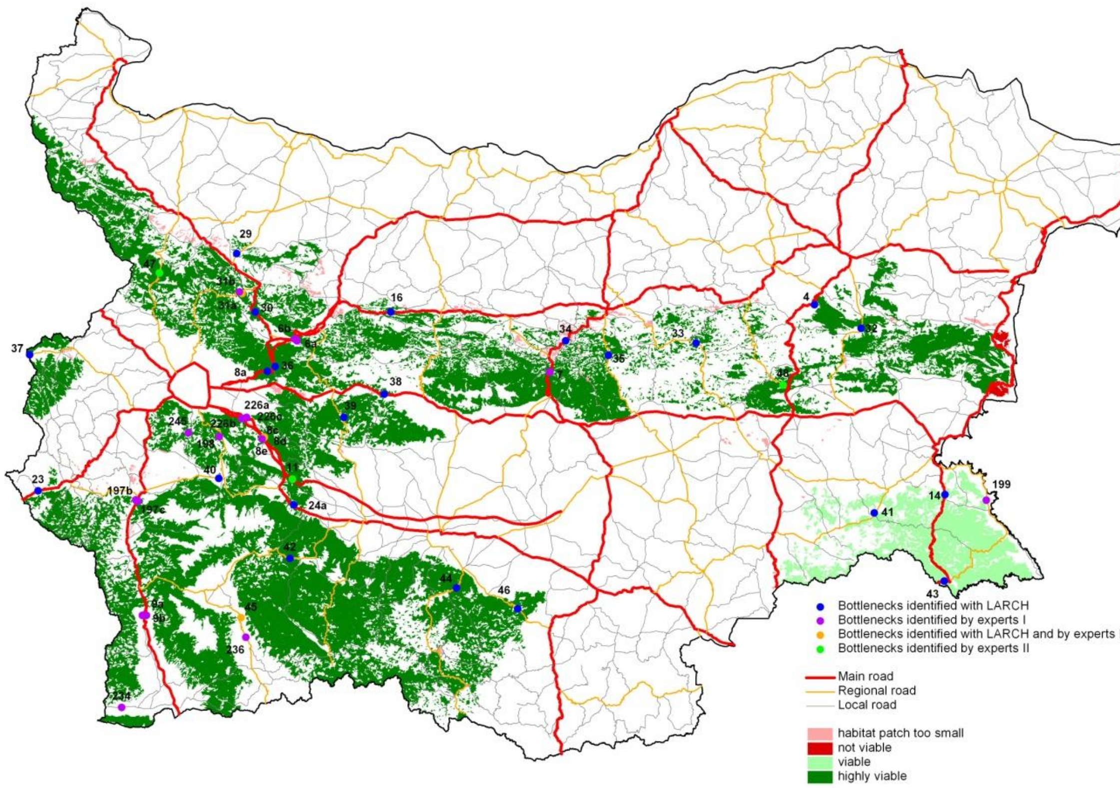
Step 1: Bottleneck locations identified with the LARCH model for the pine marten and the population viability of the species when de-fragmentation measures will be taken at these locations.



Step 2: Bottleneck locations identified by species experts for the pine marten and population viability of the species when de-fragmentation measures will be taken at these locations.



Step 3: Integration of bottleneck locations identified with the LARCH model and by species experts for the pine marten and population viability of the species when de-fragmentation measures will be taken at all these locations.



Step 4: Identification of additional spots for de-fragmentation where measures will improve the viability of the population significantly (light green spots) and population viability of the pine marten when de-fragmentation measures will be taken at all identified locations.

Figure 1. The four steps to identify bottleneck locations in the Bulgarian road and railroad network illustrated for pine marten.

Setting Priorities

The study identifies a large number of bottleneck locations and this raises the question of where to begin? What bottleneck locations should most urgently be addressed? Which locations might be addressed later? In this study we distinguished *low*, *medium* and *high* priority locations. These definitions are based upon (1) the ecological benefit classes given by the LARCH model, (2) the urgency classes given by the species experts, and (3) the amount of sustainable habitat for a species in the present situation (see also Table 2).

LARCH categorized each identified bottleneck location into one of five ecological benefit classes (see also Van der Grift & Pouwels 2006). Classes 1, 2 and 3 refer to bottleneck locations with *immediate* shifts in population viability due to de-fragmentation measures in relatively large, medium-sized and small populations, respectively. Classes 4 and 5 refer to bottleneck locations with *secondary* shifts in population viability due to de-fragmentation measures, i.e. shifts that only occur when de-fragmentation measures are initially taken elsewhere. Class 4 refers to secondary shifts of viable into highly viable populations. Class 5 refers to secondary shifts of non-viable into viable or highly viable populations. The species experts categorized each identified bottleneck location into one of two classes of urgency: *highly urgent* and *less urgent*. The need for de-fragmentation measures is less when, under the present situation most habitat is estimated to support already highly viable populations. In setting priorities we differentiate between species that currently have more or less than 75% of their habitat supporting highly viable populations, since we expect that for species with >75% of their habitat supporting highly viable populations, sufficient measures can be planned at a later stage if conditions deteriorate due to road impacts.

If a bottleneck location was identified for just one of the indicator species, the location was given the priority class as was assessed for that particular species. If a bottleneck location was identified for more than one indicator species, the location was given the highest assessed priority class in this group of species.

= High priority
= Medium priority
= Low priority

		LARCH ecological benefit class					
		Class 1 Viability shift in large population	Class 2 Viability shift in medium-sized population	Class3 Viability shift in small population	Class 4 Shift from viable to highly viable	Class 5 Shift from non-viable to viable or highly viable	None[2]
		Immediate benefit			Secondary benefit		
Species for which, at present, <75% of the habitat supports highly viable populations *Brown bear, Wolf, Wildcat, Pine marten, Otter*							
Expert urgency class	High urgency						(c)
	Low urgency						(c)
	None[1]	(a)	(a)	(a)	(a)	(a)	(b)
Species for which, at present, ≥75% of the habitat supports highly viable populations *Red deer, Souslik, Aesculapian snake, Blotched snake, Tortoises, Common toad*							
Expert urgency class	High urgency						(c)
	Low urgency						(c)
	None[1]	(a)	(a)	(a)	(a)	(a)	(b)

1 Bottleneck locations only identified with the LARCH model (a) or identified during the optimization step (b).
2 Bottleneck locations only identified by species experts (c) or identified during the optimization step (b).

Table 2. Set of rules used to identify *low*, *medium* and *high* priority locations for road and railroad mitigation.

Quick-scan of Needed Mitigation Measures

For each identified bottleneck location we explored what measures will be needed to solve the problems of barrier effect and road-kill for wildlife. To do so each bottleneck location was visited and the best set of measures was determined. Choices for measures were primarily based on the preferences of the indicator species for different types of measures, the characteristics of the road/railroad and traffic, the presence of existing crossing structures, such as bridges or culverts, and the configuration of wildlife habitat around the identified problem section. This approach can be best described as a "quick-scan"; hence the mitigations suggested here should be seen as not more than a first proposal for a more detailed de-fragmentation program.

Results

Bottleneck Locations

In total 283 bottleneck locations were identified in the existing road and railroad network of Bulgaria (Figure 2). These bottlenecks were almost equally divided between main roads and regional roads; 130 and 125 respectively. Far fewer bottlenecks were identified on local roads and railroads: 10 and 18 respectively. Although mapped as single spots on the map, each bottleneck location indicates a section of road or railroad that forms a barrier between wildlife populations of one or more indicator species on either side of the transport corridor. Hence the dots on the map do not represent the exact location where wildlife crossing structures should be established, but are merely the starting point for identifying the most appropriate locations for de-fragmentation measures.

At some bottleneck locations de-fragmentation measures will only have the desired effect on population viability if other spots are addressed simultaneously. For example, this may be the case when two roads/railroads have to be crossed to restore the desired connectivity between wildlife populations. If both are considered as barriers for one or more of the indicator species, mitigation measures at just one of them would not be very effective. A positive shift in viability can then only be obtained if wildlife-crossing structures are established at both barriers. In such cases we speak of "associated bottlenecks". In most cases a group of associated bottlenecks consists of just two locations that are close together on parallel roads or railroads. However, in six cases a group of associated bottlenecks contains more than two locations. In these associated bottlenecks each bottleneck has been given the same number, but each with a different extension (-a, -b, -c, etc). In total 24 groups of associated bottlenecks were identified.

A little more than half of all identified bottlenecks relate to two or more indicator species (Figure 3). A few locations have been identified as bottlenecks for 10 species. At locations identified as bottlenecks for several species the construction of multi-species wildlife passages, such as wildlife overpasses, can be very effective as a high number of indicator species will benefit from the measure, as well as all those species for which the indicator species are indicative. These locations are also the most likely places where a combination of different types of mitigation measures should be applied, as different species inhabit different habitats along the road section and different mitigation measures will be appropriate for each species.

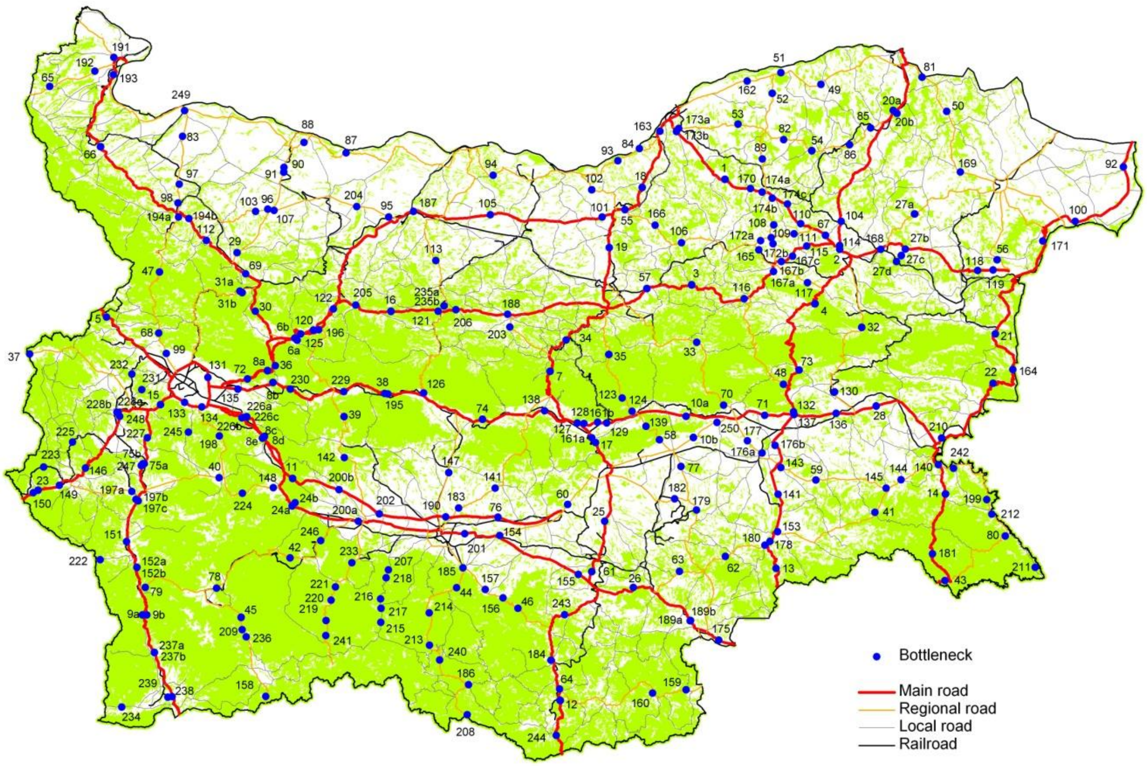


Figure 2. Identified bottleneck locations in the Bulgarian road and railroad network.

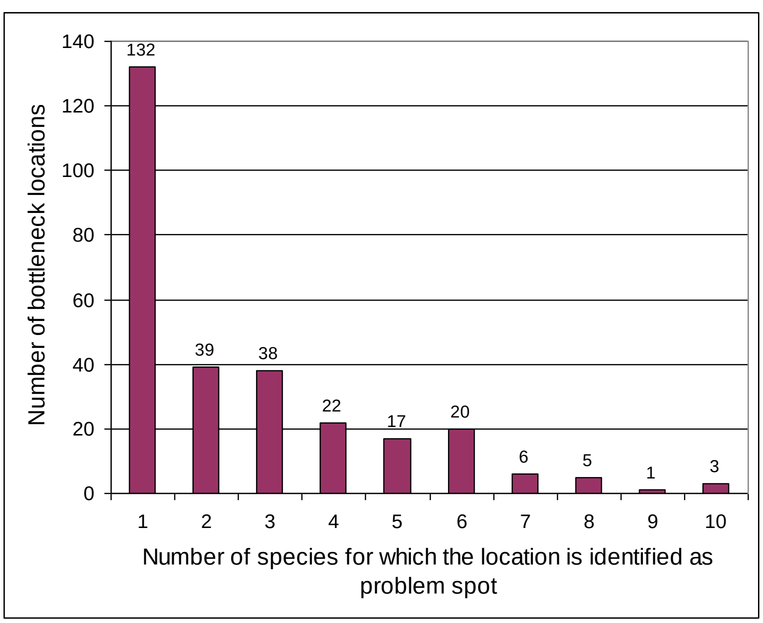


Figure 3. Distribution of the identified bottleneck locations in the Bulgarian road and railroad network over the number of indicator species for which a location is identified as problem spot.

Priorities

The identification of a total of 283 bottlenecks leads to an assessment of the locations where mitigation measures are most urgently needed. Figure 4 shows the priority class for each identified bottleneck, based on the expected increase in the viability of populations and expected decrease in wildlife mortality due to collisions in traffic after mitigation. About 30% of all bottlenecks are classified as *high priority* locations (Figure 5). Immediate action is recommended at these locations as these have been identified as locations where the barrier effect of the road or railroad is high and/or wildlife is frequently killed in traffic.

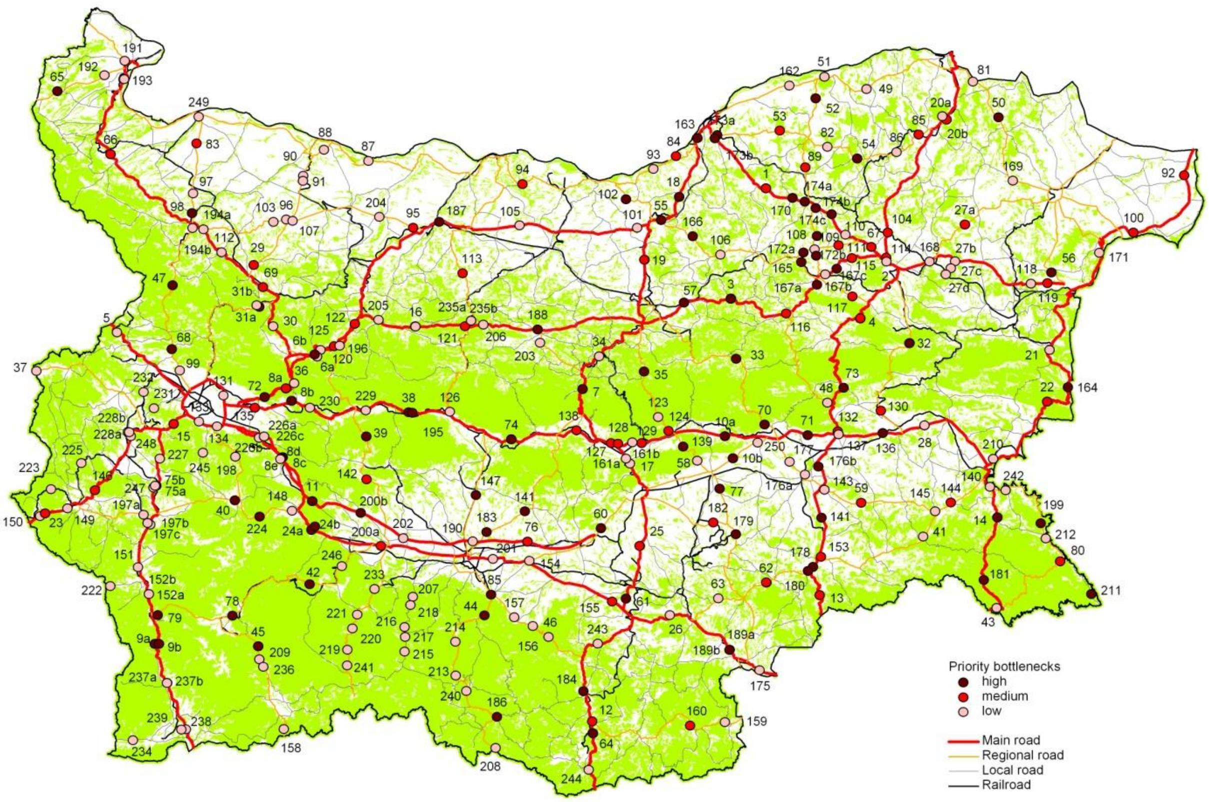


Figure 4. Priority class for each of the identified bottleneck location.

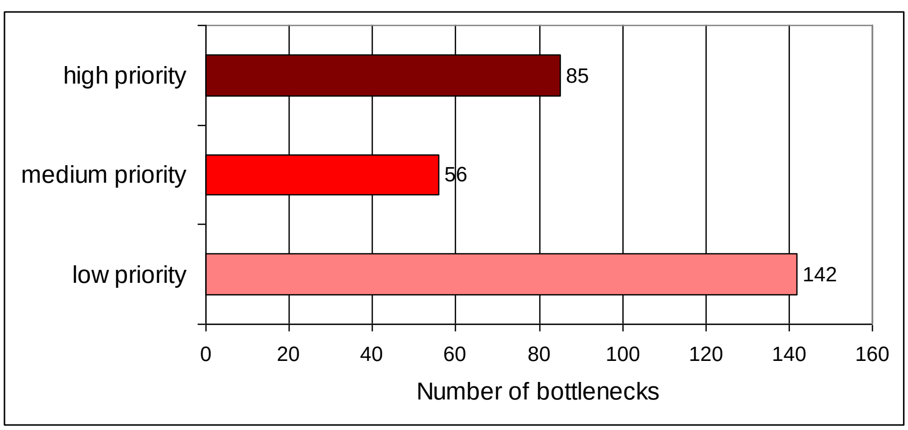


Figure 5. Distribution of bottleneck locations over priority classes. High priority = mitigation measures should be taken before 2015; Medium priority = mitigation measures should be taken before 2020; Low priority = mitigation measures should be taken before 2025.

Improvement Population Viability Indicator Species

For brown bear 67 bottlenecks have been identified in the current road and railroad network in Bulgaria. Of these, 3 were identified by the LARCH model, 56 by species experts and 8 by both the model and the species experts. At present about 40% of all populations can be categorized as *highly viable*. De-fragmentation measures at the identified bottleneck locations are expected to shift almost all *not viable* and *viable* populations towards *highly viable* populations. Most bottleneck locations for brown bears are found in the central and southwestern parts of Bulgaria. De-fragmentation initiatives for brown bear are of the highest importance at bottleneck locations in the Struma River valley, on the roads and railroads between the Central Balkan and the Rila mountain ranges, and on the roads between Vitosha and Rila. Furthermore, significant shifts in population viability can be reached through road mitigation at transport corridors between the Western and Eastern Rhodopes, on the main road between the eastern and western parts of the Central Balkan range and on main roads that crosses the Central Balkan, just east of Sofia. At most other locations de-fragmentation measures would primarily reduce road-kills of brown bear and strengthen habitat connectivity within their current distribution area.

For wolf 80 bottlenecks have been identified in the current road and railroad network in Bulgaria. Of these, 8 were identified by the LARCH model, 63 by species experts, and 7 by both the model and species experts. Two bottleneck locations were added to restore habitat connectivity between the Eastern Rhodopes and Strandja. In the current situation about 25% of all populations can be categorized as *highly viable*. As a result of de-fragmentation measures at the identified bottleneck locations all *not viable* and *viable* populations are expected to shift towards *highly viable* populations. Most bottleneck locations for wolf are found in the central and southwestern parts of Bulgaria. De-fragmentation initiatives for wolf are of highest importance at bottleneck locations in the Struma River valley, on the roads and railroads between the Central Balkan and the Rila mountain ranges, on the roads between Vitosha and Rila, and between the Eastern Rhodopes and the southeastern parts of the country. Furthermore, significant shifts in population viability can be reached through road mitigation along transport corridors between the Western and Eastern Rhodopes, on the main road between the eastern and western parts of the Central Balkan range and on main roads in the northeast of the country. At most other locations de-fragmentation measures would primarily reduce road-kills of wolf and strengthen habitat connectivity within their current distribution area.

For red deer 71 bottlenecks have been identified in the current road and railroad network in Bulgaria. Of these, 8 were identified by the LARCH model, 60 were identified by species experts and 3 by both the model and by species experts. Currently more than 75% of all populations can be categorized as *highly viable*. De-fragmentation measures at the identified bottleneck locations would lead almost all *not viable* and *viable* populations to shift towards *highly viable* populations. Most bottleneck locations for red deer are found in the western parts of Bulgaria. There are some bottleneck locations in the eastern part of the country, although far fewer. De-fragmentation initiatives for red deer are of highest importance at bottleneck locations in the Struma River valley, on the roads and railroads between the Central Balkan and the Rila mountain range, on the roads between Vitosha and Rila, and on the roads in the mainly agricultural landscape with scattered forests in northern Bulgaria. At most other locations de-fragmentation measures would primarily reduce road-kills of red deer and strengthen habitat connectivity within their current distribution area. Since more than 75% of all red deer populations are already highly viable no bottlenecks were categorized as *high priority*.

For wildcat 52 bottlenecks have been identified in the current road and railroad network in Bulgaria. Of these, 14 were identified by the LARCH model, 25 were identified by species experts, and 6 by both model and species experts. Seven bottleneck locations were added to restore habitat connectivity between the Central Balkan and Rila mountain ranges, within Strandja and between scattered wildcat habitat patches in northeastern Bulgaria. Presently no populations can be categorized as *highly viable*. De-fragmentation measures at the identified bottleneck locations are expected to shift almost all the *not viable* and *viable* populations towards *highly viable* populations. Most bottleneck locations for wildcat are found in the western parts of Bulgaria, with far fewer bottleneck locations in the eastern part of the country. De-fragmentation initiatives for wildcat are of highest importance at bottleneck locations in the Struma River valley, on the roads and railroads between the Central Balkan and the Rila mountain ranges, on the road between the eastern and western parts of the Central Balkan range, and on the coastal road along the Black Sea in Strandja. At most other locations de-fragmentation measures would primarily reduce road-kills of wildcat and strengthen habitat connectivity within their current distribution area.

For pine marten 46 bottlenecks have been identified in the current road and railroad network in Bulgaria. Of these, 25 were identified by the LARCH model, 14 were identified by species experts, and 4 by both model and species experts. Three bottleneck locations were added to restore habitat connectivity between the pine marten habitats in the most western parts of the Central Balkan range, between the most eastern parts of the Central Balkan range and the pine marten habitats along the Black Sea coast, and between the Central Balkan Range and the Rila mountains. In the current situation less than 25% of all populations can be categorized as *highly viable*. De-fragmentation measures at the identified bottleneck locations are expected to shift most *not viable* and *viable* populations towards *highly viable* populations. Most bottleneck locations for pine marten are found in the central and western parts of Bulgaria and in Strandja. De-fragmentation initiatives for pine marten are of highest importance at bottleneck locations in the Struma River valley, on the roads and railroads between the Central Balkan and the Rila mountain range, on the roads between Vitosha and Rila, on the roads between Rila/Pirin and the Western Rhodopes, and on the coastal and inland roads in Strandja. At most other locations de-fragmentation measures would primarily reduce road-kills of pine marten and strengthen habitat connectivity within their current distribution area.

For otter 110 bottlenecks have been identified in the current road and railroad network in Bulgaria. Of these, 75 were identified by the LARCH model, 21 were identified by species experts, and 10 by both model and species experts. Four bottleneck locations were added to restore habitat connectivity in river tributaries in northeastern Bulgaria. In the current situation about 25% of all populations can be categorized as *highly viable*. De-fragmentation measures at the identified bottleneck locations are expected to shift all *not viable* and *viable* populations towards *highly viable* populations. Bottleneck locations for otter are found in all parts of Bulgaria as, in all regions, important river habitats are frequently crossed by roads and railroads. De-fragmentation initiatives for otter are of highest importance at bottleneck locations in the Struma and Maritza River valleys, on the roads between the Western and Eastern Rhodopes, in Strandja, along the Black Sea coast and around Shoumen in the northeast. At most other locations de-fragmentation measures would primarily reduce road-kills of otter and strengthen habitat connectivity within their current distribution area.

For marbled polecat 61 bottlenecks have been identified in the current road and railroad network in Bulgaria. Of these, 34 were identified by the LARCH model, 19 were identified by species experts and 6 by both model and species experts. Two bottleneck locations were added to restore habitat connectivity in the region north of Shoumen. At present about 65% of all populations can be categorized as *highly viable*. De-fragmentation measures at the identified bottleneck locations are expected to shift most *not viable* and *viable* populations towards *highly viable* populations. Bottleneck locations for marbled polecat are found in all parts of the country with the exception of the high mountain regions and the Danube lowlands around Pleven. De-fragmentation initiatives for marbled polecat are of highest importance at almost half of all bottleneck locations, including bottlenecks in the Struma River valley, around the Pirin mountains, in the foothills of the Central Balkan mountain range, in Strandja and in the grassland areas of the northeast. At most other locations de-fragmentation measures would primarily reduce road-kills of marbled polecat and strengthen habitat connectivity within their current distribution area.

For souslik 125 bottlenecks have been identified in the current road and railroad network in Bulgaria. Of these, 109 were identified by the LARCH model, 11 were identified by species experts, and 5 by both model and species experts. In the current situation over 80% of all populations can be categorized as *highly viable*. De-fragmentation measures at the identified bottleneck locations are expected to lead to only a slight increase in *highly viable* populations. Bottleneck locations for souslik are found in all parts of the country with the exception of the high mountain regions. De-fragmentation initiatives for souslik are of considerable importance at almost half of all these bottleneck locations, including bottlenecks in the Struma River valley, in the foothills of the Central Balkan mountain range, in Strandja and in the grassland areas around Shoumen. Because more than 75% of all souslik populations are already *highly viable* in the current situation no bottlenecks were categorized as *high priority*.

For aesculapian snake 22 bottlenecks have been identified in the current road and railroad network in Bulgaria. All of these were identified by the species experts. Currently more than 95% of all populations can be categorized as *highly viable*. De-fragmentation measures at the identified bottleneck locations will not do much to change population viability, but road-kill of these snakes is expected to reduce significantly. Most bottleneck locations for aesculapian snake are found in the southeastern parts of Bulgaria. De-fragmentation initiatives for aesculapian snake are of considerable importance at bottleneck locations in the Struma River valley, in Eastern Rhodopes, in Strandja and along the central Black Sea coast. Because more than 75% of all aesculapian snake populations are already *highly viable* in the current situation no bottlenecks were categorized as *high priority*.

For blotched snake 39 bottlenecks have been identified in the current road and railroad network in Bulgaria. Of these, 22 were identified by the LARCH model, 14 were identified by species experts, and 3 by both model and species experts. In the current situation almost 80% of all populations can be categorized as *highly viable*. De-fragmentation measures at the identified bottleneck locations are expected to shift most *not viable* and *viable* populations towards *highly viable* populations. Most bottleneck locations for blotched snake are found in the eastern parts of Bulgaria. De-fragmentation initiatives for blotched snake are of considerable importance at about one-third of all bottleneck locations, including those in Eastern Rhodopes, Strandja, along the Black Sea coast and in the region north of Shoumen. Because more than 75% of all blotched snake populations are already *highly viable* no bottlenecks were categorized as *high priority*.

For Hermann's tortoise and spur-thighed tortoise 29 bottlenecks have been identified in the current road and railroad network in Bulgaria. All of these were identified by the species experts. At present more than 90% of all populations can already be categorized as *highly viable*. De-fragmentation measures at the identified bottleneck locations will not do much to change population viability but is expected to significantly reduce road-kills of tortoises. Most bottleneck locations for tortoises are found in the southwestern and southeastern parts of Bulgaria. De-fragmentation initiatives for tortoises are of considerable importance at bottleneck locations in the Struma River valley and along the Black Sea coast. Because more than 75% of all tortoise populations are already *highly viable* no bottlenecks were categorized as *high priority*.

For common toad 29 bottlenecks have been identified in the current road and railroad network in Bulgaria. All of these were identified by the species experts. Currently more than 95% of all populations can already be categorized as *highly viable*. De-fragmentation measures at the identified bottleneck locations are not expected to do much to change population viability, but can be expected to significantly reduce road-kills of common toads. Most bottleneck locations for common toads are found in the Struma River valley, in Eastern Rhodopes and along the Black Sea coast in Strandja. Because more than 75% of all common toad populations are already *highly viable* no bottlenecks were categorized as *high priority*.

Figure 6 shows the expected shift in population viability of each indicator species due to proposed road and railroad mitigation. Population viability in the bar 'maximum' refers to the viability of the populations in the hypothetical case of no roads or railroads existing, i.e. if the barrier effect of all roads and railroads is completely removed and where the population viability is solely dependant on the size, quality and configuration of the habitat network. This 'maximum' estimation can be seen as the maximum possible population viability achievable solely through de-fragmentation measures in the road and railroad networks. Further improvements of population viability, if any, can only be reached through measures other than road mitigation, such as habitat enlargement, improvements or establishing ecological corridors between habitat patches.

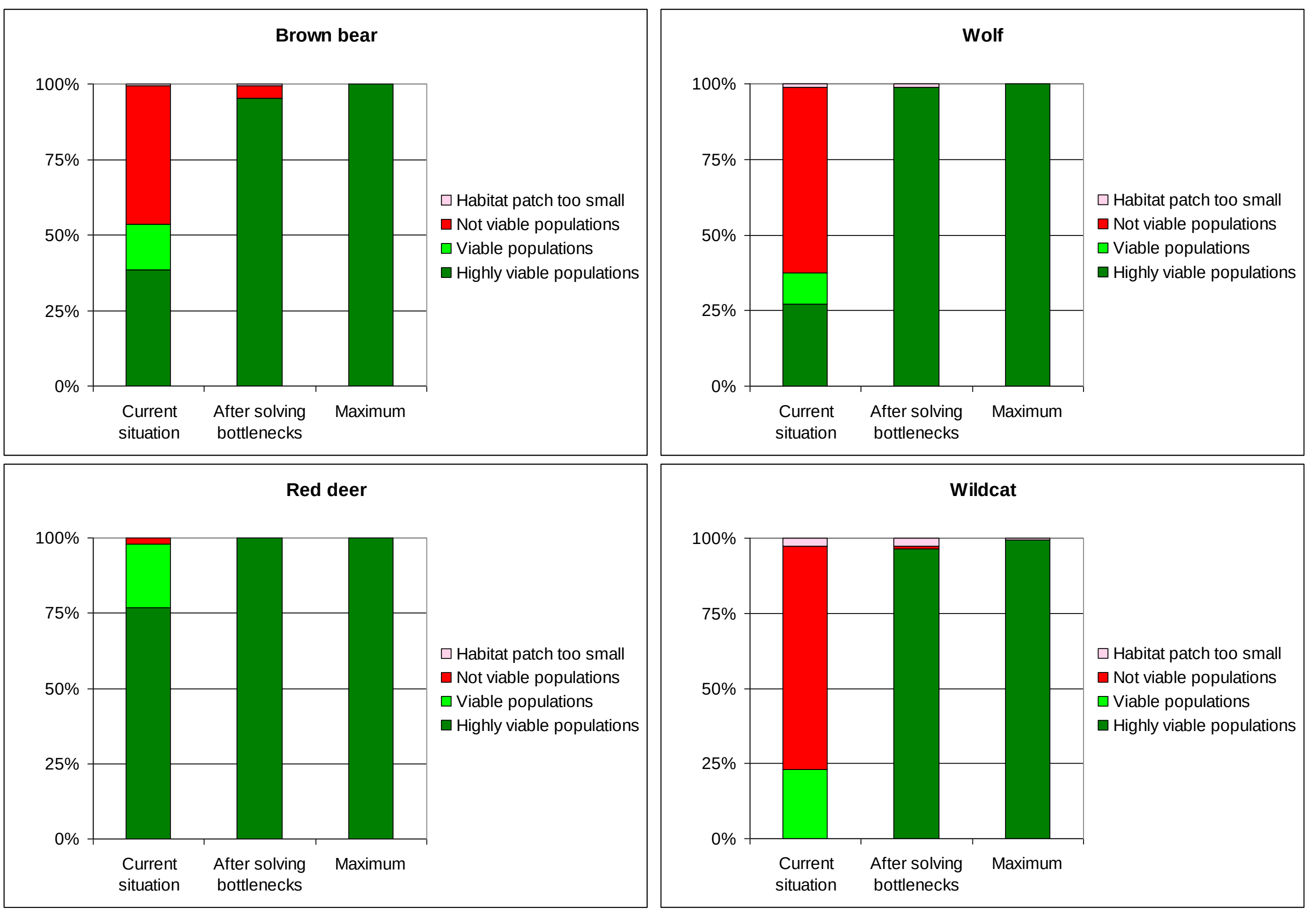
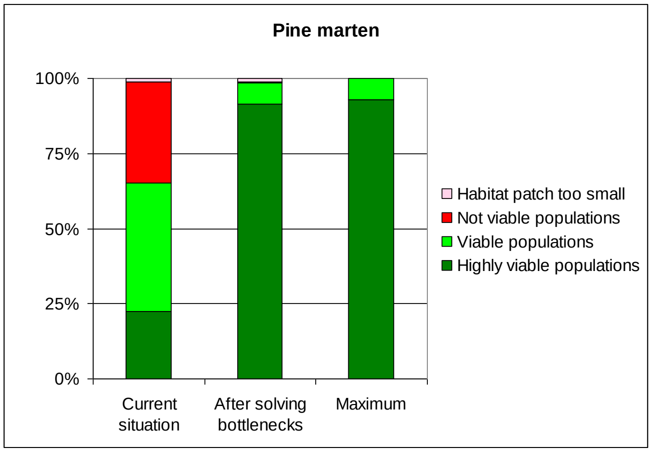
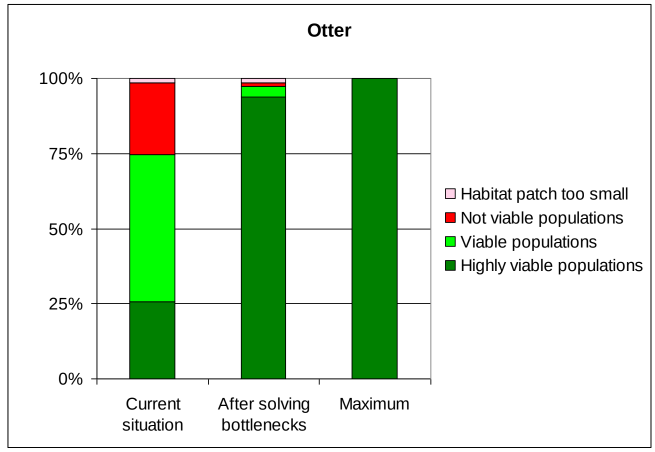
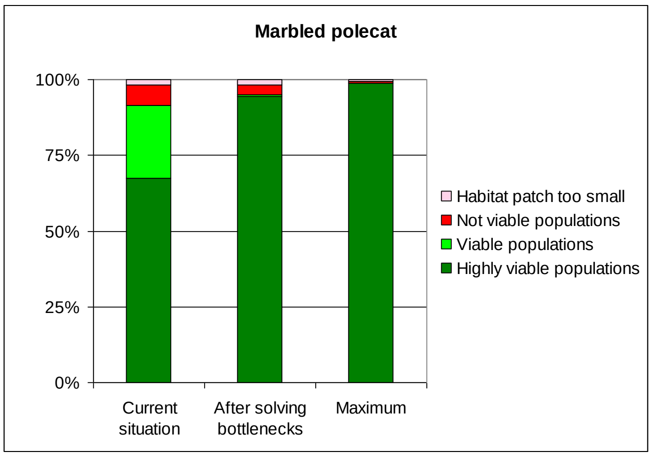
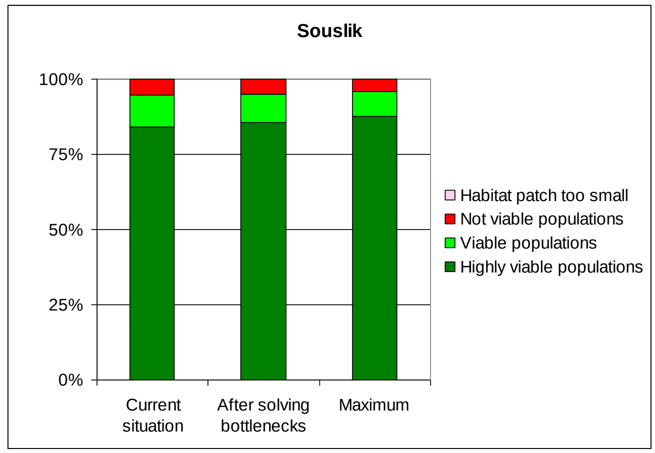


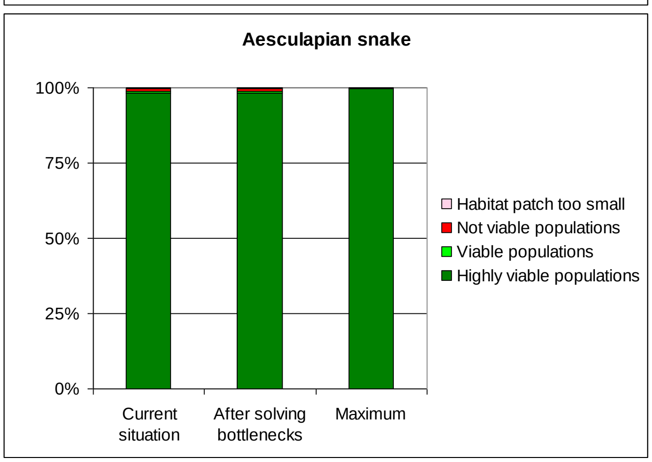
Figure 6. Shift in population viability of each indicator species due to proposed road and railroad mitigation.
(Figure continued on next page.)

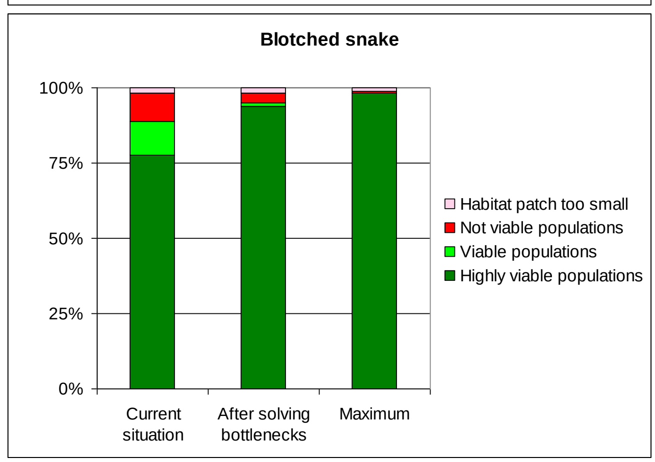

Pine marten
100%
75%
50%
25%
0%
Current situation
After solving bottlenecks
Maximum
Habitat patch too small
Not viable populations
Viable populations
Highly viable populations

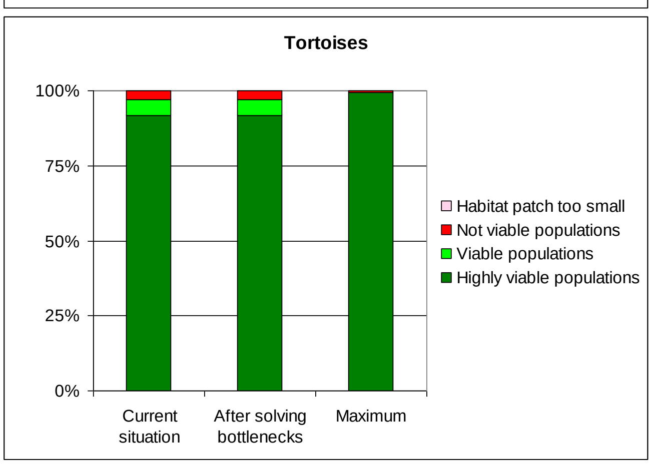

Otter
100%
75%
50%
25%
0%
Current situation
After solving bottlenecks
Maximum
Habitat patch too small
Not viable populations
Viable populations
Highly viable populations

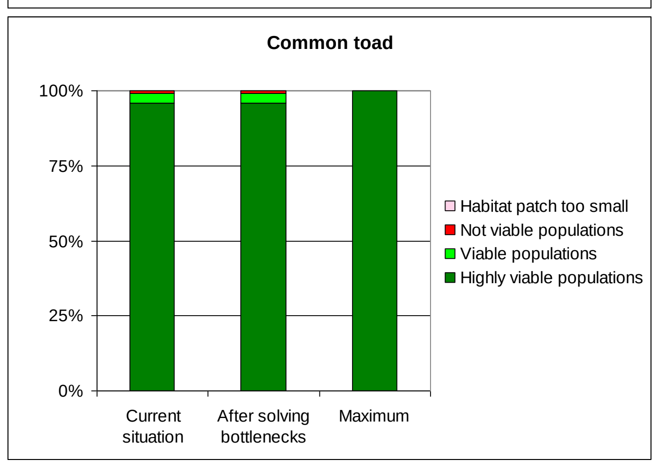

Marbled polecat
100%
75%
50%
25%
0%
Current situation
After solving bottlenecks
Maximum
Habitat patch too small
Not viable populations
Viable populations
Highly viable populations


Souslik
100%
75%
50%
25%
0%
Current situation
After solving bottlenecks
Maximum
Habitat patch too small
Not viable populations
Viable populations
Highly viable populations


Aesculapian snake
100%
75%
50%
25%
0%
Current situation
After solving bottlenecks
Maximum
Habitat patch too small
Not viable populations
Viable populations
Highly viable populations


Blotched snake
100%
75%
50%
25%
0%
Current situation
After solving bottlenecks
Maximum
Habitat patch too small
Not viable populations
Viable populations
Highly viable populations


Tortoises
100%
75%
50%
25%
0%
Current situation
After solving bottlenecks
Maximum
Habitat patch too small
Not viable populations
Viable populations
Highly viable populations


Common toad
100%
75%
50%
25%
0%
Current situation
After solving bottlenecks
Maximum
Habitat patch too small
Not viable populations
Viable populations
Highly viable populations

Mitigation Measures

In total 544 mitigation measures were identified as necessary to restore habitat connectivity and reduce wildlife mortality at all bottleneck locations. This number exceeds the number of bottleneck locations, as at 30% of all bottleneck locations more than one measure is needed to solve the problems. A significant number (331) of these proposed mitigation measures involve adapting existing structures, such as road tunnels, viaducts or bridges, to allow for better use of these structures by wildlife. In addition the construction of 213 wildlife passages is needed, which will be exclusively for the use by wildlife (Figure 7). The construction costs of all proposed de-fragmentation measures are estimated at 132 million Euros (Van der Grift et al. 2008). If the recommended timetable for implementing the plan is used – all measures taken before 2025 – the average yearly costs will be less than 10 million Euros. These costs do not include the costs for planning and designing the measures, nor do they include the costs for purchasing land if any additional (non-governmental) land is needed to allow for proper habitat development and management in “buffer-zones” around the entrances of the wildlife passages.

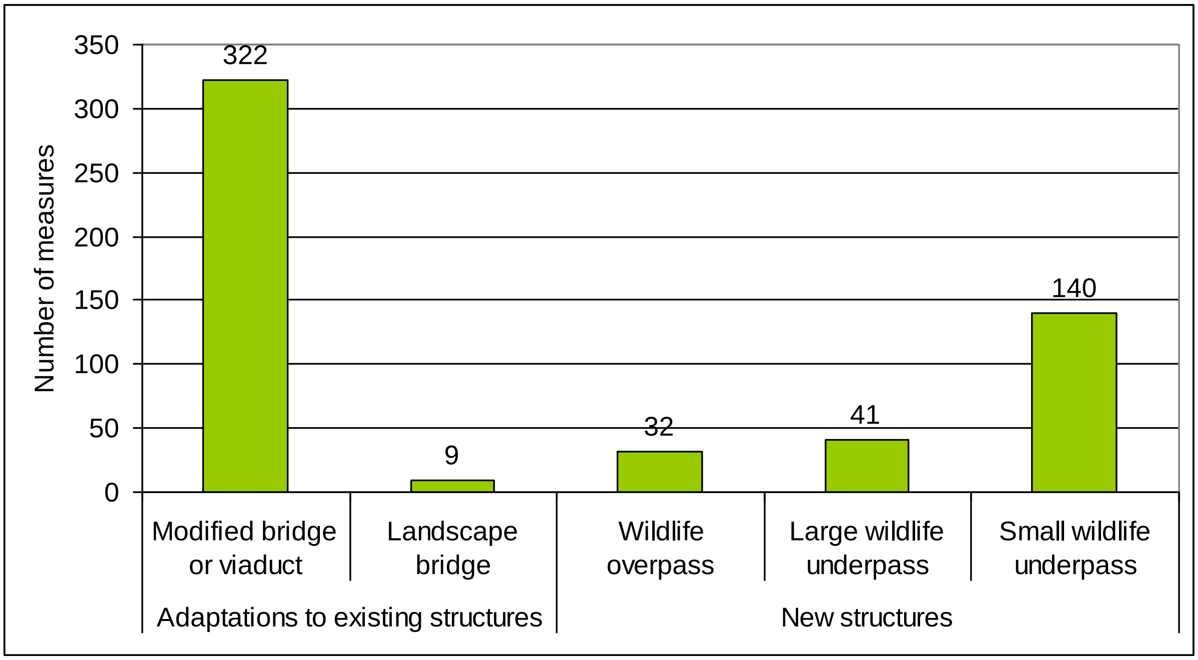


Figure 7. Number of proposed mitigation measures for each type of measure.

Next Steps

The implementation of the here proposed road and railroad mitigation is expected to significantly improve the population viability of most threatened wildlife species and, as such, is an indispensable first step in preserving Bulgaria’s biodiversity and developing a coherent and sustainable ecological network across the country. In 2008 an interdepartmental agreement between all governmental authorities involved in road development, spatial planning and biodiversity conservation was signed in order to express their support and commitment for the development and implementation of a national policy plan for habitat defragmentation across transportation corridors in Bulgaria. A few actions are recommended to create functional ecological corridors in Bulgaria, solve current bottlenecks in the road and railroad network and prevent future fragmentation of nature areas by transport infrastructure: (1) Appoint a taskforce for the De-fragmentation of Transportation Corridors in Bulgaria, with representatives from all relevant ministries, stakeholders, NGOs and scientists. The taskforce initiates the compilation of a national de-fragmentation program and its implementation. (2) Appoint a national coordinator for de-fragmentation measures in the road and railroad network, responsible for coordinating all actions carried out by the taskforce and communication with the general public. (3) Work out a national de-fragmentation program with political approval and secure the required budget. (4) Compile a handbook that provides guidelines for the planning, design and construction of effective wildlife passages. This should draw on experiences and best practice elsewhere in Europe. (5) Set up an implementation plan in which the planning and procedure for each de-fragmentation location is worked out. Gear the implementation plan to the planning of road construction/upgrading projects. Choose a regional planning approach in order to coordinate measures at adjacent infrastructural barriers. (6) Choose one or two pilot projects to work out an efficient way to plan and construct de-fragmentation measures, to allow Bulgarian experts to gain knowledge and experience, and to raise awareness among the general public over the issue of habitat fragmentation and the need to restore ecological networks. (7) Incorporate the maintenance of established de-fragmentation measures in current road management procedures and arrange for proper nature management of surrounding areas in compliance with the preferred conditions for an effective wildlife corridor. (8) Set up a monitoring program to evaluate whether de-fragmentation measures function properly and whether conservation objectives are achieved.

Biographical Sketches

Edgar van der Grift works as a senior research scientist at Alterra, Wageningen University and Research Institute, Wageningen, The Netherlands. His work focuses on the assessment of the impacts of habitat fragmentation on wildlife populations and the effectiveness of measures that aim to reduce such fragmentation and increase habitat connectivity, e.g. the establishment of landscape linkages, ecological corridors and wildlife crossing structures at roads and railroads. Besides his scientific research he acts as a consultant for policy makers, road planners and conservation groups during the preparation and implementation phase of projects that aim for the establishment of effective ecological networks and road mitigation measures.

Valko Biserkov is director of the Central Laboratory of General Ecology of the Bulgarian Academy of Sciences in Sofia, Bulgaria. He studied the distribution and ecology of amphibians and reptiles in the Balkan. His current work focuses on the development of ecological network such as the establishment of a NATURA2000 network in Bulgaria. Furthermore he is involved in the planning of defragmentation measures at existing and new motorways across Bulgaria.

Vanya Simeonova is a research scientist at Alterra, Wageningen University and Research Institute, Wageningen, The Netherlands. She works on environmental policy integration in urban and suburban areas as well as regional development studies in Eastern European countries. Furthermore she is involved in studies on the implementation of ecological networks and the optimization of planning processes for such networks.

Marcel Huijser received his M.S. in population ecology and his Ph.D. in road ecology at Wageningen University in Wageningen, The Netherlands. He studied plant-herbivore interactions in wetlands for the Dutch Ministry of Transport, Public Works and Water Management, hedgehog traffic victims and mitigation strategies in an anthropogenic landscape for the Dutch Society for the Study and Conservation of Mammals, and multifunctional land use issues on agricultural lands for the Research Institute for Animal Husbandry at Wageningen University and Research Center. Currently he works on wildlife-transportation issues for the Western Transportation Institute at Montana State University. He is a member of the Transportation Research Board (TRB) Committee on Ecology and Transportation and co-chairs the TRB Subcommittee on Animal-Vehicle Collisions.

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DEVELOPMENT AND UTILIZATION OF A REGIONAL INVASIVE PLANT SPECIES DATABASE AT THE NEW YORK STATE DEPARTMENT OF TRANSPORTATION

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Abstract

In a 2003 ICOET abstract submission, the New York State Department of Transportation (NYSDOT or the Department) outlined a Ten-Point Invasive Species Management Plan. Two of the ten components detailed in the plan included; the field and Geographic Information System (GIS) mapping of existing invasive species populations and, the integration of invasive species identification and analysis as a part of the Department's normal National Environmental Policy Act (NEPA) and State Environmental Quality Act (SEQRA) processing of capital improvement projects (CIPs) (Falge, et al, 2003). In the years following the submission of the 2003 ICOET paper, the Department has actively engaged environmental staff in the acquisition of spatial data on invasive species within Department owned right-of-ways (ROWs).

This paper will discuss the development and utilization of a region-wide invasive species database. It will also explore the methods the Department has used to include geographic data on invasive species into CIPs.

Invasive species data collection has been incorporated into the Department's Asset Management initiative. Initial planning for the development of an invasive species database included intra and inter agency coordination, a literature review to determine best management practices and coordination with Operations personnel to determine how to increase the database's functionality and usefulness. A prioritized list of corridors for targeted data collection was developed and data collection began in the summer of 2006. The collected data is archived on a regional server and embedded into an ArcMap document called the "environmental viewer". The Department's environmental staff uses the environmental viewer to make environmental assessments during project scoping.

In 2008, the acquisition of invasive species spatial data was expanded to include data for capital improvement projects (CIPs). CIPs are reviewed for asset management data collection opportunities at all stages of project development. Invasive species data collected for a CIP fall into two categories; pre-construction data and post-construction data. Pre-construction data are used to by design engineers to provide quantities for cost estimates or to highlight locations on the plans the contractor should avoid during construction. Post-construction data are used by the environmental staff to measure the success of invasive species control efforts.

Invasive species data is collected using a Trimble® GeoXT™ 2005 unit. Databases developed before 2008 were created using ArcPad 7.0/7.1. Currently, the Region uses TerraSync™ software on the Trimble® GeoXT™ unit and Trimble® GPS Pathfinder® Office for data post processing. Exported shapefiles are converted to CADD format and incorporated into Microstation® design files.

The development and use of geospatial data on invasive species in capital project planning and design has been beneficial. It has increased the accuracy of quantity take-offs for invasive species control item numbers in capital projects, provided the environmental staff with a tool to track the spread of invasive species after a construction project, increased the Department's compliance with NEPA and SEQRA regulations and helped Department's Operations staff ensure that their activities do not advance the spread of targeted invasive species.

The region will continue to collect GPS data on invasive species. This data is integral to the planning and design of capital projects and maintenance activities. The regional environmental staff continue to look for ways to expand the utility of the database.

Introduction

In a 2003 ICOET abstract submission, the New York State Department of Transportation (the Department) outlined a Ten-Point Invasive Species Management Plan. Two of the ten components detailed in the plan included; the field and Geographic Information System (GIS) mapping of existing invasive species populations and, the integration of invasive species identification and analysis as a part of the Department's normal National Environmental Policy Act (NEPA) and State Environmental Quality Act (SEQRA) processing of capital improvement projects (CIPs) (Falge, Ambuske and Frantz 2003). In the years following the submission of the 2003 ICOET paper, the Department has actively engaged environmental staff in the acquisition of spatial data on invasive species within Department owned right-of-ways (ROWs).

This paper will discuss the development and utilization of a region-wide invasive species database. It will also explore the methods the Department has used to include geographic data on invasive species into CIPs.

The discussion will begin with a cursory overview of invasive species including a summary of the federal legislation that mandates their consideration on federally funded projects. This will be followed with a review of the current NYSDOT policies and procedures on invasive species as well as guidance on inventory and management. Finally, the paper will detail the current program for invasive species management in NYSDOT's Region 5. Program elements include the inventory of invasive species on priority corridors and capital projects and the development of an invasive species database for use in project programming, planning, design, construction and maintenance. The paper will end with a discussion on the long term implications for invasive species control.

Invasive Species

The problem of invasive species is well documented. Invasive species have been reported to cause extensive economic and ecological damage. Invasive species include insect pests, pathogens, animals, plants and other organisms (United States Department of Agriculture 2009).

In 1999, then President William J. Clinton issued Executive Order (E.O.) 13112. E.O. 13112 mandates that federal agencies whose actions have the potential to impact an invasive specie must:

> *"identify actions…detect and respond rapidly to control…monitor invasive species populations…restore native species and habitat…conduct research on invasive species…not authorize, fund or carry out actions that…cause or promote the spread of invasive species* (Clinton 1999)*."*

The Federal Highway Administration (FHWA) clarified E.O. 13112 in an August 10, 1999 document, *Guidance on Invasive Species* by stating that federal funding could not be "used for construction, revegetation, or landscaping activities that purposely include the use of known invasive plant species (Federal Highway Administration 1999)." In addition, the same document noted that "Consideration of invasive species should occur during all phases of the environmental process to fulfill the requirements of (the) National Environmental Protection Act (NEPA) (Federal Highway Administration 1999)."

In Region 5 of the NYSDOT, the federal share of the capital program is significant (Greater Buffalo-Niagara Regional Transportation Council 2007). As a result, most transportation infrastructure projects in the region are required to consider invasive species during project planning, design, construction and subsequent maintenance.

Invasive Species at the New York State Department of Transportation

The New York State Department of Transportation (NYSDOT or the Department) responded to E.O. 13112 by issuing a series of policy and guidance documents. Examples include Environmental Manuals, Handbooks, Programs, Special Specifications, Engineering Instructions and Engineering Bulletins.

In a recent training presentation, staff at the Department's Office of the Environment identified seven (7) documents issued by the NYSDOT that discussed the handling of invasive plant species on Department owned land. Examples include the Environmental Handbook for Operations, the Green and Blue Highway Program, the GreenLITES Certification program, the Department's Landscape Stewardship Policy and the Integrated Vegetation Management update (Dunleavy and Kappeller, Invasive Species - An Overview of NYSDOT Involvement and Guidance 2009). These documents support the policies described in the Environmental Procedures Manual (EPM) by providing examples of policy implementation.

The following text summarizes the Department's invasive species policy guidance found in the Environmental Procedures Manual (EPM).

NYSDOT Invasive Species Policy – The Environmental Procedures Manual

Chapter 4-8 *"Invasive Species"* of the Environmental Procedures Manual (EPM) is the Department's policy on invasive species. The document contains the NYSDOT's standards and procedures for handling invasive plant species on Department owned land. A sampling of the guidance found in the document includes:

- a definition of invasive species,
- a discussion of E.O. 13112, its relation to the National Environmental Policy Act (NEPA) and their relevance to Department actions,

- a discussion of an invasive species inventory as a method for complying with E.O. 13112 and the requirements under NEPA,
- a discussion of control measures (equipment cleaning, use of invasive-free mulches, topsoil and seed, establishment of native species and control or eradication strategies) that could be undertaken by the Department to ensure compliance with E.O. 13112 and NEPA,
- a procedure for the Department's environmental staff to follow. This procedure included seven (7) guiding principles such as:
    - Education and Outreach,
    - Inventory,
    - Early Detection and Rapid Response,
    - Prevention,
    - Control,
    - Monitoring and
    - Research.

  The procedure also included six (6) steps to ensure that the Department's staff were "incorporating the appropriate preventative measures and control practices into project documents and activities (New York State Department of Transportation 2004)." These steps were actions to be taken during the various stages of project development and system operations and maintenance.
- the identification of four "priority invasive species", including Purple Loosestrife, Common Reed, Japanese Knotweed and Giant Hogweed. The guidance left room for additional species to be added as, "determined through accepted National and State lists with consideration of Regional priorities (New York State Department of Transportation 2004)."

NYSDOT Invasive Species Inventory Methods

Chapter 4.8.4 – Invasive Species Inventory Methods, provides instructions for establishing and maintaining a regional database of invasive species. Regional environmental staff are required to maintain an "electronic database of ALL priority invasive plant locations identified in association with Capital project development and delivery (New York State Department of Transportation 2004)." In addition, the document recommends that each region "initiate and manage an inventory of priority invasive plant species for the highway system in their jurisdictional area (New York State Department of Transportation 2004)." When deciding which highways to inventory, the regions are advised to prioritize and begin with the Interstate, Expressway and Parkway systems, since these components of the transportation infrastructure are "the primary introduction and dispersal conduits for invasive plant species (New York State Department of Transportation 2004).

Suggested inventory methods include the submission of a NYSDOT *Inventory Data Collection Form*, the collection of global positioning systems (GPS) data using a pre-programmed GPS data dictionary and "other inventory examples" (New York State Department of Transportation 2004).

Invasive species data collection forms are provided in the EPM at the end of chapter 4.8.4. In addition to the forms, the guidance requires environmental staff to note the invasive specie stand's reference marker locations. The information gathered using data forms and reference markers is manually entered into a geographic information system (GIS) database (New York State Department of Transportation 2004).

Alternatively, the manual recommends the use of GPS units to catalogue the location of invasive plant species within a project's construction limits or within the highway right-of-way on a targeted corridor. Two methods are proposed for collecting GPS data. The first directs environmental field staff to collect point data in the middle of an invasive specie stand. A second GPS method uses point, line and polygon features to collect data. The shapefile data collected using either method would be populated with attribute fields using a pre-defined invasive species data dictionary.

Other methods reported in the EPM include the *Adirondack Park Invasive Plant Program* (APIPP) Methodology and The Nature Conservancy's (TNC) *Weed Information Management System* (WIMS). Chapter 4.8.4 contains links to the Adirondack Park Invasive Plant Program's (APIPP) website. The Adirondack Park Invasive Plant Program database was reported in the 2006 National Cooperative Highway Research Program Synthesis 363 document, Invasive Species and was the subject of a 2003 Abstract submission to the International Conference on Ecology and Transportation (Falge, Ambuske and Frantz 2003). The APIPP invasive plant program included an extensive electronic inventory as well as the tracking and evaluation of invasive species control measures in the Adirondack Park (Venner 2006).

Regardless of the method chosen, the EPM envisions the development of a regional invasive species database which would serve as a screening tool for regional staff to use during all phases of project development. In addition, Operations staff would be able review invasive plant species mapping on targeted corridors and make better decisions regarding maintenance activities that have the potential to impact established stands of priority invasive plant species. Finally, a statewide invasive plant species database would assist department staff in the tracking and monitoring of invasive species control measures (New York State Department of Transportation 2004).

The Framework for Data Collection – Asset Management

Region 5 of the NYSDOT has incorporated invasive species data collection into the Department's Asset Management initiative.

The FHWA (1999) defines Asset Management as:

> "*Asset management is a systematic process of maintaining, upgrading, and operating physical assets cost-effectively. It combines engineering principles with sound business practices and economic theory, and it provides tools to facilitate a more organized, logical approach to decision-making. Thus, asset management provides a framework for handling both short- and long-range planning* (Federal Highway Administration 1999)."

When invasive species are viewed as environmental assets it places the issue within the program development process (Shufon and Adams 2003, Cambridge Systematics, Inc. 2004). This is consistent with the NYSDOT policy to incorporate consideration of invasive species in all phases of project development (New York State Department of Transportation 2004). In addition, the FHWA notes that "incorporating environmental considerations into each phase of transportation planning and project development" is widely considered to be a "best practice" (Cambridge Systematics, Inc. 2004).

The New York State Department of Transportation's (NYSDOT) policy on Asset Management has been described in *Conceptual Framework for Defining and Developing an Asset Management System.* The stated purpose of the NYSODT's asset management system is to "enable the Department to make more informed and better decisions on investing limited resources for the repair and maintenance of the transportation system (Shufon and Adams 2003)." Shufon (2003) has defined the NYSDOT's approach to asset management using four basic precepts:

- asset inventories,
- condition and performance assessment
- program development (vertical and horizontal), and
- program implementation (Shufon and Adams 2003).

The document goes on to list several "major goal assets" and "other NYSDOT assets"; the list does not include invasive species or any other environmental asset. So, does invasive species data fit within the NYSDOT's asset management program?

It could be reasoned that the control of invasive species is not critical to the functioning of the transportation infrastructure and does not adequately meet the criteria of a manageable asset. Asset management systems are used to inform the program development process by prioritizing degrading assets, with the most severely degraded assets receiving primary consideration (vertical). Competition for a spot on the capital program occurs between differing asset classes (horizontal). The Shufon and Adams (2003) paper furthers this concept by reasoning through a cost/benefit analysis aimed at enhancing decision-making. Again, how does invasive species data fit within this system?

Certainly, a roadside environment that is plagued with terrestrial invasive plant species constitutes a degraded asset. But a degraded roadside ecology will not stop a commuter from traveling safely from point A to point B. Moreover, under this scenario is the asset being managed the roadside ecology or the invasive species? Trying to quantify the costs and benefits of improving an ecosystem (if the ecosystem can be "improved") is tricky at best.

E.O. 13112 effectively tied federal funding for transportation infrastructure improvements, (through the NEPA process), to the control and management of invasive species within a project boundary, and the control and management of invasive species can be an extremely costly endeavor. When invasive species are found within a project's boundaries, consideration of these costs must be included in the total assessment of the project's asset upgrade.

> "*Quality data for decision-making includes reliable information about the relative costs of implementing alternative environmental strategies. Cost is a critical matrix for transportation agencies in electing to implement specific environmental activities. An accurate analysis of cost needs to consider the direct costs or savings related to specific alternatives, as well as the indirect*

financial impact to a project or an overall program that can result from project delays and revisions (Cambridge Systematics, Inc. 2004)."

The intent of any transportation asset management system is to provide decision makers with the appropriate tools they need to make decisions regarding the maintenance and development of a transportation system. According to Shufon and Adams (2003), "the goal at NYSDOT is to develop an asset management system that better quantifies tradeoffs among asset classes and thus leads to a more integrated program of transportation projects." Moreover, the FHWA (2004) has noted that transportation dollars are allocated for a variety of reasons including environmental stewardship. Decision making processes are hampered by ineffective, inefficient or incongruous data management systems. Grouping environmental assets with more traditional transportation assets ensures equivocal consideration of environmental issues, and allows decision makers to view layers of information within the same analytical framework. And when the database includes the cost of managing invasive species, the data's value increases significantly.

Work Plan for Developing an Invasive Species Database

In June 2006, the NYSDOT's Region 5 Landscape Architecture Environmental Unit (LA-ES Unit) dedicated one staff member to the collection of environmental asset data. The work began with the development of an asset management work plan for four target assets. Included among these assets was invasive plant species. Strategies for developing the asset management plan followed the guidance offered in the February 2006 NYSDOT internal policy document, *A Plan for the Comprehensive and Integrated Approach to Asset Management at the NYSDOT*. The desired end product was a database that described each asset according to a predefined, asset specific set of characteristics. The end product would then be incorporated into a geographic information system (GIS) map that would facilitate decision-making for Department managers.

The work plan outlined a specific step-by-step plan of action for each targeted asset. The plan components included a comprehensive listing of resources required to complete data collection for each asset and a list of potential constraints to data collection. The work plans were intentionally preliminary; each plan provided opportunities for expansion, clarification and the incorporation of unforeseen tasks. In addition, the work plan provided both short- and long-term goals for data acquisition. Finally, the process was designed to be iterative. After data collection for one component was completed, the "product" would be made available to end users for their comment and input. Adjustments to any aspect of the data would be made as requested by end users.

The objective for the invasive plant species asset management program was to locate and map all targeted invasive plant species within Department owned right-of-way (ROW) in Region 5. This objective was consistent with the guidance outlined in chapter 4.8 of the Department's EPM (New York State Department of Transportation 2004)."

Work Plan Strategies

To achieve the objectives outline the EPM and the workplan, the following strategies were identified:

Strategy #1: Conduct a review of the existing literature on data collection efforts for invasive species.

This review was conducted both within Region 5, within the entire Department, and to agencies outside the NYSDOT at the state, federal and local level.

- Communication within Region 5 was extended to other function units and service groups. Examples included the Information Technology (IT) Group (for GIS and GPS support), Operations and Planning and Program Management (PPM) (for Asset Management).
- Communication within the Department was extended to other regional LA-ES units and the Environmental Science Bureau (ESB) at the Main Office (formerly known as the Environmental Analysis Bureau (EAB)). The intent was to review other data collection efforts, and to analyze other's methodologies for possible adoption.
- It was suggested that communication outside the Department be established with "sister" agencies at the state, federal and local level. The idea was to establish a database sharing program. A list of potential partnering agencies included local universities (SUNY at Buffalo), New York State Department of Environmental Conservation (NYSDEC), New York State Office of Parks, Recreation and Historic Preservation (NYSOPRHP), United States (and New York State) Department of Agriculture (USDA for Agriculture and Markets, Natural Resource Conservation Service and the Cooperative State Research, Education and Extension Service), United States Army Corps of Engineers (USACE), the City of Buffalo and Erie County. The literature review included guidance documentation from several of these agencies (and a few more). Finally, Non-Government Organizations (NGOs) were also tapped as an information resource and potential data partner.

Strategy #2: Conduct a review of existing data collection alternatives.

Although the Region did own two (2) Trimble GeoXT (2003 version) units, field collection using global positioning system (GPS) technology was not assumed to be the preferred method of data collection. Other methods of data collection considered included:

- Aerial photograpy.
- NYSDOT Photolog. According to the NYSDOT website, the photolog is a series of images taken along all state roadways. These images were taken at 52.8 foot intervals and are presented sequentially. The images show the condition of the roadway and roadside at a particular point in time. Roads are catalogued in both directions (New York State Department of Transportation 1999-2008).
- Windshield surveys using mile markers. This was one of the methods recommended in Chapter 4.8.4 of the EPM (New York State Department of Transportation 2004).
- Field data collection using a measuring device and mile markers to locate species. This is another method that was recommended in the EPM.
- Field data collection using a GPS unit. As discussed previously, the Region owned two (2) units at the time, and data collection had already been an on-going effort. In addition, this method was supported in the EPM.
- Infrared technology. This technique was reported in the literature. However, the resources required to utilize this technology is currently not available to the NYSDOT (or Region 5) and this precluded the use of this technique.

Strategy #3: Develop a data dictionary for attribute information in the invasive, terrestrial plant species database.

The attribute information offered through the Main Office consisted of the NYSDOT's *Inventory Data Collection Form* and a sample data dictionary found in chapter 4.8.4 of the EPM (New York State Department of Transportation 2004). In addition, Region 5 had already developed its own data dictionary as part of an earlier inventory exercise. The two dictionaries were reviewed by all involved functional units to determine if additional data fields (attributes) were warranted.

Strategy #4: Develop a list of priority corridors and locations for the inventory of invasive terrestrial plant species.

This action step was also recommended in the EPM (New York State Department of Transportation 2004). This action was subdivided into two major components.

- Prioritize corridors. The objective is to have a hierarchical list of corridors to determine a sequencing of data collection. Communication was established with key personnel from the LA-ES Unit, Operations, and the Main Office Environmental Science Bureau (ESB). The list would address short- and long-term data acquisition goals.
- Prioritize locations. The objective is to have a hierarchical list of site locations that require data collection for invasive plant species. To achieve this, the following steps were taken:
    - *Step 1*: A review of the capital program to identify capital projects on target corridors. Communicate was established with design staff to determine if there were invasive plant species within project boundaries.
    - *Step 2*: Coordination with other functional units or departments to develop a list of priority locations based on "other" criteria. A short list of units would include Operations, Real Estate, Structures or LA-ES.
    - *Step 3*: The development of a methodology for determining priority locations. Examples of criteria include;
        - The location is on a priority corridor.
        - The species is a priority species. The two examples are Giant Hogweed and Wild Parsnip. Hogweed infestations are typically controlled as soon as possible to avoid injury to the public and to department staff. Similarly wild parsnip was identified by our Cattaraugus Operations staff as being a pernicious plant that caused significant harm to the Department's maintenance staff. This was occurring during "weed wacking" activities.
        - The location is highly visible and therefore sensitive to the public.
        - The location is adjacent to a sensitive natural area, is within an identified Local Waterfront Redevelopment Plan (LWRP) area (consistency with Coastal Zone Management Act (CZMA) regulations), has been identified as a priority location by a "sister" agency such as the NYSDEC, NYSOPRHP or USACOE or "other" similar criteria
        - The location is in an area with poor drainage or clogged ditches that contain one or more of the target invasive plant species.

Timeframe for Developing an Invasive Species Database

The time frame for achieving the end product was labeled as "continuous and on-going". Invasive plant stands continue to grow and establish along the roadside. In addition, eradication or control efforts are becoming more common in Operations activities and in capital projects. It was reasoned that even after a corridor was "completely" surveyed, follow-up surveys would have to be conducted to maintain database accuracy. The need to establish immediate-, intermediate- and long-term goals for data acquisition emerged as a recurring theme. Once these goals were developed, a more refined schedule would then be assigned to each goal.

The immediate time frame for field data collection was recognized as seasonal with limited winter work. Winters in Buffalo, New York are harsh and often involve heavy snow cover. All four (4) of the target priority plant species identified in the EPM are herbaceous perennial plants. Perennial plants are plants that survive two or more years; herbaceous perennial plants die to the ground every winter and return in the spring from rootstock. Field identification of these plants can only occur during the spring and summer growing months. The primary season for data acquisition was identified as late spring, summer and fall; roughly early June through early November, weather permitting.

Of the four target plant species, phragmites has the longest "data collection season". The physical remains of the phragmites plants are visible along the roadside much of the year and stands can be seen from far distances. As a result, the plant is easy to spot from the roadside. In the winter months, phragmites debris can be mistaken for cattails if not observed closely; close contact with phragmites stands may not be possible with heavy snow cover.

Japanese Knotweed is also easy to identify from the roadside. The plant's trademark white blooms are distinctive even when the plant is located deep in the right-of way. Like phragmites, Japanese knotweed produces a significant amount of vegetative debris after initial dieback. However, the plant tends to reduce significantly after the second and third hard frost and is not visible under snow cover.

Giant hogweed is often confused with two closely related plants; angelica and cow parsnip. Field identification of hogweed is facilitated by their distinctive palmate leaves which are best viewed at near to close distances. Contact with giant hogweed is strongly discouraged. The plants are renown for their ability to cause significant, painful and persistent skin lesions. Giant hogweed is also an herbaceous perennial that subsides completely during its dormant period.

The most difficult plant to identify in the field is purple loosestrife. Purple loosestrife is most visible when blooming, but can be identified upon close observation during its growing season. In upstate New York, purple loosestrife blooms from July through September. The loosestrife's inflorescence, the plant's most striking feature when in bloom, persists even into the winter months. This characteristic can be used to extend the field identification season of the plant. However, not every loosestrife plant blooms every season and relying solely on the inflorescence for locating loosestrife will not give a reliable indication of the number of individuals that may be present in the field.

Implementation of the Work Plan for Developing an Invasive Species Database

The winter months in the 2006 season were dedicated completing the four (4) strategies outline above. The literature review that was conducted under the first strategy informed the subsequent three (3) strategies. The following briefly describes the products realized from the implementation of the remaining three (3) strategies outlined above.

Strategy #1

The literature review conducted provided a wealth of information regarding data collection techniques and methods for invasive plant species. As previously stated, this information was used to inform subsequent strategies outlined in the work plan.

Partnering opportunities and outreach efforts were, however, limited. Management felt that these types of activities would be best handled through the Main Office's EAB (now known as the ESB) division. In 2003 the Governors Task Force on Invasive Species called for a team of agencies to review New York State's invasive species policy. The NYSDOT is an involved agency in the Task Force. The state's Invasive Species Council (ISC) is a product of the Task Force, as are the state's Partnerships for Regional Invasive Species Management (PRISMs). A thorough discussion of this topic is outside the scope of this paper; however, recent updates provided through the Department's Office of Environment indicate that partnering is well underway with several of the agencies mentioned in the working plan through the PRISM program (Dunleavy 2009). In addition, the New York State Department of Environmental Conservation's (NYSDEC) Natural Heritage Program along with The Nature Conservance (TNC) and other state organizations have formed a "consortium to develop an online, GIS-based mapping tool called IMapInvasives (Florida Natural Areas Inventory (FSU-FNAI) n.d.)." Invasive species data collected at the Department will be shared with this consortium and displayed in their mapping service. It is anticipated that these types of partnerships will continue to be explored at the Department.

Strategy #2

After reviewing the data collection alternatives presented in the literature review, the regional management supported the use of GPS technology for field surveys. The region's Operation Unit owned two (2) Trimble® GeoXT™ (2003 version) units. These units were initially loaded with the following software:

- Windows Mobile operating system,
- ArcPad 6.1, which was switched to ArcPad 7.1 in subsequent seasons and ArcPad 8.0 in the near future,
- TerraSync™,
- Trimble® GPScorrect™ extension for ArcPad, and
- Microsoft® Active Sync.

Desktop units that would be used to for data transfer were loaded with ArcPad, Microsoft® Active Sync software and Trimble® GPS Pathfinder® Office software.

Databases developed before 2008 were created using ArcPad 7.0/7.1. Currently, the Region uses TerraSync™ software on a 2005 Trimble® GeoXT™ unit. Trimble® GPS Pathfinder® Office is used for data post processing.

Strategy #3

The literature review uncovered volumes of information on data dictionaries for invasive plant species. A complete review of all data dictionaries reviewed is outside the scope of this paper, but a few warrant mentioning. The EPM (New York State Department of Transportation 2004) refers to The Nature Conservancy's (TNC) *Weed Information Management System* (WIMS) and the mapping standards developed for the Adirondack Park Invasive Plant Program (APIPP). Another example is the North American Weed Management Association's (NAWMA), *Invasive Plant Mapping Standards*. This document promotes the development of data standards to facilitate information sharing. The standards are offered as the minimum required for adequate data sharing (North American Weed Management Association 2002).

After conferring with the region's involved functional units, it was determined that the core information in regional data dictionary was similar to the NAWMA's database (as well as others that were reviewed). In addition, many of the data fields suggested by the NAWMA seemed redundant with other state databases. For example, the NAWMA database requires data input on hydrological units and USGS quadrangles (North American Weed Management Association 2002). This information is not readily available in the field and would have to be added to the database at a desktop computer using the state's soil database (which contains information on hydrological units) and the United States Geological Survey's (USGS) Quadrangle maps. Because these files are routinely added to GIS documents, the fields were omitted from the Region's data dictionary.

The most important characteristic of an invasive plant species database is its usefulness to all end users. The regional version of the invasive plant data dictionary provided information that is useful to planners, designers and operations staff. Therefore, it was decided that the initial round of data collection would use the regional data dictionary as the field interface for database development. Table 1.0 compares the data fields in the Region 5 database to the statewide data dictionary.

In the winter of 2007, a statewide consortium of NYSDOT GPS users convened to discuss data collection along with state standards for data collection. The working group agreed that the original state database (as outlined in the EPM) should be the standard for field data collection. The decision was based on the idea of creating a NSYDOT statewide database. The task of combining regional databases is simplified when the attribute fields in the database are the same.

Region 5 switched its field data dictionary to the statewide model for the 2008 season and subsequent seasons. Nonetheless, several of the regional fields were retained, including "Proximity to Surface Water", "Adjacent Land Use" and "MileMarker". These fields are added to the database during post processing.

Statewide Data Dictionary	Region 5 Data Dictionary
n/a	Mile Marker
Plant Name	Plant Name
n/a	Extent of Spread
n/a	Extends off ROW
Date	Date
Observer Name	n/a
Contact Name	n/a
Contact Phone	n/a
Control Recommendations	Best Management Practices
n/a	Application Date
n/a	Inspection Date
n/a	County
n/a	Topography
n/a	Accessibility for Mechanical Equip.
n/a	Adjacent Land Use
n/a	Coordination with Adjacent Land Owner
Location	n/a
Habitat	n/a
Individual Condition	n/a
Abundance of Individuals	n/a
Abundance Small Area	n/a
Abundance Large Area	n/a
Abundance Length	n/a
Individual Condition	n/a
n/a	Surface water w/in 100’
n/a	Approximate Distance to Water
n/a	Surface Water Type
n/a	Approx Width of Surface Water
Samples	n/a
Photo	n/a
Comment	Comment

Table 1. Comparison of Statewide and Region 5 Data Dictionary

Strategy #4

Region 5 of the NYSDOT includes four counties in western New York; Cattaraugus, Chautauqua, Erie and Niagara. The region’s western and northern boundary constitutes the shoreline for two of the country’s five great lakes. Lake Erie lies to west of both Erie and Chautauqua County. Lake Ontario is to the north of Niagara County. The NYSDOT Region 5 website reports 3675 miles of state highways. The regional roadway system includes four (4)Interstates, four (4) Expressways, two (2) Parkways, and numerous state highways and arterials (New York State Department of Transportation 1999-2008).

In June of 2006, an email was circulated to environmental staff in the Design, Operations, Planning and Construction Units. This email requested managerial input for the development of a prioritized list of corridors for invasive plant species data collection. The process for developing the list relied on the combined knowledge of several senior staff members who knew the problem roadways and were familiar with the guidance from the EPM. The following is a list of prioritized target corridors.

Rank	Roadway	Name	Type	Comments
1	NY Rte. 33	Kensington	Expressway	Only portions of the Kensington Epwy. were included in the survey list. NY Rte 33 extends from downtown Buffalo to the Erie/Genesee County Line. The surveyed portion extends from downtown to the Buffalo International Airport.
2	NY Rte. 400	Aurora Expressway	Expressway	The 400 extends between the NYS Thruway on its northern end to NY 16 in Aurora, NY. The northern half of the roadway is characteristically urban; the southern half is more rural.
3	I-290	Youngman Memorial Highway	Interstate	Located in Northern Erie County, the 290 connects the I-190 to Niagara Falls with the NYS Thruway. The roadway is predominately urban.
4	I-990	Lockport Expressway	Interstate	Located in Northern Erie County, the I-990 connects the I-290 to Millersport Highway and Transit Road.
5	Route 5	Seaway Trail Fuhrmann Boulevard Main Street	State Highway	NY Route 5 passes through Chautauqua and Erie Counties. It extends from the Pennsylvania border to the Genesee County line.
6	NY Rte. 219	Southern Expressway	Expressway	The Southern Expressway is located in S. Erie County. It connects Buffalo (at the NYS Thruway) with Springville, NY (at NY Rte. 39).
7	NY Rte. 198	Scajaquada		The Scajaquada runs through the City of Buffalo's northern neighborhoods. It connects the I-190 to NY Rte. 33.
8	I-190	Niagara Expressway	Interstate	The I-190 becomes a state roadway just before it crosses the Niagara River and enters into Grand Island. The roadway starts in northern Erie County and ends at the Lewiston-Queenston International Bridge.
9	957A	Robert Moses Parkway	Parkway	The Robert Moses Parkway is in Niagara County. It extends from the Grand Island Bridges to Niagara Falls State Park, then follows the Niagara River up to Lake Ontario, where it ends at NY Rte. 18.
10	957C	West River Parkway	Parkway	The West River Parkway is in northern Erie County on Grand Island. The parkway runs along the island's western shore.
11	I-86	Southern Tier Expressway	Interstate	The Southern Tier Expressway runs the along the lower boundary of the Region, through Chatuaqua and Cattaraugus County.

Table 2: Priority Corridors for Invasive Plant Species Data Collection

Progress on Invasive Species Data Collection

Data collection began in earnest in July of 2006. Data surveys were conducted every day of the work week, weather permitting. The first roadway (NY Rte. 33) was surveyed using one employee. Subsequent surveys were conducted with two employees; one from Design (surveyor) and another from Operations (driver).

Survey methods vary according to the roadway and right-of way conditions. NYSDOT right-of-way is bound on one side by the roadway shoulder and a metal chain link fence (ROW fence) at the property's edge. When the ROW fence, and all property in between, is clearly visible from the roadway shoulder, the survey is conducted from the vehicle, with the vehicle driven at very slow speeds (between five to ten miles per hour) along the highway shoulder. The surveyor monitors the right-of-way (ROW) from the vehicle, watching out for any of the four targeted invasive plant species. As stands are spotted, the surveyor leaves the vehicle, surveys the stands then returns to the vehicle or continues on foot to the next stand. When the ROW property is not clearly visible from the vehicle, the surveyor either walks along the back edge of the shoulder, or enters the ROW and conducts the survey on foot with the Operation's staff trailing behind in the state vehicle.

The two person system functions adequately a number of reasons, but the primary reason is safety. Most of the state's right-of-way property is not mowed and the ground plane is not clearly visible. The topography can change very rapidly with little indication. In addition, the ground plane is fraught with hazards such as burrows, dens, fallen tree limbs, vines and rocks that are all concealed by tall grasses and herbaceous weeds. Falling is a real concern. So are encounters with wildlife. Maneuvering through the ROW is difficult and hazardous. Both staff members are equipped with walky-talkies that make communication possible when the team members are out of visual range. If a surveyor is in a deep gorge surveying ditches for an extended period of time, the driver can and will communicate with them. This method of data collection has proven to be very efficient and safe.

Since data collection started in the summer of 2006, nine roadways have been surveyed. The following is a brief summary of the progress made to date:

The 2006 data collection season included three roadways.

- The Kensington Expressway was completed by the middle of July 2006.
- The Aurora Expressway was completed by the end of August 2006.
- The remainder of the 2006 data collection season was dedicated to the Youngmann.

Data collection for the 2006 season ended the first week of November.

Data collection in the 2007 season also included three roadways.

- The Youngmann Memorial Highway survey was completed in June.
- The Lockport Expressway survey was conducted in July and August.
- The season ended with the Southern Expressway.

Data collection for the 2007 season ended in the second week of November.

Data collection in the 2008 season included five roadways.

- The Southern Expressway survey was finished in August.
- The I-190 survey was expanded to include the LaSalle Arterial. These roadways were surveyed during the month of September.
- The Robert Moses Parkway was started during the 2008 season.
- The West River Parkway was surveyed in November.

The season ended during the first week in November.

Database Utility

The collected data is archived and incorporated into an ArcMap document called the "environmental viewer". The environmental viewer is available to all environmental and landscape staff. Databases linked to the environmental viewer include cultural resources, hazardous materials, wetlands (both state and federal), coastal zone management areas, agricultural districts (state and federal farmland information), threatened and endangered species, air quality, aquifers, terrestrial invasive plant species and more. The document is stored on a shared (networked) drive and the databases contained in the map are updated periodically.

The data found in the environmental viewer are used by Landscape Architects and Environmental Specialists during their review of projects at project scoping. The technology helps environmental professionals identify environmental issues that have the potential to add to the project's cost. Currently, the invasive plant species database contains the location of the four (4) targeted species for seven (7) priority corridors.

Invasive Species Data Collection on Capital Projects

In 2008, GPS data collection for invasive plant species was expanded beyond the priority corridors to include capital improvement projects (CIPs). Under the environmental asset management program, capital projects are reviewed for asset management opportunities at all stages of project development, including:

- Scoping
- Design Report (Draft and Final)

- Advanced Detailed Plans (ADPs)
- Local PS&E
- PS&E

Asset management data collection for a CIP falls into two (2) categories; pre-construction and post-construction. Pre-construction data surveys collect GPS data on assets that are not found on the project base mapping. Pre-construction managed assets fall into two categories, assets to be protected and assets not found on the surveyed base map. Post-construction managed assets are environmental elements that are created under the CIP. Examples include, Americans with Disabilities Act (ADA) compliant pedestrian facilities, permanent state pollution discharge elimination systems (SPDES), mitigation wetlands and terrestrial invasive plant species controlled areas. Post-construction GPS data on invasive plant species can be used by the environmental staff to measure the success of invasive plant species control efforts.

Recommendations for data collection are made by the unit's Environmental Asset Management Coordinator (EAMC). The recommendations are sent (via email) to the unit's Project Manager during project review. The unit's Project Manager, in conjunction with the appropriate Environmental Specialist (ES), recommends the GPS collection of asset data to the Regional Environmental Contact (REC) based on a need for quantity take-offs for cost estimates or the need to highlight locations (on the plans) the contractor should avoid during construction. The REC then tasks the EAMC with the GPS data collection.

Case Study for Incorporating Terrestrial Invasive Plant Species Data into a Capital Project

The remainder of the paper will review the process for incorporating invasive plant species data into a capital project. The chosen example focuses on the GPS collection of asset data during a project's design phase, or a "pre-construction GPS data survey". The process described will detail the integration of GPS data from its collection through final CADD design. In addition, the example will demonstrate how GPS data can provide quantity take-offs for cost estimates, and highlight locations on the plans the contractor should avoid during construction.

BIN 1011810 over Cattaraugus Creek – Project Background

The selected project involves the reconstruction of a NYSDOT bridge over Cattaraugus Creek located in the towns of Sardinia and Yorkshire at the Cattaraugus County and Erie County border. The bridge carries NY Rtes. 16 and 39 over Cattaraugus Creek. In its current condition, the creek's stream meander is creating severe erosion to the upstream left channel embankment, the southeast highway embankment and the north abutments. In turn, the erosion is causing slope failures along the north bridge abutment and scour around the bridge's center pier. The objectives of the project are to correct and prevent further erosion of the embankments adjacent to BIN 1011810, stabilize the stream banks immediately upstream of BIN 1011810, and enhance the surrounding habitat and vegetation within the project area (New York State Department of Transportation 2008).

The project site is completely infested with Japanese knotweed. The original site survey did not show the extent of the invasive plant infestation within the project boundaries. Moreover, the proposed stream re-alignment bisects the site's largest individual stand of Japanese knotweed. To comply with federal guidelines, the Department's actions cannot promote the spread of the knotweed. The contract must contain provisions for the control of Japanese knotweed during project construction.

In July of 2008, the project was reviewed for all environmental issues at the advanced detailed plan (ADP) stage of project development. The project's environmental asset management reviewer recommended that the site be surveyed for invasive plant species. It was reasoned that a GPS survey would provide a more accurate footprint of the Japanese knotweed. This would facilitate quantity take-offs for invasive plant species control item numbers and allow the contractor to plan project equipment and material staging areas.

BIN 1011810 over Cattaraugus Creek – GPS Data Collection

GPS data collection occurred on August 28 and 29, 2008. The data was collected using a 2005 Trimble® GeoXT™ unit that was equipped with ArcPad v. 7.1. The Department's GIS database uses the Universal Transverse Mercator (UTM), North American Datum (NAD) 1983 coordinate system as a geographic reference. Western New York State is located Zone 18N.

The configuration files for ArcPad have been standardized by the NYSDOT's Office of Environment. The GPS protocol for ArcPad is GPSCorrect set to Port Com3. The GPS capture for points and vertices is set to enable averaging. This setting tells the unit to record the averaged position from ten continuous fixes when collecting point data. The streaming feature was not used for the collection of lines or polygon features. The Positional Dilution of Precision, or PDOP, value is an indicator of the quality of the GPS signal. The PDOP value is set at a maximum of eight (8). The GPS unit is capable of generating “Z” values or elevation data, however, this function is not often used for invasive plant species data collection. Finally, the GPS datum is set at NAD 1983.

The data were collected as point, line and polygon shapefiles. The line shapefiles were later converted to polygon data using aerial photography as a reference.

The data were transferred from the Trimble® GeoXT™ unit to a desktop computer. The shapefiles were referenced into an ArcMap document to check for accuracy and to perform any required data post processing. The original shapefiles were archived at their current coordinate system and added to the regional invasive plant species database.

BIN 1011810 over Cattaraugus Creek – Conversion to CADD

The process for converting shapefile data into CADD data is outlined in the NYSDOT’s internal guidance *GIS Standards and Procedures 3.1.4 – Exporting GIS Data to CADD file format using ArcGIS 9.X* (New York State Department of Transportation Information Technology Division 2008). Because the state’s CADD system uses State Plane coordinates, the files had to be converted from UTM to State Plane. The conversion process was easily completed using ArcToolbox. The converted files were then exported from GIS format to CADD file format also using ArcToolbox.

The exported files were brought into a Microstation design file (.dgn file) as reference layers. The conversion process was completed once the reference layers were turned into elements using the “Merge into Master” command. Layers and layer symbology were then assigned to the elements according to the standards developed in the Department’s *CADD Procedures Manual* (New York State Department of Transportation 2003). The GPS data are now ready to be used by the designer to determine estimated quantities for invasive plant species handling.

BIN 1011810 over Cattaraugus Creek – Calculating Soil Volumes

The vectorized shapes that represent stands of Japanese knotweed are copied into the project’s design file. The project design file is a three dimensional file that contains, among other things, surveyed topographic data. For this project, area calculations were used to quantify the amount of invasive plant species that required control measures. However, the project design engineers also needed to be able to calculate the total volume of Japanese knotweed infested soil that would require handling.

Three dimensional data is manipulated in Bentley® Microstation® using the InRoads® design tools. Personal communication with the project design engineers indicate that that invasive plant species vector data was turned into a “feature based surface” by draping the shapes over the digital terrain model for the original ground surface. Soil removal depths were calculated by comparing the differences between the invasive plant species grades and the proposed grades. Using the two dimensional footprint for the stream realignment, the designer was able to quantify the total area of knotweed “infected” soil that would be displaced by the stream re-alignment. A simple calculation is then used to quantify the total volume of soil displaced by the creek realignment (Gott 2008).

Conclusion

The development and use of geospatial data on terrestrial invasive plant species in capital project planning and design has been beneficial. It has increased the accuracy of quantity take-offs for invasive species control item numbers in capital projects, provided the environmental staff with a tool to track the spread of invasive species after a construction project, increased the Department’s compliance with NEPA and SEQRA regulations and helped Department’s Operations staff to use to ensure that their activities do not advance the spread of targeted invasive species.

The region will continue to collect GPS data on invasive species. This data is integral to the planning and design of capital projects and maintenance activities. The regional environmental staff will continue to look for ways to expand the utility of the database.

Biographical Sketch

Christine Colley graduated from the University of Texas at Arlington in 1997 with a Masters of Landscape Architecture. Chris has worked in various firms throughout the United States as a Landscape Architect. She joined the New York State Department of Transportation in 2001 as a Junior Landscape Architect. She passed her Landscape Architecture licensure examination in 2007 and graduated from the State University of New York at Buffalo in June of 2008 with a Masters of Engineering degree. She is currently working in the Landscape Architecture/Environmental Services Unit as a Landscape Architect. Her work focuses on the collection of GPS data for Environmental Assets.

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USING SPECIALISED TUNNELS TO REDUCE HIGHWAY MORTALITY OF AMPHIBIANS

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Abstract

Previous studies identified roads as a source of habitat fragmentation and mortality for amphibians in Waterton Lakes National Park, Alberta, Canada, thus reducing the effects of roads became an important management issue. Vehicle traffic resulted in appreciable mortality of the Linnet Lake population of long-toed salamanders when adult and juvenile animals moved between this breeding site and terrestrial habitats. Tiger salamanders, western toads and red-sided garter snakes have also been killed by vehicles at this location.

In spring 2008, drift fences and pitfall traps were installed for about 500 m along both sides of the Entrance Road that runs parallel to Linnet Lake to intercept and capture migrating amphibians attempting to cross the road. Road surveys were conducted daily before dawn for animals that evaded the fencing. Captured long-toed salamanders were marked with visible implant elastomer so a population estimate could be derived using a mark-recapture method and so that individual movement could be detected.

Four specialised tunnels (AT500, built by ACO Wildlife) were installed in summer 2008 to allow long-toed salamanders and other small animals to cross safely under the road. Each tunnel is a “box culvert” 600 mm wide x 520 mm high. Each 1-m pre-cast segment was made of polymer concrete with slots that allowed air, moisture and light into the tunnel, creating a hospitable environment for amphibians. Segments were fitted together to span the width of the road (12 m), and set in concrete. Distances between tunnels varied from 80 m to 110 m. Installation took about two weeks; half of each tunnel was installed, traffic re-routed until the concrete set, then the other half was installed. We installed remotely-triggered cameras at the roof of each tunnel entrance to record animal movements. Cameras were set to detect motion and also to record images at fixed time intervals. We continued monitoring the population, movement patterns, and use of tunnels in 2009.

In 2008 we captured 445 long-toed salamanders; the population was estimated at 1492 ± 214 adults. We also captured 15 tiger salamanders and 21 western toads. Two percent of long-toed salamanders (i.e., 10 of 445 individuals) travelling to or from Linnet Lake died on the road in 2008. Cameras photographed long-toed and tiger salamanders, western toads, and a variety of small mammals using the tunnels from 28 August to November 2008.

Relatively few amphibians used the tunnels in 2008, because drift fences were still directing animals into the pitfall traps, and trapped animals were transported across the road. In spring 2009, fences were re-constructed to direct animals to the mouth of the tunnels, with one pitfall trap at the end of each tunnel. To 9 June 2009, 107 long-toed salamanders, moving both to and from the lake, have successfully navigated through the tunnels. Most images of salamanders have been captured using fixed-time monitoring rather than motion detection.

Our preliminary observations suggest that installation of drift fences effectively reduced road mortality and that the installation of road tunnels provides an effective and safe route of travel for a diversity of animals including long-toed salamanders. Monitoring via trapping and cameras promises to produce a meaningful assessment of the use of tunnels by amphibians and their effectiveness in reducing road mortality in Waterton Lakes National Park.

Introduction

Amphibians require a complex set of habitats to satisfy their life histories. For example, ambystomatid salamanders migrate from terrestrial non-breeding sites to breeding ponds, and return after courtship and egg deposition. Salamander larvae grow in breeding ponds, dispersing into surrounding terrestrial areas during summer. Roads fragment habitat that amphibians use for breeding, foraging/maintenance activities and over-wintering. Habitat fragmentation can affect the size, health, and persistence of populations (McDonald and St. Clair 2004).

Amphibians are killed while attempting to cross roads between habitats, mostly on rainy nights in the spring and autumn. When migrations intersect roads, hundreds or thousands of salamanders from a single population may be killed while moving between habitats (Wyman 1991, Clevenger et al. 2001).

The LTSA (*Ambystoma macrodactylum*) is a Species of Special Concern in Alberta (ASRD 2008). In Waterton Lakes National Park (WLNP) previous studies (Fukumoto 1995, Pearson 2002) showed that vehicle traffic results in appreciable mortality of a population of long-toed salamanders at Linnet Lake during three periods annually. Mortality occurs when animals traverse the Entrance Road as: a) adults migrate from terrestrial over-wintering habitat to Linnet Lake to breed (April-May), b) adults leave the lake to return to their over-wintering habitat (May-June), and c) newly metamorphosed juveniles leave the lake for their over-wintering habitat (September-October). Migration is intermittent, taking place primarily at night during rainfall. Tiger salamanders (*A. tigrinum*), western toad (*Bufo boreas*; listed as a species of Special Concern under Canada's *Species At Risk Act*) and red-sided garter snakes (*Thamnophis sirtalis*) have also been killed by vehicles at this location.

In 1994, the Linnet Lake long-toed salamander population was estimated to be about 4000 adults (Fukumoto 1995), which declined to 289 individuals in 2001 (Pearson 2002). In 1994, at least 10% of long-toed salamanders that attempted to cross the road were killed by vehicles, and up to 44% in 2001. Carcasses found along the road represent an unknown fraction of the total mortality, because scavengers often remove remains (Mumme et al. 2000). Pearson (2002) noted that highway traffic in the months of April, May, September and October, when salamanders are most frequently migrating across the roadway, increased by 52%, 17%, 18% and 20%, respectively, between 1989 and 2000. Increased traffic volume commonly results in increased wildlife mortality (e.g., Fahrig et al. 1995, Trombulak and Frissell 2000, Mazerolle 2004).

Although amphibian populations in high-traffic areas may be depressed from cumulative road mortality, they continue to suffer proportionately higher rates of roadkill over time. Nonspecific with respect to age, sex, and condition of the individual animal, mortality due to roadkill can have substantial effects on a population's demography (Trombulak and Frissell 2000).

Preservation of ecological integrity is the primary mandate for national parks in Canada; therefore Waterton Lakes National Park determined to undertake measures to protect amphibian populations in Linnet Lake by reducing highway mortality (Parks Canada 2000). Specialized structures have long been used under roads in Europe (Langton 1989) and more recently in the U.S.A. (Allaback and Laabs 2003) to prevent vehicle-caused mortality of amphibians. The objective of this study was to evaluate the effectiveness of four road tunnels under a section of the Entrance Road in Waterton Lakes National Park, that were installed to serve as safe access routes for long-toed salamanders and other amphibians travelling between aquatic breeding habitat and terrestrial non-breeding habitat.

Methods

Tunnel Installation

In order to reduce road mortalities prior to tunnel installation and to direct amphibians to the tunnel entrances once they were completed, in April, 2008, we installed 500 m of plastic silt fencing (Corn 1994) on each side of the Entrance Road near Linnet Lake (Fig. 1). The west drift fence was designed to capture adult salamanders migrating from over-wintering sites to Linnet Lake to breed in the spring. The east fence was aimed at capturing adult salamanders migrating from Linnet Lake to over-wintering sites in the early summer and young-of-the-year dispersing in fall.

Four amphibian tunnels were installed in June, 2008 (Fig. 2). Each tunnel is a "box culvert" 600 mm wide by 520 mm high (AT500 built by ACO Wildlife, http://acousa.com/wildlife/index.htm). Each 1-m section is made of polyester resin polymer concrete with the following material properties (AT500 Amphibian Guidance System Specification Clause, http://acousa.com/pdf/1619.pdf): compressive strength range between 14,000 and 15,000 psi; flexural strength between 3600 and 4500 psi; tensile strength of 1500 psi; material water absorption rate does not exceed 0.1% by weight. The concrete has resistance to prolonged salt exposure, repetitive frost cycles and is chemically resistant to dilute acids and alkalis. The finished installation is built to withstand loadings to road class D (DIN9580). Each concrete section has air slots along the top that allow air, moisture and light into the tunnel, creating an acceptable environment for amphibians to enter (Allaback and Laabs 2003, Dulisse 2005). Segments were placed together and set in concrete (Fig. 3), to span the width of the road (and sidewalk on one side), approximately 12 m (Fig. 4). Tunnels were placed 80 to 110 m apart. Installation took about two weeks; half of each tunnel was installed and traffic re-routed until the concrete set, then the other half was completed.

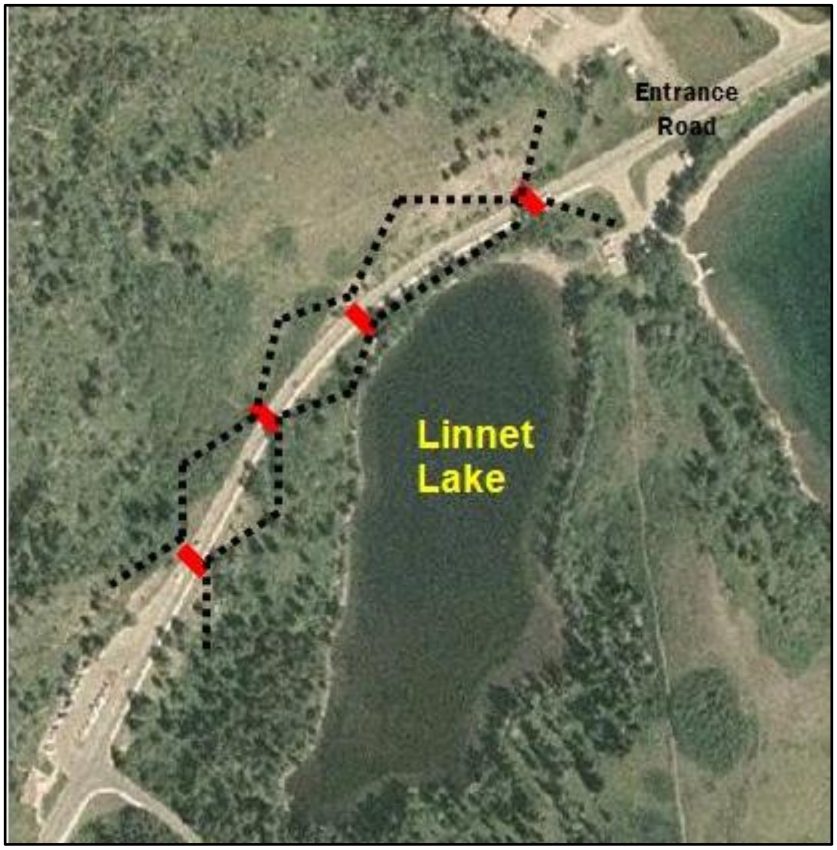

Figure 1. Aerial photograph showing the location of the tunnels (red bars) and drift fences (dotted lines) in relation to the Entrance Road and Linnet Lake.

Figure 2. Tunnel segment, suspended flush with surface of pavement, above trench to be filled with concrete. Photo courtesy of Parks Canada.

In 2009, drift fencing was re-routed to intercept salamanders at an angle to their direction of travel (Jackson and Tyning 1989). Some sections of silt fencing was replaced with UV-resistant HDPE (high density polyethelene) black corrugated piping, with the goal of creating a more permanent, lower-maintenance fence (Fig. 5).

Visual Surveys for Road Mortality

As it was possible for salamanders to circumvent drift fences at each end, we conducted visual surveys before dawn to document movement and road mortality. From 14 April to 14 October in 2008 and starting on 2 May in 2009, we walked along the Entrance Road where it parallels Linnet Lake, and recorded each amphibian encountered. Live animals were captured, measured and released off the road, facing the direction they were travelling. Dead amphibians were collected and frozen.

Figure 3. Half of one tunnel waiting for concrete to set, before diverting traffic and completing second half of tunnel. Photo courtesy of Parks Canada.

Figure 4. Completed tunnel under the Entrance Road. Tunnel mouths were later covered with biodegradable matting to stabilize soils and provide more natural cover. Photo courtesy of Parks Canada.

**Figure 5. Ground-level view of section of HDPE plastic pipe.
Photo courtesy of Parks Canada.**

Monitoring Amphibian Activity and Long-toed Salamander Population Size

In 2008 we installed pitfall traps every 18 m along both drift fences, for a total of 24 traps along the west fence and 20 traps along the east fence. Each pitfall trap was an eight-litre plastic bucket that contained a wet sponge to prevent desiccation, a rock to provide cover, and two sticks to allow escape of small mammals. A plywood cover provided shade, prevented flooding, and reduced the risk of predation on trapped amphibians. Migrating salamanders were intercepted by the fence and directed to a pitfall trap. Traps were checked daily before 0800 H from 18 April to 14 October, 2008 and starting 22 April, 2009.

We recorded age, sex, snout-vent length and weight of each captured long-toed salamander before marking and releasing it. Adult salamanders were marked with Visible Implant Elastomer (VIE; Northwest Marine Ltd., Shaw, WA; http://www.nmt-inc.com/products/vie/vie.htm) (Binckley et al. 1998). Salamanders were released on the opposite side of the road, in their direction of travel, under leaf litter. We used the Schnabel Method of mark-recapture to estimate population size (Lancia et al. 1994, Krebs 1999, Pearson 2002). All other captured amphibians were measured, aged, and released.

Assessing Tunnel Use

On 28 August 2008, we installed a remote infrared camera (Reconyx PC85, http://reconyx.com) at each tunnel entrance on both sides of the road (eight cameras). These were used until 3 November to monitor use. Cameras were set to take three photographs at one-second intervals every time a motion event was detected, regardless of the time of day. Because small, slow-moving salamanders might not trigger the motion detector, the cameras were also set to take photographs at timed intervals. Cameras were programmed to take one photograph every one minute from 2100 to 0600 H daily. An animal photographed at a tunnel entrance was termed an "event." Events were further broken down into the following categories: "approach" (animal appears to have triggered the camera incidentally and does not enter tunnel), "enter/exit" (animal enters tunnel, does not cross but exits through the same entrance), "enter" (animal enters tunnel, but is not seen leaving either entrance), "exit" (animal leaves tunnel but was not seen entering), "crossing" (animal is seen entering the tunnel and leaving through the other side). Camera data allows assessment of climate/season/time of day tunnel use, species-specific tunnel use, and differences in use of the four locations.

Results and Discussion

Estimates of Road Mortality

During visual surveys for road mortalities in 2008 we encountered a total of six live animals (five long-toed salamanders and one western toad) and 21 dead animals (10 long-toed salamanders, six western toads, two red-sided garter snakes, one mouse, and one bat (*Myotis* sp.). Two percent of long-toed salamanders (10 of 445 individuals) travelling to or from the lake died on the road in 2008. To 20 June 2009, we have documented only two dead LTSA. Compared to previous levels of mortality reported by Pearson (2002), it appears that the combination of drift fences and tunnels has been effective in reducing roadkill of salamanders.

Monitoring Amphibian Activity and Long-toed Salamander Population Size

In spring 2008, we intercepted and marked 445 adult long-toed salamanders migrating to Linnet Lake to breed. Of 186 long-toed salamanders travelling from Linnet Lake to over-wintering habitat 103 were previously marked. We also captured 15 tiger salamanders and 21 western toads.

To 9 June 2009, we have handled 278 adult long-toed salamanders in pitfall traps associated with the road drift fences and tunnels; 194 of these events were adult salamanders migrating to Linnet Lake and 84 were leaving the lake. Because 171 of these were captured while travelling along the fence, then released to continue their migration, and some of these were recaptured after using the tunnels, this is likely an over-estimate of the actual number of individuals captured. Of long-toed salamanders captured at the mouths of tunnels, after successfully passing through, 84 were moving towards Linnet Lake and 23 were leaving the lake.

Based on all capture data from 2008 we calculated a population estimate of 1492 ± 214 adult long-toed salamanders for Linnet Lake. A population estimate for 2009 will be calculated in the fall. To date, our estimates suggests that, even prior to the installation of tunnels, a larger population of long-toed salamanders exists in Linnet Lake than Pearson recorded for 2001, but the population is still considerably smaller than Fukumoto reported for 1994. One possible explanation for this is that during a major flood in 1995 Linnet Lake was connected to the larger Middle Waterton Lake, resulting in increased numbers of fish in Linnet Lake after the waters receded (R. Watt, pers. comm.), which may have had an impact on amphibian eggs and juveniles.

Documenting Use of Road Tunnels Using Cameras

A variety of small vertebrates were photographed using the tunnels to travel safely under the road between 28 August and 3 November, 2008. Based on over 250,000 images, we documented tunnel use by the following species (scientific name, # of total events): snowshoe hare (*Lepus americanus,* 113), red squirrel (*Tamiasciurus hudsonicus,* 109), mouse (*Perocmyscus* spp., 77), least chipmunk (*Tamias minimus,* 44), vole (*Microtus* spp., 32), raccoon (*Procyon lotor,* 12), striped skunk (*Mephitis mephitis,* 10), garter snake (*Thamnophis* sp., 5), long-toed salamander (2), tiger salamander (1) and unidentified shrew (1). Of these 405 events, 45 were validated crossings, that is where an animal was photographed entering and then exiting the tunnel. Because pitfall traps were located along the fences in 2008, many long-toed salamanders were intercepted before they could use the tunnels. This resulted in the very low numbers of validated crossings by this species. Between 21 April and 21 May, 2009, we have documented 26 LTSA using the tunnels. Western toad has also been documented using the tunnels in 2009.

Image analysis indicates that the majority of amphibians photographed entering and exiting the tunnels were recorded during the fixed-time image-capture events. Conversely, few amphibian images were captured using the motion detection option, suggesting that the cameras were not sufficiently sensitive enough to detect small slow-moving animals. For 2009, we will be able to compare the number of long-toed salamanders “captured” on camera vs. the number captured in pitfall traps at tunnel entrances. If camera records can be calibrated to develop an index of abundance, this technique could become part of a long-term monitoring program for the tunnels, requiring significantly less effort than trapping and marking animals.

Summary and Ongoing Efforts

Continued research is required to provide a more detailed understanding of tunnel use and the extent that animals are successfully directed towards the tunnels by drift nets. Our preliminary observations suggest that installation of drift fences effectively reduced road mortality and that the installation of road tunnels provides an effective and safe route of travel for a diversity of animals including long-toed salamanders.

Figure 6. Image of long-toed salamander passing through a tunnel.
Photo courtesy of Katie Pagnucco.

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Biographical Sketches

Cyndi M. Smith has a BES from Waterloo University in Ontario, and an MSc in Wildlife Ecology from Simon Fraser University in British Columbia. She has worked for Parks Canada since 1980 in national parks in western and northern Canada in a variety of positions. Since 2001 she has been employed as an Ecosystem Scientist in Waterton Lakes National Park, where her responsibilities include the Ecological Integrity Monitoring Program, vegetation research and data management.

Katie Pagnucco is currently an MSc student at the University of Alberta. She completed her BSc degree in Ecology and Evolution at the University of Western Ontario in London, Ontario. Prior to working with amphibians, Katie conducted research on songbird vocalizations for an Honors Thesis project and as a research assistant.

Barb Johnston has a BSc in biology from Guelph University in Ontario, and an MSc in ecology from the University of British Columbia, where her thesis focused on coastal giant salamanders. Since 2000, she has worked for Parks Canada as a park warden and as ecosystem specialist in several national parks across western and northern Canada. In WLNP she is the aquatics specialist.

Cynthia Paszkowski received a PhD in Zoology from University of Wisconsin-Madison. She has been at University of Alberta since 1984 where she is a professor in the Biological Science Department. She conducts ecological research on fishes, amphibians, and birds. Cindy serves on a variety of committees associated with conservation, museums, and undergraduate education.

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A QUANTITATIVE COMPARISON OF THE RELIABILITY OF ANIMAL DETECTION SYSTEMS AND RECOMMENDED REQUIREMENTS FOR SYSTEM RELIABILITY

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Abstract

Animal–vehicle collisions affect human safety, property, and wildlife, and the number of animal–vehicle collisions has been increasing in many regions across North America. For this project we investigated the reliability of nine different types of animal detection systems from five different manufacturers with regard to system reliability. These systems have the potential to improve human safety while not blocking or confining animal movements across the road. However, reliable warning signs are essential as the effectiveness of these systems depends on driver response. To investigate the reliability of the systems we constructed a controlled access test facility near Lewistown, Montana. The systems were installed to detect horses and llamas that roamed in an enclosure. The llamas and horses served as a model for wild ungulates. Data loggers recorded the date and time of each detection for each system. Animal movements were also recorded by six infrared cameras with a date and time stamp. By analyzing the images and the detection data, researchers were able to investigate the reliability for each system. The percentage of false positives (i.e., a detection is reported by a system but there is no large animal present in the detection zone) was relatively low for all systems (≤1%). The percentage of false negatives (i.e., an animal is present in the detection zone but a system failed to detect it) was highly variable (0–31%). The percentage of intrusions (i.e., animal intrusions in the detection area) that were detected varied between 73 and 100 percent. The results suggest that some animal detection systems are quite reliable in detecting large mammals with few false positives and false negatives, whereas other systems have relatively many false negatives. We also surveyed three stakeholder groups—employees of transportation agencies, employees of natural resource management agencies, and the traveling public—with regard to their expectations on the reliability of animal detection systems. Based on the results from the survey, the researchers recommend the following performance requirements for the reliability of animal detection systems: 1) Animal detection systems should detect at least 91 percent of all large animals that approach the road; and 2) Animal detection systems should have fewer than 10 percent of all detections be false. The recommended reliability requirements of animal detection systems were compared to the results of the reliability tests. Five of the nine systems tested met the recommended requirements. The results of this study provide transportation and other agencies with the data to decide on minimum reliability requirements for animal detection systems. Furthermore, the data show that some of the systems tested are quite reliable and may be considered for implementation along a roadside where they can be investigated for their effectiveness in reducing collisions with large wild mammals. However, experiences with installation, operation and maintenance showed that the robustness of animal detection systems may have to be improved before the systems can be deployed on a large scale.

Introduction

Animal–vehicle collisions affect human safety, property, and wildlife, and the number of animal–vehicle collisions has been increasing in many regions across North America (Huijser et al. 2007). Here we investigate a relatively new mitigation measure aimed at reducing animal–vehicle collisions while allowing animals to continue to move across the landscape. We evaluated the reliability of a range of different animal detection technologies from different manufacturers.

Animal detection systems detect large animals (e.g., deer (*Odocoileus* spp.), pronghorn (*Antilocapra americana*), elk (*Cervus elaphus*) and moose (*Alces alces*)) as they approach the road (see reviews in Huijser et al. 2006, 2009a). When an animal is detected, signs are activated, warning drivers that large animals may be on or near the road at that time. Previous studies have shown variable effects of activated warning signs on vehicle speed: substantial decreases in vehicle speed (≥5 km/h (≥3.1 mi/h)) (Kistler 1998; Muurinen and Ristola 1999; Kinley et al. 2003; Dodd and Gagnon 2008); minor decreases in vehicle speed (<5 km/h (<3.1 mi/h)) (Kistler 1998; Muurinen and Ristola 1999;

Gordon and Anderson 2002; Kinley, et al. 2003; Gordon, et al. 2004; Hammond and Wade 2004; Huijser et al. 2009a); and no decrease or even an increase in vehicle speed (Muurinen and Ristola 1999; Hammond and Wade 2004). This variability of the results is likely related to various conditions (see review in Huijser et al. 2009a):

- The type of warning signal and signs.
- Whether the warning signs are accompanied with advisory or mandatory speed limit reductions.
- Road and weather conditions.
- Whether the drivers actually see an animal.
- Whether the driver is a local resident.
- Perhaps the road length of the zone with the animal detection system and the road length that the warning signs apply to (the more location specific the better).
- Perhaps also cultural differences that may cause drivers to respond differently to warning signals in different regions.

Activated warning signs may also result in more alert drivers, which can lead to a substantial reduction in stopping distance: 20.7 m (68 ft) at 88 km/h (55 mi/h) (review in Huijser et al. 2009a). Finally, research from Switzerland has shown that animal detection systems can reduce ungulate–vehicle collisions by as much as 82 percent (Mosler-Berger & Romer 2003). Preliminary data from Arizona showed a reduction of 91 percent (Dodd and Gagnon 2008).

Before animal detection systems can be effective, they must be able to detect large animals reliably. Therefore it is important to know how reliable animal detection systems are when detecting large animals and to establish minimum norms for system reliability. Until now, measuring and comparing the reliability of different animal detection systems has been problematic due to the following factors:

- Most systems have not been properly studied, or the results have not been published.
- Different studies have evaluated systems with regard to different parameters.
- Different studies used different methods.
- Different systems have been evaluated under varying conditions (e.g., varying road and climate conditions).

For this study we investigated the reliability of different types of animal detection systems from different vendors at the same site and under similar circumstances. A test facility (Roadside Animal Detection System (RADS) test-bed) was constructed near Lewistown, Montana. Nine different animal detection systems from five different manufacturers were installed to detect horses and llamas that roamed in an enclosure. Data loggers recorded the date and time of each detection for each system. The animal movements were also recorded by six infrared cameras with a date and time stamp. By analyzing the images and the detection data, researchers were able to evaluate the system for a variety of reliability parameters. In addition, we recommend minimum standards for system reliability.

Methods

Test-bed location

The RADS test-bed is part of the TRANSCEND cold region rural transportation research facility and is located along a former runway at the Lewistown Airport in central Montana (Figure 1). The test-bed location experiences a wide range of temperatures, and precipitation ranges include mist, heavy rain, and snow; the topography is flat, and the rocky soil does not sustain much vegetation that may obstruct the signals transmitted or received by the sensors. The test-bed consists of an animal enclosure, nine different animal detection systems, and six infrared cameras with continuous recording capabilities (Figure 2). The distance covered by the systems (except for System 9) was 91 m (300 ft) (from the left to the right side of the enclosure).

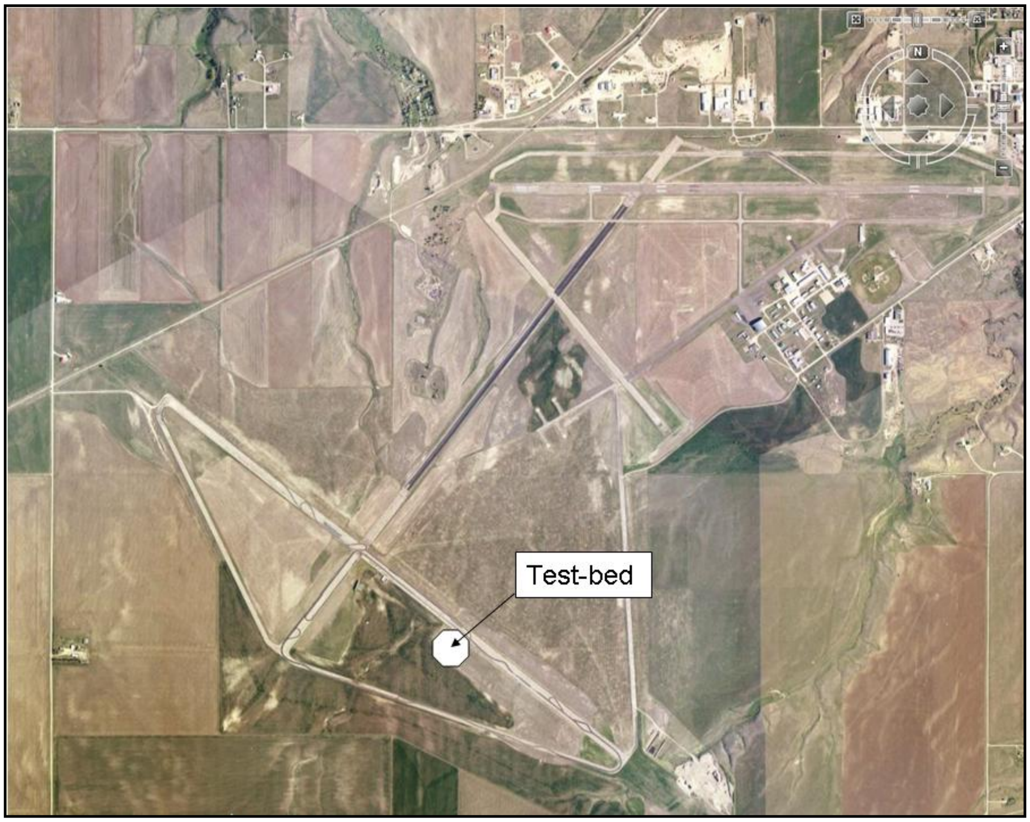

Figure1. The location of the test-bed along a former runway at the Lewistown Airport in central Montana. The current municipal airport is located on the upper right of the photo.

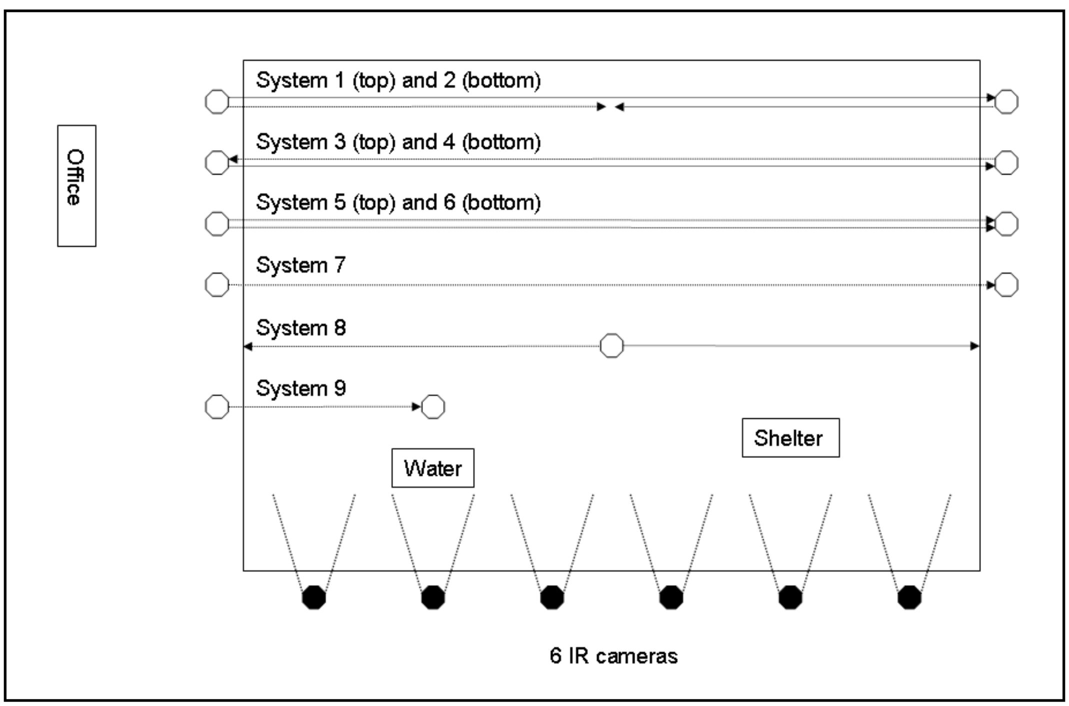

Figure 2. Test-bed design including an animal enclosure, the nine detection systems (open circles represent the sensors), the six infrared (IR) cameras aimed at the enclosure from the side (solid circles), and the office with data recording equipment. The arrows show the direction towards which each sensor or transmitter is pointed.

System number (Figure 2)	Manufacturer and system name	ID number	System type	Signal type	Maximum range	Installation date
1	Xtralis (ADPRO)	7	Area cover	Passive IR	500 ft (152 m)	Sep 21, 2006
2	Xtralis (ADPRO)	5-6	Area cover	Passive IR	200 ft (61 m) (one detector on each side)	Sep 21, 2006
3	STS (RADS I)	1	Break-the-beam	Microwave radio (± 35.5 GHz)	¼ mi (402 m)	Oct 19, 2006
4	STS (RADS II)	2	Break-the-beam	Microwave radio (± 35.5 GHz)	Well over ¼ mi (402 m)	Jul 19, 2007
5	Calonder Energy (CAL 92, LS-WS-WE 45)	1	Break-the-beam	Laser	984 (built-up areas) – 1148 ft (open areas) (300–350 m)	Sep 21-22, 2006
6	Calonder Energy (CAL 92, IR-204-319/M3)	2	Area cover	Passive IR	328 ft (100 m)	Sep 21-22, 2006
7	Camrix (A.L.E.R.T.)		Area cover	IR ITS Camera Technology	300 ft (91 m) (Note: 1 unit detects both sides of a road)	Oct 19-31, 2006
8	Xtralis (ADPRO)	1-2	Area cover	Passive IR	200 ft (61 m) (2 detectors, one facing each way)	Aug 8, 2006
9	Goodson		Break-the-beam	Active IR	90 ft (27 m)	Dec 2006

Table 1. The characteristics of the nine animal detection systems. See appendix A for manufacturer contact details.

Animal Detection Systems

During the first five tests, which were conducted from January through May 2007, there were eight systems, all installed parallel to each other (Table 1). Five of these were area-cover systems and the other three systems were break-the-beam systems (Table 1). A second STS break-the-beam system was installed on July 19, 2007, resulting in a total of nine systems. Two of the systems required two detectors to cover the 91 m (300 ft) distance. One of these systems (System 8, Xtralis 1-2) had its two sensors installed on a pole in the middle of the 91 m (300 ft) distance, with the sensors facing opposite directions (Figure 2). The other system (System 2, Xtralis 5-6) had a detector installed at each end with the sensors facing each other (Figure 2). In addition, there was one system that did not cover the 91 m (300 ft) and for which only one set of sensors was available (System 9, Goodson). This system was installed across a shorter section, equivalent to the maximum distance for this particular system 27 m (90 ft) (Figure 2).

The six infrared cameras (Fuhrman Diversified, Inc.) were installed perpendicular to the detection systems on November 8–9, 2006. These cameras and a video recording system recorded all animal movements within the enclosure continuously, day and night. The animal detection systems saved their individual detection data with a date and time stamp. These data were compared to the images from the infrared cameras, which also had a date and time stamp, to investigate the reliability of each system. Cones within the enclosure defined the detection zone for each system.

Area-cover systems are designed to detect animals within a certain area and range from a sensor. This area is typically cone-shaped—narrow close to the sensor and wider as the distance from the sensor increases (Figure 3). All area-cover systems tested in this study detect animals based on body heat and motion. Break-the-beam systems consist of a transmitter that transmits a signal to a receiver. Break-the-beam systems detect animals when their body blocks the signal or when the signal received by the receiver is greatly reduced. The break-the-beam systems tested in this study use infrared, laser or microwave radio signals.

The detection area is the area within which area-cover systems should detect large animals, and the detection line is the line between sensors where break-the-beam systems should detect large animals (Figure 3). The detection areas and detection lines were indicated by the manufacturers and were marked with cones that were visible on the images from the individual cameras. Area-cover systems have relatively large, cone-shaped detection areas, whereas break-the-beam systems have a detection line that is linear or mostly linear in shape. However, STS 1 break-the-beam system uses microwave signals and has a 3° angle from the transmitter, which resulted in a detection area that was 2.4 m (7.8 ft) wide at 91.4 m (300 ft) from the transmitter (Pers. com., Lloyd Salsman, Sensor Technologies & Systems, October 10, 2007).

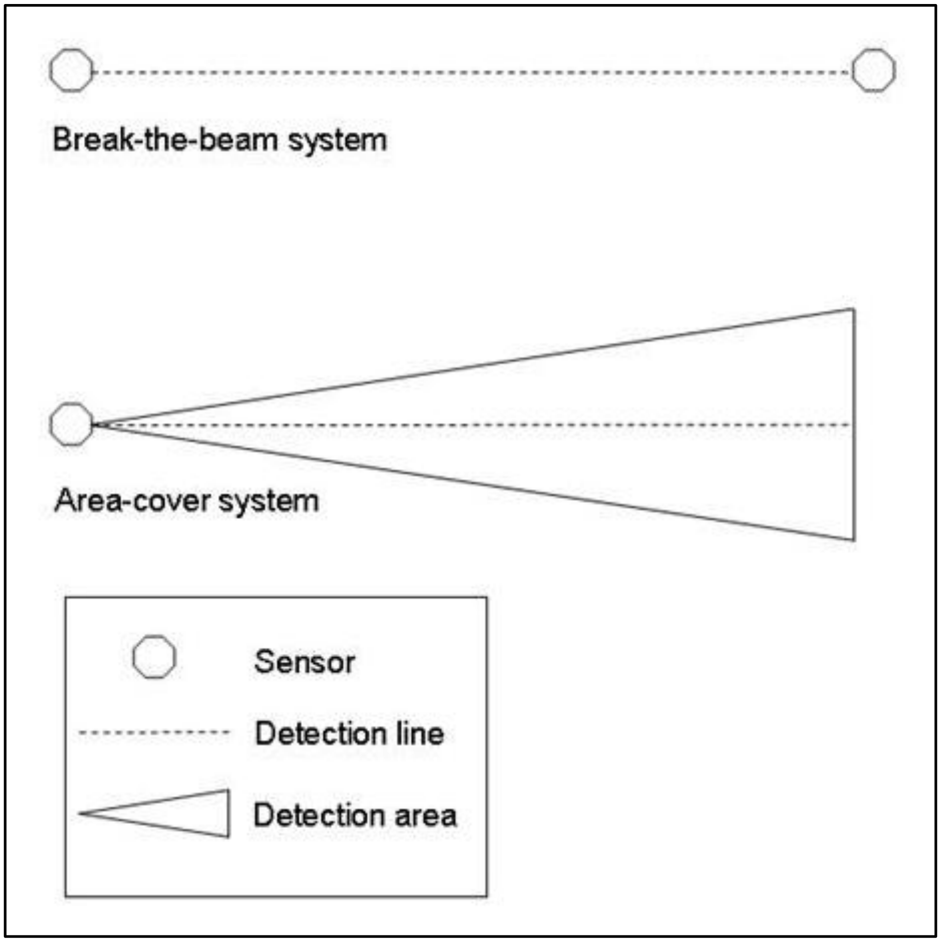

Figure 3. Schematic representation of break-the-beam and area-cover systems showing the detection line (or center line) for break-the-beam and area-cover systems, and the detection area for area-cover systems.

Animal Detection System Technologies

The Xtralis systems detect changes in infrared radiation (8–13μm) (Pers. com., Andreas Hartmann, Xtralis, October 1, 2007), which allows the system to detect the motion of an object against a stationary background. Such motion leads to changes in infrared radiation, which are processed by the system. Filtering and algorithms help distinguish between large animals and other objects to help reduce or prevent false detections. The STS systems transmit microwave radio signals (around 35.5 GHz) (Huijser et al., 2006). These signals are received by a sensor on the other end, and when an animal or object passes between the sensors, the signal is reduced. If certain thresholds are met, the reduction in signal strength results in a detection. STS 2 is more compact than STS 1 and has parts integrated into fewer components. The detection line of the STS 1 system is about 2.4 m (7.8 ft) wide at 91.4 m (300 ft) from the transmitter (Pers. com. Lloyd Salsman, Sensor Technologies & Systems, October 10, 2007). For the STS 2 system the detection line is 40.6 cm (16 in) wide consistently (Pers. com. Lloyd Salsman, Sensor Technologies & Systems, October 10, 2007). In addition, both the STS 1 and STS 2 systems have a wider detection area 4.5 m (15 ft) close to the sensors (Pers. com., Lloyd Salsman, Sensor Technologies & Systems, October 10, 2007). Calonder Energy 1 transmits a laser signal that is received by a sensor on the other end. When an animal or object blocks the laser signal, the system reports a detection. Calonder Energy 1 was installed at 105 cm (41.34 in) above the ground. Calonder Energy 2 detects changes in infrared radiation as a result of objects moving 0.2–5 m/s (8 in/s – 16.4 ft/s) (Pers. com., Giacomo Calonder, Calonder Energy, September 22, 2006; Calonder Energy, not dated). Algorithms help distinguish between large animals and other objects to help reduce or prevent false detections. This system was installed 3 m (9.8 ft) above the ground, pointing downwards at a 3–5º angle. There is a blind spot of approximately 10-12 m (32.8-39.4 ft) directly under the sensor, and the detection area is about 3 m (9.8 ft) wide at 100 m (328 ft) from the sensor (Pers. com., Giacomo Calonder, Calonder Energy, October 10, 2007). This blind spot is normally covered by another passive infrared sensor with a range of 18 m (59.1 ft) (Pers. com. Giacomo Calonder, Calonder Energy, October 10, 2007). The Calonder Energy 2 system (IR-204-319/M3) was discontinued in 2007 and Calonder Energy now offers an ADPRO unit from Xtralis (Pers. com., Giacomo Calonder, Calonder Energy, October 9, 2007). The Animal Location Evasive Response Technology (A.L.E.R.T.) system from Camrix uses a camera, optics, infrared illumination, and a computer to gather and analyze digital imagery (Pers. com., Mike Doyle, Camrix, October 3, 2007). Advanced proprietary machine vision algorithms process the images and decide whether a detection should be declared. The Goodson system (TM 1550) transmits an infrared signal that is received by a sensor on the other end. Whenever an animal or object blocks the infrared signal, the system reports a detection.

Wildlife Target Species and Models

In a North American setting, animal detection systems are typically designed to detect white-tailed deer (*Odocoileus virginianus*) and/or mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), elk (*Cervus elaphus*) or moose (*Alces alces*). For this study, which took place within an enclosure, two horses and two llamas were used as models for these wildlife target species. Horses are similar in body shape and size to moose, whereas the body shape and size of llamas is similar to deer (Tables 2 and 3). The body size and weight of the individual horses and llamas used in this experiment are shown in Table 4.

Species	**Height at shoulder**	**Length (nose to tip of tail)**	**Source**
Target species			
Moose	195-225 cm (6'5"-7'5")	206-279 cm (6'9"-9'2")	Whitaker (1997)
Elk	137-150 cm (4'6"-5')	203-297 cm (6'8"-9'9")	Whitaker (1997)
White-tailed deer	68-114 cm (2'3"-3'9")	188-213 cm (6'2"-7')	Whitaker (1997)
Mule deer	90-105 cm (3'-3'5")	116-199 cm (3'10"-7'6")	Whitaker (1997)
Pronghorn	89-104 cm (2'11"-3'5")	125-145 cm (4'1"-4'-9")	Whitaker (1997)
Models			
Feral horse	142-152 cm (4'8"-5')		Whitaker (1997)
Quarter horse	150-163 cm (4'11"-5'4"')		UHS (2007), Wikipedia (2007)
Llama	91-119 cm (3'-3 '11")		Llamapaedia (2007)

Table 2. Height and length of wildlife target species and horses and llamas.

Species	Weight male	Weight female	Source
Target species			
Moose	400-635 kg (900-1400 lbs)	315-500 kg (700-1,100 lbs)	Whitaker (1997)
Elk	272-494 kg (600-1089 lbs)	204-295 kg (450-650 lbs)	Whitaker (1997)
White-tailed deer	68-141 kg (150-310 lbs)	41-96 kg (90-211 lbs)	Whitaker (1997)
Mule deer	50-215 kg (110-475 lbs)	32-73 kg (70-160 lbs)	Whitaker (1997)
Pronghorn	41-64 kg (90-140 lbs)	34-48 kg (75-105 lbs)	Whitaker (1997)
Models			
Feral horse	360-390 kg (795-860 lbs)	270-340 kg (595-750 lbs)	Whitaker (1997)
Quarter horse	386-540 kg (850-1200 lbs)		UHS (2007), Wikipedia (2007)
Llama	113-204 kg (250-450 lbs)		Llamapaedia (2007)

Table 3. Body weight of wildlife target species and horses and llamas.

Individual	Height at shoulder	Weight
Horse 1	152 cm (5')	513 kg (1,130 lbs)
Horse 2	160 cm (5'3'')	658 kg (1,450 lbs)
Llama 1	104 cm (3'5'')	168 kg (370 lbs)
Llama 2	110 cm (3'7½'')	213 kg (470 lbs)

Table 4. Body size and weight of the horses and llamas used in the experiment (Pers. com., Lethia Olson, livestock supplier).

Test periods

There were eight test periods with test animals between January 10, 2007 and December 9, 2007. Each test period with animals lasted 7–11 days. Camera images were recorded on site on a hard drive that is capable of storing 10–14 days of data. Camera images from selected time periods were reviewed and compared to the detection logs of the individual systems to measure the reliability of each system. The selected time periods were based on a stratified random selection with animals present: three, one-hour-long sections of video were randomly selected for each test day for review. A total of 225 hours were analyzed for eight of the nine systems. The ninth system 9 (system 4, STS (RADS II)) was analyzed for 91 hours.

Reliability Parameters

The time periods reviewed were analyzed for valid detections, false positives, false negatives, and intrusions in the detection area. These terms are defined below (see Huijser et al. 2009b for more details).

- *False positives* – A false positive was defined as "when the system reported the presence of an animal, but there was no animal in the detection zone." Thus, each incident in which a system's data logger recorded a detection, but there was no animal present in the detection zone of that system, was recorded as a false positive. The date and time were recorded for all false positives.
- *False negatives* – A false negative was defined as "when an animal was present but was not detected by the system." However, due to animal behavior and the design of some detection systems (i.e., some systems are desensitized by the continuous presence of an animal), there are several ways for a false negative to occur. Therefore, various types of false negatives were distinguished and these were recorded separately.
- *Intrusions in detection area* – An intrusion was defined as "the presence of one or multiple animals in the detection zone." An intrusion began when one or more animals entered the detection zone and ended when all animals left the detection zone.

Results

The results of the reliability tests showed that different detection technologies differ in their reliability with regard to detecting large animals and that some types of systems result in multiple detections if an animal enters the detection zone whereas other types of systems result in one detection. The percentage of false positives (i.e., a detection is reported by a system but there is no large animal present in the detection zone) and the average number of false positives per hour was relatively low for all systems (≤1%; ≤0.10/hr). The percentage of false negatives (i.e., an animal is present in the detection zone but a system failed to detect it) and the average number of false negatives per hour was highly variable (0–31%; 0–1.61/h) (all types of false negatives combined). The percentage of intrusions (i.e., animal movements across the detection line) that were detected varied between 73 and 100 percent. The results suggest that some animal detection systems are quite reliable in detecting large mammals with few false positives and false negatives, whereas other systems have relatively many false negatives. For more details on the reliability of individual systems, please see Huijser et al. (2009b).

Three stakeholder groups—employees of transportation agencies, employees of natural resource management agencies, and the traveling public—were surveyed with regard to their expectations on the reliability of animal detection systems. We analyzed the data and calculated what reliability requirements would satisfy the majority (>50%) of each of the three stakeholder groups. For more details on the calculation of the suggested minimum reliability requirements, please see Huijser et al. (2009b). Based on the results, the researchers recommend the following reliability requirements for the reliability and effectiveness of animal detection systems:

- Animal detection systems should detect at least 91 percent of all large animals that approach the road.
- Animal detection systems should have fewer than 10 percent of all detections be false.

The reliability of the nine different animal detection systems was compared to suggested reliability requirements (Table 5). Five of the nine systems tested met the recommended performance requirements for reliability. However, experiences with installation, operation and maintenance showed that the robustness of animal detection systems may have to be improved before the systems can be deployed on a large scale.

System number (Figure 2)	**Manufacturer and system name**	**ID number**	**Meets false positives (yes/no)**	**Meets false negatives (yes/no)**	**Meets intrusions detected (yes/no)**	**Meets overall recommended norms (yes/no)**
1	Xtralis (ADPRO)	7	Yes	No	Yes	Yes
2	Xtralis (ADPRO)	5-6	Yes	No	No	No
3	STS (RADS I)	1	Yes	No	No	No
4	STS (RADS II)	2	Yes	No	No	No
5	Calonder Energy (CAL 92, LS-WS-WE 45)	1	Yes	Yes	Yes	Yes
6	Calonder Energy (CAL 92, IR-204-319/M3)	2	Yes	Yes	Yes	Yes
7	Camrix (A.L.E.R.T.)		Yes	No	No	No
8	Xtralis (ADPRO)	1-2	Yes	Yes	Yes	Yes
9	Goodson		Yes	Yes	Yes	Yes

Table 5. The reliability of each system in relation to the recommended minimum norms. The percentage of intrusions detected is similar, though not exactly the same as the complement of the percentage of false negatives (see Huijser et al. 2009b).

Discussion and Conclusion

Based on the results of this study, the researchers concluded:

- The results of the reliability tests showed that different detection technologies differ in their reliability with regard to detecting large animals and that some types of systems result in multiple detections if an animal enters the detection zone whereas other types of systems result in one detection. This implies that care must be taken in evaluating the reliability of different technologies, and in comparing them to other systems or minimum performance requirements.
- The percentage of false positives and the average number of false positives per hour was relatively low for all systems (≤1%; ≤0.10/hr). False positives do not appear to be a major concern with regard to the reliability of animal detection systems.
- The percentage of false negatives (all types of false negatives combined) and the average number of false negatives per hour under the test circumstances was highly variable (0–31%; 0–1.61/hr). The percentage of intrusions (i.e., situations where at least one animal was present in the detection area) that were detected varied between 73 and 100 percent. The results suggest that false negatives are a major concern for some animal detection systems but not for others.
- The recommended performance requirements for the reliability of animal detection systems were compared to the results of the reliability tests. Five of the nine systems tested met the recommended performance requirements for reliability. However, experiences with installation, operation, and maintenance show that the robustness of animal detection systems may have to be improved before the systems can be deployed on a large scale.

Biographical Sketches

Marcel Huijser received his M.S. in population ecology (1992) and his Ph.D. in road ecology (2000) at Wageningen University in Wageningen, The Netherlands. He studied plant-herbivore interactions in wetlands for the Dutch Ministry of Transport, Public Works and Water Management (1992-1995), hedgehog traffic victims and mitigation strategies in an anthropogenic landscape for the Dutch Society for the Study and Conservation of Mammals (1995-1999), and multifunctional land use issues on agricultural lands for the Research Institute for Animal Husbandry at Wageningen University and Research Centre (1999-2002). Currently Marcel works on wildlife-transportation issues for the Western Transportation Institute at Montana State University (2002-present). He is a member of the Transportation Research Board (TRB) Committee on Ecology and Transportation and co-chairs the TRB Subcommittee on Animal-Vehicle Collisions.

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EVALUATION OF AN ANIMAL-ACTIVATED HIGHWAY CROSSWALK INTEGRATED WITH RETROFIT FENCING APPLICATIONS

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Abstract

We evaluated the efficacy of 4 km of retrofit fencing integrated with an animal-activated detection system (AADS) to reduce wildlife-vehicle collisions (WVC) and maintain permeability across State Route 260 in central Arizona. Two types of right-of-way (ROW) fence extension (electric and barbed-wire) were used to prevent at-grade crossings by wildlife and funnel animals to 2 underpasses and a bridge. At the western fence terminus, an AADS-activated signs alerted motorists when wildlife approached the highway helping prevent an "end-run effect." The objectives of our 2007-2008 study were to evaluate:

1) WVC incidence before and after ROW fence modification,
2) effectiveness of an AADS in modifying motorist behavior,
3) AADS operational reliability, and
4) wildlife use of the crosswalk associated with the AADS.

We compared WVC incidence after ROW fence modification to data from our long-term research project. In over 2 years since fence modification, only 1 WVC involving elk (*Cervus elaphus*) occurred, a 96% reduction from the 2001-2006 mean (11.7/year). The proportion of animal-caused single-vehicle accidents dropped 64%.

To assess effectiveness of the our AADS and warning signs in eliciting modified motorist behavior (increased alertness and lowered vehicle speed) we assessed motorist response during paired 15-min sampling periods with and without variable message and crosswalk flashing signs activated. To assess speed, we determined average speeds with a permanent traffic counter. To assess braking, our measure of motorist alertness, we counted the proportion of vehicles braking during sampling periods. We documented a significant 16% reduction in motorist speed (15 km/hr) with signs activated, and braking 67% of the time signs were activated versus 8% with signs off.

We assessed AADS reliability during 250 field visits and by 4-camera video surveillance of wildlife entering the detection zone that allowed simultaneous determination of warning sign status. We encountered few instances when the system was inoperable; it performed properly on 94% of our visits. Video surveillance recorded 104 groups of elk and 40 of white-tailed deer (*Odocoileus virginianus*) in the detection zone; 97% were detected by the RADS with warning signs activated before reaching the roadside.

We assessed wildlife behavior and traffic relationships during at-grade crossings by video surveillance. Of 448 animals (8 species), 18% crossed the highway and 20% went around the end of the fence into the ROW. Elk and deer passage rates averaged 0.21 and 0.10 crossings/approach, respectively. Probability of elk crossing the highway once approaching in crosswalk was 0.25 with traffic <1 vehicle/min and dropped to 0.02 at 12 vehicles/min.

Our applications of an AADS crosswalk and retrofit fencing add valuable options to our collective road ecology toolbox and base of knowledge.

Introduction

As highways are upgraded to accommodate increasing traffic volume, measures to reduce wildlife-vehicle collisions (WVC) while maintaining wildlife permeability across highway corridors are essential to the safety of motorists and viability of wildlife species (Forman et al. 2003). Wildlife crossing structures (e.g., underpasses and overpasses) are increasingly being implemented to provide safe passage across highways and to reduce the incidence of WVC. When combined with appropriate fencing to funnel animals to crossing structures, these structures have proven to be effective for a range of species (Foster and Humphrey 1995, Clevenger and Waltho 2000, 2005; Dodd et al. 2007*a,b,c,d*). However, in some cases crossing structures may not be feasible due to topography, budget limitations, or scheduling of highway reconstruction. In such cases, transportation managers need options to "retrofit" highways to improve highway safety by reducing WVC and to accommodate wildlife permeability.

One alternative approach being applied to reduce the incidence of WVC is the application of animal-activated detection systems (AADS; Gordon et al. 2004; Huijser and McGowen 2003, 2004; Huijser et al. 2006*a*,*b,* 2007). The general purpose of these systems is to modify driver behavior using flashing signs to warn motorists when animals are adjacent to or within the roadway. AADS appear promising as an alternative to expensive wildlife crossing structures, and have shown positive results in reducing WVC (Ward et al. 1980, Huijser and McGowen 2003, Gordon et. al. 2004). AADS are a relatively new technology to North America, though they have been used in Europe and Scandinavia for quite some time (Huijser and McGowen 2003). Ward et al. (1980) was an AADS pioneer and first documented the promising results of this method achieving a reduction in accidents and a 15 mph decrease in motorist speed when warning signs were activated. However, Gordon et al. (2004) later documented minimal reduction in motorist speeds of about 4 mph, although they reduced by 20% when a deer decoy was simultaneously present. As Huijser et al. (2006*a*) pointed out, many of these systems have not been adequately evaluated and remain experimental. Huijser et al. (2007) conducted one of the most extensive evaluations to date of various AADS, testing nine different systems in a controlled environment.

One potential drawback of AADS is the necessity for wildlife to continue to cross highways at grade, risking collision with vehicles or being subject to the barrier effect created by high traffic volumes (Mueller and Berthoud 1997). Gagnon et al. (2007*a*) documented that at-grade elk crossing frequencies were deterred by increasing traffic volumes; conversely, elk crossing rates showed no effect from traffic volumes while crossing below grade through wildlife underpasses (Gagnon et al. 2007*b*). Species that exhibit sensitivity to road-associated impact (e.g., traffic, noise) may not benefit from the installation of AADS if traffic volumes are high, as these animals likely will not attempt at-grade road crossings.

Project Need and Objectives

Wildlife-highway research has been ongoing along State Route (SR) 260 in central Arizona since 2001, tied to the phased reconstruction of the highway (Dodd et al. 2007*d*, 2009). The first phase of research took place on the 5-km Preacher Canyon section, the first of five highway sections reconstructed along a 30-km stretch of SR 260. Reconstruction of the Preacher Canyon section from a two-lane roadway to a four-lane divided highway with two wildlife underpasses and a large bridge was completed in 2001. We evaluated the incidence of elk-vehicle collisions (EVC) and movement of wildlife through the two underpasses that included limited fencing (<0.4 km). A high number of crossings by GPS-collared elk and EVC occurred along the unfenced portion of section (Dodd et al. 2006, 2007*d,* 2009). The incidence of EVC after reconstruction (2001–2006; mean = 11.7 EVC/year) was higher than the before-reconstruction (1994-2000) mean of 9.7 EVC/year; indicating wildlife underpasses and limited fencing collectively did not serve to adequately promote highway safety.

On the second reconstructed section of SR 260 (Christopher Creek section), approximately half the section was strategically fenced using elk GPS crossing data (Dodd 2007*b*) to intercept elk at peak crossing areas and funnel them to underpasses, resulting in both an 85% reduction in the incidence of EVC and a 53% increase in permeability (Dodd et al 2007*c*). With these insights, we pursued an enhancement grant to modify the ROW fence along the Preacher Canyon section to similarly reduce the incidence of at-grade highway crossings by animals and potentially the incidence of WVC.

As part of this enhancement project, existing right-of-way (ROW) fence along approximately 4 km of the highway was modified and raised to 2.2–2.4 m to make the fence impermeable to elk and to funnel animals toward the Preacher Canyon Bridge and the two underpasses. At the west end of the section, no passage structure or impassable topographical feature (e.g., canyon, large cut slope) existed where we could effectively terminate the fence. Therefore, we installed an experimental AADS to prevent an "end-run" effect (e.g., Clevenger et al. 2001) where wildlife could pass around the end of the fence. We configured our AADS such that a defined wildlife "crosswalk" was created with fencing similar to Lehnert and Bissonette (1997). We conducted a 2-year evaluation of the effectiveness of the AADS and fencing modification for future application to highway retrofit applications elsewhere, as well as assessing their potential for use as an alternative to costly wildlife passage structures. Although this project will benefit multiple species, elk were a focus as this species accounts for >80% of all WVC along this stretch of SR 260 and the vast majority of property loss and human injuries (Dodd et al. 2006, 2009).

Implementation of fencing modifications and the AADS was completed in February 2007. The primary objectives of our research study were to evaluate the effectiveness of the experimental components of the Preacher Canyon wildlife fencing enhancement project, including:

1) comparison of WVC incidence o before and after ROW fence modification,
2) evaluation of the effectiveness of the AADS in modifying driver behavior at the wildlife crosswalk,

3) evaluation of the operational reliability of the AADS, and
4) evaluation of wildlife use of the crosswalk and west wildlife underpass following ROW fence modification.

The purpose of this paper is to provide an overview of the Preacher Canyon wildlife fencing enhancement project and our research evaluation. Our complete final report (Gagnon et al. 2009) is available from the authors and individual journal manuscripts are now in preparation. As such, this paper provides only a summary of the research methodologies and findings from our 2-year project evaluation.

Project Components and Implementation

First and foremost, our enhancement project including the AADS was a fencing effort when compared to other AADS applications used as alternatives to fencing (Huijser et al. 2003, 2006*b*). Such an approach was deemed too costly and complex for SR 260. We relied on the AADS and animal crosswalk to address the potential for an end-run effect at the western terminus of our fencing. We selected an undivided 2-lane section of SR 260 immediately adjacent to the 4-lane divided Preacher Canyon section to install the AADS and crosswalk to minimize the complexity of the system and potential for animals to enter the highway ROW at the crosswalk (Figure 1). This project included several separate components that were integrated in a package to enhance highway safety. Our AADS and crosswalk is a hybrid system, incorporating elements of systems evaluated by Gordon et al. (2004) and Huijser et al. (2006*b*) combined with a defined crossing area as evaluated by Lehnert and Bissonette (1997).

Retrofit ROW Fence Modification

We evaluated the efficacy of 3 retrofit fence modifications to raise the existing ROW fence to 2.2−2.4 m to funnel animals to the underpasses, the bridge, and the AADS/crosswalk: 1) 3-m T-posts and barbed-wire, 2) T-post sleeve extensions and barbed-wire (appropriate for steep or rocky sites), and 3) ElectroBraid™ braided rope electric fence (Seamens and VerCauteren 2006) affixed to fiberglass poles and with an electrified “kicker” attached to the ROW fence T-posts (Figure 2). These cost-effective (<$30/m, compared to the standard woven wire ungulate-proof fence currently at >$120/m) retrofit fencing designs were integrated into the existing ROW fence for possible future modification or removal and to evaluate their effectiveness on other highways where reconstruction and installation of new ungulate-proof fence is not planned or feasible. We evaluated both 110-v AC and 12-v DC (solar powered) applications of electric fence.

Wildlife Escape Mechanisms

In the event that animals breached the fenced portion of the project and became trapped within the ROW, measures to allow them to escape were installed. These mechanisms included: 1) escape ramps, 2) “slope jumps” built into the fencing, 3) one-way gates (Reed et al. 1974), and 4) a pair of experimental animal-activated self-opening electronic gates. The electronic gates were opened with a break-beam photo sensor situated along the fence far enough in advance of the gate so animals did not see movement of the gates as they opened; the gates closed automatically after two minutes.

Animal-Activated Detection System and Motorist Alert Signage

At the western terminus of the raised ROW fence, the Arizona Department of Transportation (ADOT) contracted with ElectroBraid Fence, Inc. to design and implement an AADS-integrated “crosswalk.” This system was intended to alert motorists to wildlife entering the AADS detection zones. The crosswalk consisted of an infrared camera detection system integrated with military-grade target acquisition software to detect wildlife movement (Figure 3). This software was sensitive to both movement and size of the moving object such that small animals would not trigger the alert signs.

Once an animal was detected by the AADS, radio signals activated signs alerting approaching motorists of the presence of animals within the detection zone and potentially the crosswalk. Motorists were presented with a sequential series of signs: 1) a static sign reading “TEST AREA - ELK CROSSING - 1500 FT (450 m) AHEAD,” 2) a variable message board 180 m from the crosswalk activated by the AADS when wildlife were present, displaying “CAUTION – ELK – DETECTED” (Figure 4), and 3) an AADS-activated warning sign at the crosswalk with flashers that displayed the silhouette of an elk (Figure 5). The system was operational 24 hours a day.

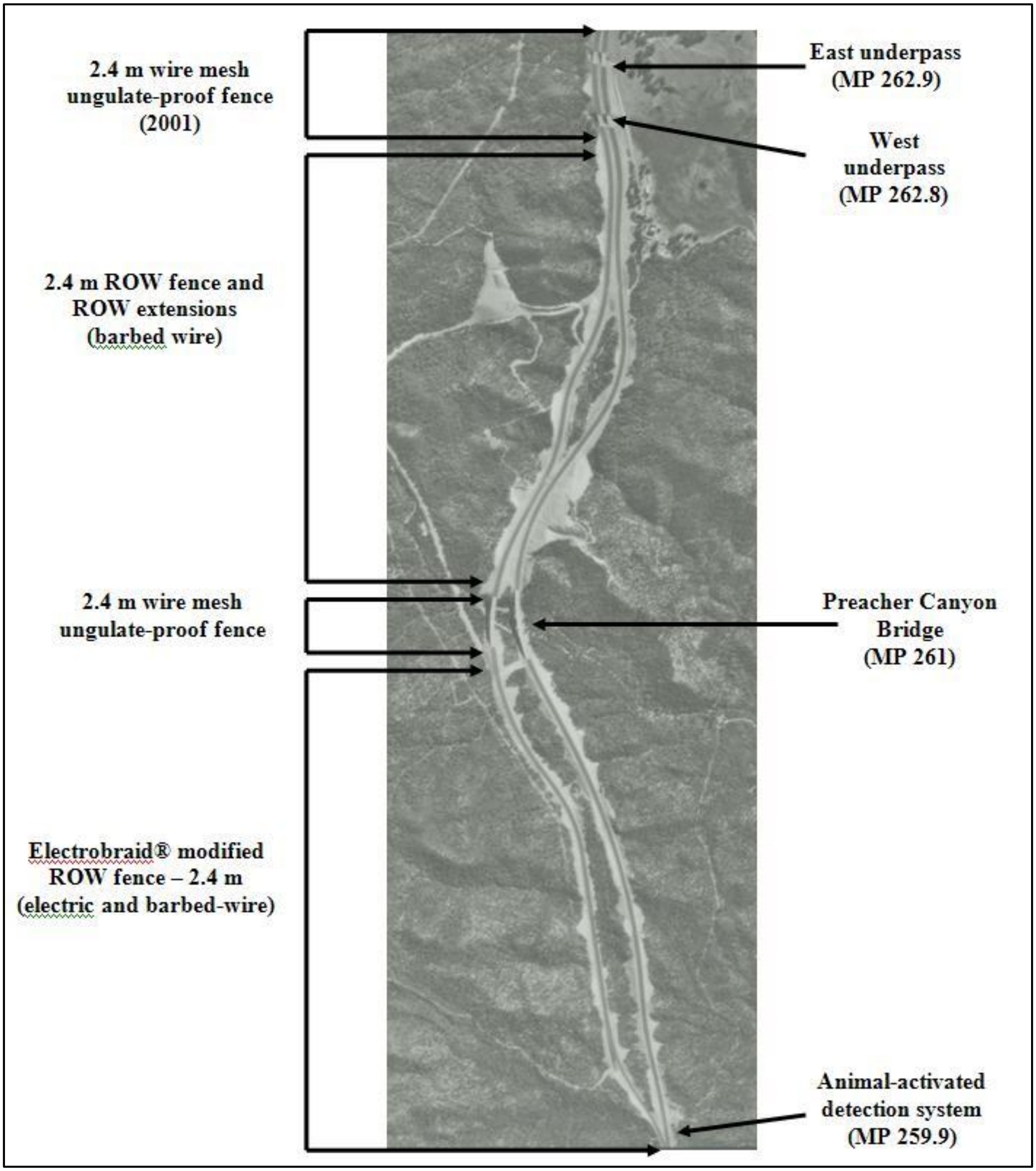

Figure 1. Aerial view of the layout of the Preacher Canyon wildlife fencing enhancement project along 4 km of State Route 260 in central Arizona, including 2 existing underpasses at Little Green Valley, the Preacher Canyon Bridge, retrofit modifications of right-of way (ROW) fencing (barbed-wire and electric), and the animal-activated detection system and crosswalk.

Figure 2. Applications of modified right-of way fence raised to 2.2–2.4 m to funnel wildlife to underpasses, a bridge, and the animal-activated detection system crosswalk, including fence raised with: 1) 3-m T-posts and barbed-wire (left), 2) T-post sleeve extensions and barbed-wire (middle), and 3) ElectroBraid™ braided rope electric fence and fiberglass posts (right).

Figure 3. The tower-mounted infrared detection camera as part of the animal-activated detection system (AADS; left), and an infrared camera image of elk detected moving through the detection zone (right) after which radio signals activate motorist alert signage.

Figure 4. Caution Elk Detected

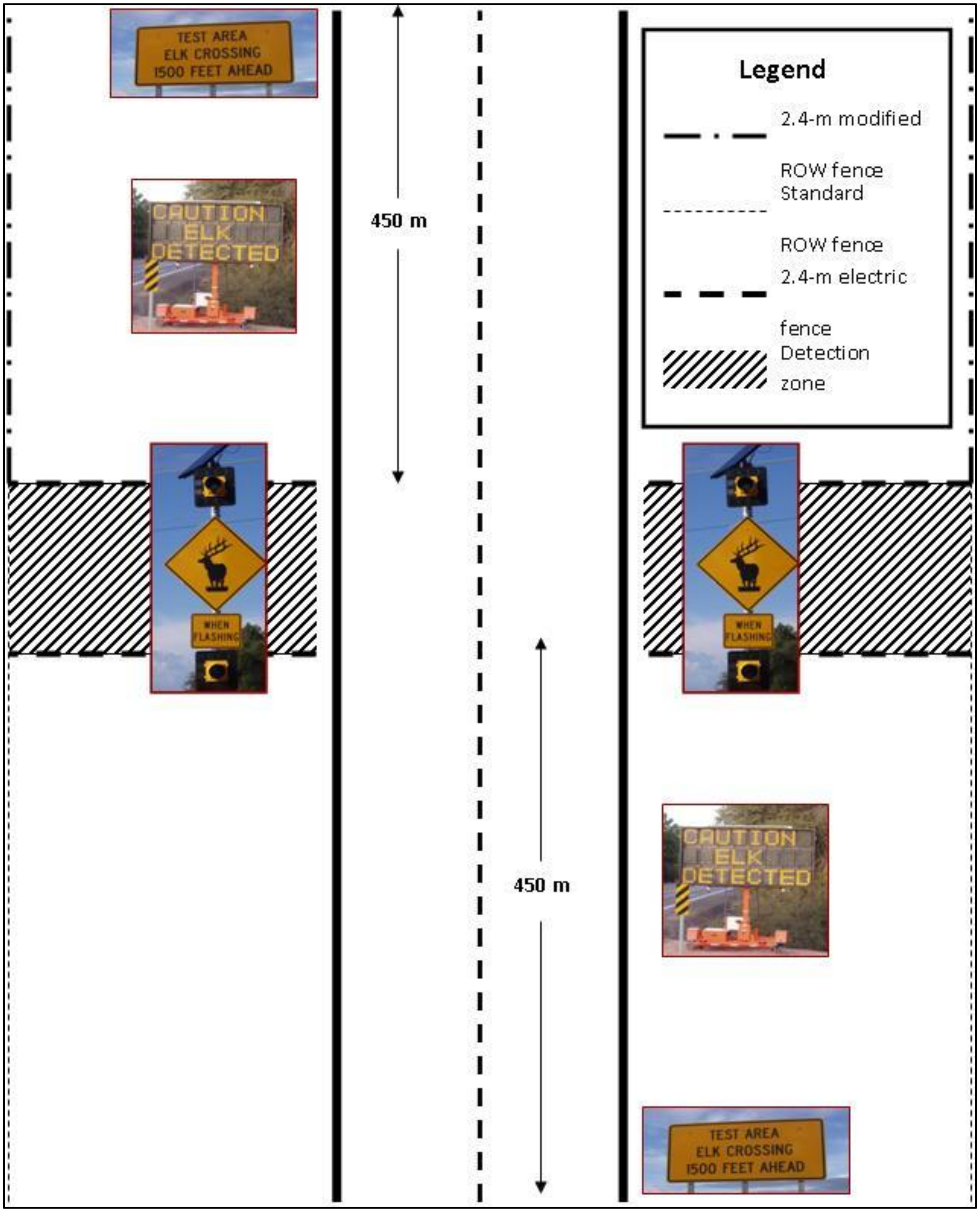

Figure 5. Layout of the motorist alert signage associated with the Preacher Canyon animal-activated detection system and crosswalk along State Route 260, central Arizona, including static signs 450 m from the crosswalk, variable message sign 180 m from the crosswalk, and flashing warning sign at the crosswalk.

Evaluation Methodology and Results Summary

Wildlife-Vehicle Collision Incidence Before and After ROW Fence Modification

Because of the risk of injury and even death to motorists and wildlife, the ultimate measure of any WVC mitigation project including fencing and AADS is the ability to reduce the incidence of WVC. All other factors, including system reliability and altered motorist behavior are moot if the incidence of WVC is not reduced. Achieving a reduction in WVC along the Preacher Canyon section was the primary focus of this enhancement project. With the long-term (>15 years) ADOT road kill database and our research project database maintained since 2000, we documented WVC after reconstruction of the Preacher Canyon section but before fence modification (Dodd et al. 2009). We compared 6 years of before-fence modification data to the 2 years of data collected following completion of the enhancement project. In addition, ADOT crash records were used to determine the proportion of single-vehicle accidents that involved wildlife before and after implementation of the project.

Since completion of fence modifications, 2 WVC were recorded along the Preacher Canyon section, one involving an elk and the other a black bear (*Ursus americanus*). The bear was killed along the stretch of ROW where the barbed-wire fence was raised. This fence type is considered "semi-permeable" to animals other than elk where they can either climb over (e.g., bears) or go under the fence (e.g., deer). The single EVC occurred in March 2007 along the stretch with raised electric fence soon after it was completed; in the 24 months since, no EVCs have been recorded along the entire 4-km section. The after-fence modification EVC incidence represents a nearly 96% reduction compared to the before-modification (2001-2006) mean of 11.7 EVC/year. The proportion of all single-vehicle accidents that involved wildlife dropped from a mean of 0.47 (2001-2006) to 0.17 (2007-2008), or an overall reduction of 64%. We also documented a 42% decrease in EVC on the adjacent unfenced Lion Springs section of SR 260, indicating that there was no displacement of accidents to this section.

Effectiveness of Motorist Alert Signage in Modifying Driver Behavior at the Crosswalk

Central to reducing or eliminating WVC by deployment of an AADS is its ability to achieve modified driver behavior. Two components of driver response to an AADS can be measured: 1) increased driver alertness, and 2) lowered vehicle speed (Huijser et al. 2006*a*). Modified motorist response to AADS in turn can ultimately result in either avoiding a collision altogether, or hitting the animal at a slower speed thus reducing the risk of injury (Huijser et al. 2006*a*). To determine the effectiveness of our AADS, we assessed motorist response prior to and at the crosswalk by conducting paired sampling with and without activation of the motorist alert signs. Using a permanent automatic traffic counter, we determined average vehicle speeds during paired 15-min sampling periods. To assess motorist braking (our surrogate measure for motorist alertness) we hid and observed the proportion of vehicles braking during 15-min sampling periods.

Motorist speeds were reduced by 15% (13 km/hr) in the westbound lane and 18% (16 km/hr) in the eastbound lane when the motorist alert signs were activated. In the westbound lane, 76% of motorists braked when the signs were activated versus only 8% when the signs were off. In the eastbound lane with better approach visibility to the crosswalk, 58% of motorists exhibited a braking response when the signs were activated versus only 8% when the signs were off. Overall, the AADS and associated warning signs successfully achieved modified driver behavior thereby reducing the risk of collision with wildlife.

Operational Reliability of the Animal-Activated Detection System

Although secondary to the reduction in WVC, the operational reliability of an AADS can likewise influence its success. Should motorists be frequently exposed to activated signs when animals are not present ("false positives"), they may become complacent and ultimately ignore the system when animals are present. Worse is presence of wildlife without the system being activated ("false negatives"), leading to unaware motorists encountering wildlife in the detection or crosswalk zone. We used two methods to assess AADS reliability: 1) periodic field visits, and 2) video surveillance of wildlife entering and passing through the detection zone. Periodic visits were made to the crosswalk site where warning sign operational status was noted (e.g., activated, not activated, system under repair). To determine if signs were activated when wildlife was present we used a 4-camera infrared video surveillance system that allowed simultaneous determination of animal presence and warning sign status, similar to Dodd et al (2007*a*).

Between May 2007 and September 2008, we made 250 test visits, including days when traffic and braking counts were conducted. We encountered few instances when the AADS and signs were inoperable; overall, the crosswalk system performed properly on 94% of our test visits. Our camera system documented 104 groups of elk and 40 groups of white-tailed deer entering the detection zone and approaching to within 15 m of the roadway; in 97% of these instances, the animals were detected by the AADS resulting in the motorist warning signs being activated prior to the animals reaching the roadside.

Wildlife Use of the Crosswalk and West Wildlife Underpass Following Fence Modification

Although RADS have been implemented in various locations throughout the world, wildlife behavior associated with at-grade highway crossings has not been thoroughly investigated. Wildlife interaction with the roadway and associated traffic volume may be an important indication of the applicability of AADS and crosswalks under different scenarios. We used a 4-camera video surveillance system to: 1) calculate passage rates (crossings/approach) of animals that approached the highway through the detection zone and ultimately crossed the highway, 2) document the incidence of animals that crossed around the end of the crosswalk fencing and traveled along the side of the highway within the right-of-way, and 3) evaluate traffic volumes associated with elk and deer at-grade crossings at the crosswalk. To determine passage rates at the crosswalk, we used methods similar to calculations made for wildlife underpasses along SR 260 in previous research by calculating the proportion of highway crossings to approaches through the detection zone (Dodd et al. 2007*a*, 2009). This allowed for a direct comparison of passage rates at the crosswalk and underpasses, and provided insight as to the efficacy of the crosswalk as an alternative to crossing structures.

The west Little Green Valley underpass was located at the east end of the 4-km stretch of modified ROW fencing. We originally began our video surveillance monitoring here in late-2002 during previous research along SR 260 (Dodd et al. 2007*a*). We continued monitoring of this underpass to determine changes in wildlife use and passage rates with the increase in the height and length of impermeable fencing that might funnel animals toward the underpass.

Through October 2008, we recorded 448 animals and 8 species on videotape within the crosswalk detection zones, including 307 elk, 68 white-tailed deer, and 56 javelina (*Tayassu tajacu*). Of the 351 animals (193 groups) that approached the crosswalk from the south side, 18% successfully crossed the highway, whereas 20% went around the end of the electric fence and into the highway corridor. Passage rates (crossings/approaches) across SR 260 at the crosswalk were 0.21 and 0.10 for elk and deer, respectively. The probability of an elk crossing the highway once it approached the detection area was 0.25 when traffic volumes were low (<1 vehicle/min) and dropped to 0.02 as traffic volumes increased to 12 vehicles/min. Deer showed an even greater avoidance to increased traffic volume with only 6 highway crossings at a maximum traffic volume of 0.7 vehicles/min, or approximately 42 vehicles/hr. All elk crossings occurred during the hours when traffic volumes were at their lowest (2400–0400 hr) with the exception of two elk that crossed at 0700 hr. Average hourly traffic volumes during this four-hour period averaged 32 vehicles/hr, whereas the average hourly traffic volume for the entire 24-hour period along this same stretch of highway was 308 vehicles/hr.

Although elk showed no difference in use of the west underpass and maintained a >80% passage rate, white-tailed deer showed a dramatic increase in use of the underpass following fencing modification. Overall, 61 deer used this structure in the year following completion of fencing versus a total of 6 crossings dating back to the installation of our video system in 2002. The odds of a successful crossing for deer following completion of fencing was 38:1 of that prior to fencing.

Conclusions and Recommendations

Now more than two years after implementation, this enhancement project has performed well and resulted in a significant 96% reduction in the incidence of EVC. Further, the experimental AADS and crosswalk have performed reliably and effectively in detecting animals and alerting motorists to the presence of crossing wildlife. Motorists responded both by reducing their speed and displaying alertness in response to the warning signs and crosswalk. All 3 ROW retrofit fence designs performed well and represented cost-effective alternatives to more costly traditional ungulate-proof fencing; continued monitoring will provide insights into their long-term durability. Currently, EVC have been reduced to a level where the reduction has yielded a near $445,000 economic benefit in its first two years; this rate will exceed initial project costs within 3-4 years and show a benefit of close to $2 million over the next 10 years if similar reductions in EVC are maintained (Gagnon et al. 2009). We recommended that the system remain in place with continued monitoring to reduce WVC and potential injuries to motorists and impact on wildlife populations (Gagnon et al. 2009). The passage of 20% of the animals moving through the detection zone around the end of the crosswalk fence is problematic; this breeching of the fenced ROW corridor will be addressed in the near future with and electrified ElectroMat® installed across the highway. Lastly, though effective along SR 260, the average annual daily traffic (AADT) volume here (7,500 vehicles/day) appears to be the upper limit where such benefit and success can be obtained from the application of AADS and a crosswalk.

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Biographical Sketches

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EFFECTIVENESS OF MITIGATION MEASURES TO REDUCE ROAD MORTALITY IN THE NETHERLANDS: BADGER *MELES MELES*

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Parts of this paper are based at the article that will be published in *Lutra*, the scientific magazine of the Dutch Mammal Society: "Badger *Meles meles* road mortality in the Netherlands: victim characteristics and effects of mitigation measures" (Jasja J.A. Dekker & Hans G.J. Bekker; 2009)

Abstract

In the 1900's, the badger population of the Netherlands was estimated to count 2500 to 3000 setts with over 4000 individuals. Between then and the 1960's, the number declined drastically and stayed low until the mid-1980's with about 400 setts in the whole of the Netherlands. In the 1980's a high percentage of the population, locally up to 25%, was killed yearly by road traffic. For this reason the Dutch government implemented mitigation measures such as fauna tunnels and fences. It was easy to monitor the use of such measures. By census we know that the population increased to around 5000 individuals in 2006. But were these "badger tunnels" effective: did the number of traffic victims at these tunnels decrease?

To answer this question we analyzed data on badger traffic victims gathered by NGO "Das & Boom" and the Center for Transport and Navigation (Rijkswaterstaat) between 1990 and 2006. First, we determined the distribution of victims over motorways, provincial roads and local roads. In absolute terms, most victims were reported from local roads. However, relative to the length of road in the range of the badger, most victims occur at provincial roads.

Second, we tested whether taking mitigating measures resulted in a decrease of traffic victims. Realization of fauna tunnels resulted in a small but significant decrease in the local number of victims, but effects varied from site to site: at most sites, the number of victims was lower, but at some the number of victims was higher after implementation of the measure. Analysis on a local scale should provide a clearer picture of the effect of mitigation measures on badger mortality.

Such a study was done in the area 'Eindegooi' where the increase of the population of badgers is spectacular. It appears that the increase is related to a package of measures taken in that area.

The challenge for conservation now lies in minimizing victim numbers at local roads. As badger victims occur over a huge length of local roads, mitigation will be difficult. Still, a number of measures are feasible, for example locally designed tunnels and fences, decreasing speed limits or closing roads for through traffic, especially at 'black spots' with high numbers of victims.

Keywords: badger, road mortality, de-fragmentation measures, traffic victims, wildlife passage, road ecology, effectiveness

Introduction

Between 1900 and the 1960's, the number of badgers declined drastically (Van Wijngaarden & Van de Peppel 1964) and stayed until the mid-1980's (Van Wijngaarden et al. 1971, Wiertz & Vink 1986), with about 400 setts in the whole of the Netherlands. In the 1900's, the badger population of the Netherlands was estimated to be 2500 to 3000 setts with over 4000 individuals.

A number of causes for this decline have been suggested (Van Wijngaarden & Van de Peppel 1964, Wiertz & Vink 1986, Van Apeldoorn et al. 1995): hunting and poaching, disturbance and destruction of setts, habitat loss, and pollution, isolation of metapopulations and hampered migration, and traffic. In the 1980's, it became clear that a high percentage of the population was killed by traffic: locally up to 25% (Bekker & Canters 1997, Broekhuizen et al. 1994, Van Apeldoorn et al. 1995).

In 1990 at national level both nature policy in the Nature Policy Plan (Ministerie van Landbouw, Natuur en Visserij 1990) and transport policy in the Second Transport Structure Plan (Ministerie van Verkeer en Waterstaat 1990) underlined the necessity to halt further habitat- and population fragmentation by roads and to diminish existing fragmentation. These combined governmental policies paved the way for de-fragmentation programs and actions (Bekker & Canters 1997).

In the 1990s and 2000s, the distribution and population size of the badger has strongly increased (Wiertz 1992, Van Moll 2005, Witte et al. 2008) (figure 1). This increase may be attributed to the resolving of most of the assumed causes of decline, such compensation of damage to crops (between €13.000 and €71.000 yearly; Faunafonds 2006) and contracting management scheme agreements with farmers with setts on their land (with approximately 500 farmers in 2001-2005, Faunafonds 2006), the decrease in PCBs and heavy metals (except in floodplains, Van den Brink & Ma 1998), raising and translocation of orphaned or threatened badgers (see Van Moll 2005) and the countering of habitat loss and implementing of large mitigation measures at problem points in the major roads.

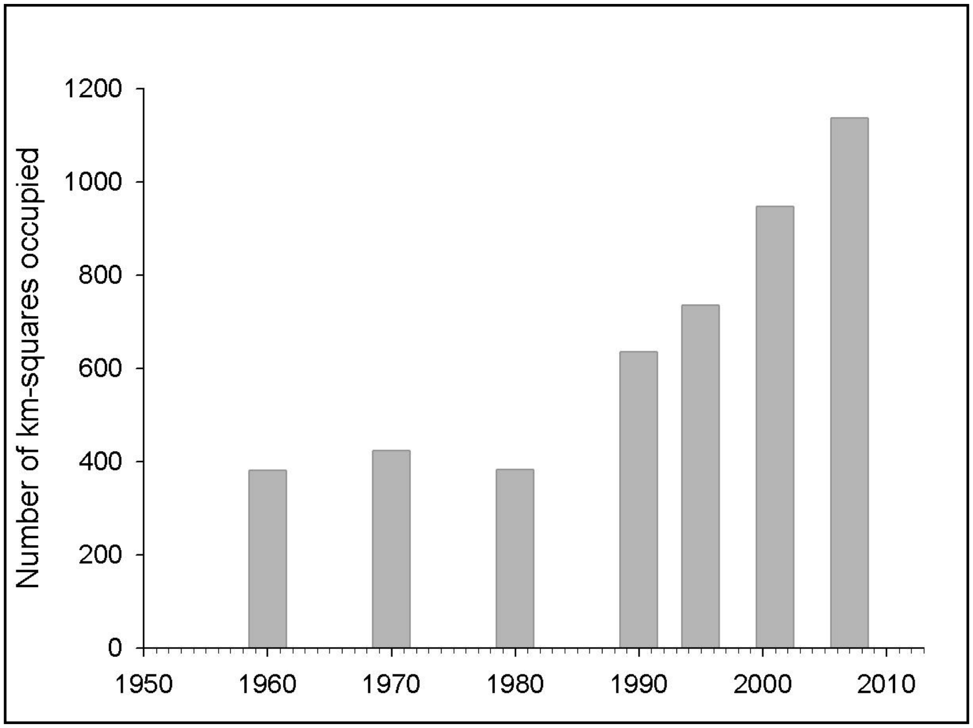


Figure 1. Number of 1km x 1km squares in the Netherlands, occupied by the badger from census. Sources: Van Wijngaarden & Van de Peppel (1964); Van Wijngaarden, Van Laar & Trommel (1971); Wiertz & Vink (1986), Wiertz (1991); Van Moll (2005) and Witte et al. (2008).

The most used mitigation measures aimed at badgers are tunnels under roads, combined with fencing (Kruidering et al. 2004) (figure 2). These tunnels are known to be used by badgers (Maaskamp 1983, Derckx 1986, Van Dinther 1994, Bekker & Canters 1997, Brandjes et al. 2002).

However, it has not been reported what part (in terms of percentage, age and sex) of the population is killed by traffic, or if there is a difference between road types, nor has it been tested whether implementation of tunnels actually decreases mortality. With this knowledge, conservation and mitigation measures can be optimally implemented, using them at certain road types, certain times of the year of certain parts of badger range, using badgers as a model species for other terrestrial mammals.

In this paper, we present and analyse data on badger traffic victims gathered by NGO “Das & Boom” (Bekker & Canters 1997, Vereniging Das & Boom 1990-2006) and the Centre for Transport and Navigation. First, we determine the national distribution of victims over motorways, provincial roads and local roads. Secondly, again at national spatial scale, we test whether taking mitigating measures resulted in a decrease of traffic victims.

Thirdly, we “zoom in” to a local situation, to provide the insight of these measures at the local badger population.

Figure 2. New badger tunnel.

Methods

Censuses, traffic victims, mitigation measures and roadmaps

The datasets of badger victims and of the mitigation measures taken were not gathered specifically for the goal of this study. The NGO Das & Boom and Rijkswaterstaat gathered the data on traffic victims. Victims were generally found by the public, by inspectors of Rijkswaterstaat or by a network of volunteers, and reported to Das & Boom. The location in coordinates with 10 meters precision, road name, date, road type and road manager were then documented. The dataset covers the period from 1 January 1990 until 31 December 2006.

The changes in badger range and number of the last 40 years has been well documented by the badger censuses: using systematic surveys, all suitable badger habitats were checked for inhabited setts in 1960 (Van Wijngaarden & Van de Peppel 1964), 1970 (Van Wijngaarden et al. 1971), 1980 (Wiertz & Vink 1986), and 1990, Wiertz (1992), 1995, 2000 (Van Moll 2005) and 2007 (Witte et al. 2008) (figure 1). We assume that the 2007 census represents the range of 2006 well. The ranges and estimates of the population size are used in this paper to correct for the increase in numbers and range that occurred during the study period.

The Centre for Transport and Navigation, Delft, provided spatial data of the complete Dutch road grid and the spatial data of the mitigation measures for motorways (database Wegensnip; Rijkswaterstaat 2007). Das & Boom provided the data for the provincial and local roads. This dataset contained the type of mitigation measure, location, road type and year of construction.

Distribution of victims

First, we report the number of victims per year. Then, we summarize the number of victims of the period 1990-2006 per month.

We separately analyze victims that were reported outside the known range for the years for which we have census. Badgers are considered to be outside the known range when they are reported on a location farther than two kilometres from the known range, as two kilometres is the maximum distance resident badgers move away from their setts in the Netherlands (Van Wijngaarden & Van de Peppel 1964, Wansink 1995) and elsewhere in western Europe (Neal & Cheeseman 1993, Palphramand et al. 2007).

Next, to correct for effects of population growth and increasing distribution on victim numbers, we express the number of recorded victim as a percentage of the population. We do this by dividing the number of victims by population size for the years a census was done. Following the approach from Wiertz & Vink (1986) we assume that there is usually one sett per km^2, and that 3.2 badgers inhabit one sett. So, to calculate which percentage of the population the recorded victims constitute, we divide the number of badger victims by the number of populated km^2 x 3.2 badgers km^{-2} x 100%.

Road types

In the analyses, we distinguish three road types: motorways (major roads), provincial (county) roads and local (municipal) roads. These roads have different speed limits of respectively 120 or 100 km $hour^{-1}$, 100 or 80 km $hour^{-1}$ and 50 to 30 km $hour^{-1}$, and different traffic density.

Traffic victims and road maps were entered in a GIS, and each victim was attributed to the nearest road. To gain insight in the effect of road type on number of traffic victims, we first calculated the absolute number of traffic victims per road type. There are much kilometers of more municipality roads than there are county or major roads, so it is likely that more victims will fall on these roads than on the other types. To correct for this, we also calculated the number of victims per kilometre of road that lie within the known distribution of badgers, for the years when a census was done.

Effect of mitigation measures

We tested the effect of mitigation measures on badger mortality by comparing the number of victims around the place of the road with a mitigation measure with and without the measure, i.e. before and after implementation. We used 2 kilometres of road on both sides of the mitigation measure, as this is the maximum range a badger moves from it's sett in the Netherlands (Van Wijngaarden & Van de Peppel 1964): we assume that the victim number on roads further from the mitigation measure than this maximum range of movement from the sett are not 'influenced' by this measure.

When testing the effect of mitigation measures, the recent increase in numbers and the expansion of the range of badgers could be a confounding factor: a road can show more victims after the implementation of a mitigation measure if badgers were absent in the area in the years before the implementation and present in the years after. To correct for this, we select only those mitigation measures that were in the distribution area of the badger in the census of 1990. These locations could have had badger victims over the whole period.

First, we compare the number of victims at these locations in the two years before the implementation with the number of victims in the two years after the implementation.

Next, we test the effect of mitigation measures on the number of victims using a Generalized Linear Model (McCullagh & Nelder 1983) approach. Sampling units are 2 kilometre stretches of road surrounding the measure taken. The number of victims per year at these stretches is modelled as a function of the presence-absence of the measure. We used a hierarchical design, with number of victims and presence of measures per year nested in locations. Because the data follows a Poisson-distribution with inflated zeros, we use a Poisson-distributed error term and a log-link function.

At the sites selected for our analyses, i.e. where victims were reported between 1990 and 2006, the number of mitigation measures increased: in 2006, 138 locations with mitigation measures existed, but in 1990 only 11 of these were in place. To correct the bias caused by changing numbers of mitigation measures over years, we select the year in which the number of locations with mitigation measures in present and mitigation measures absent is almost equal: 1998. To further correct for effects of population growth and range expansion we only used those stretches of road surrounding mitigation measures where a victim occurred at least once in the period of 1990-2006.

All statistical analyses were done in statistical package R (R Development core team 2006).

Results

Distribution of victims

The number of badger recorded as victims of traffic shows a steady rise over the period from 1960 to 1990, but stabilizes in the 2000's (figure 3). Of course, these numbers are the minimal number of victims: not all animals that are found are reported, and not all animals hit by cars are found.

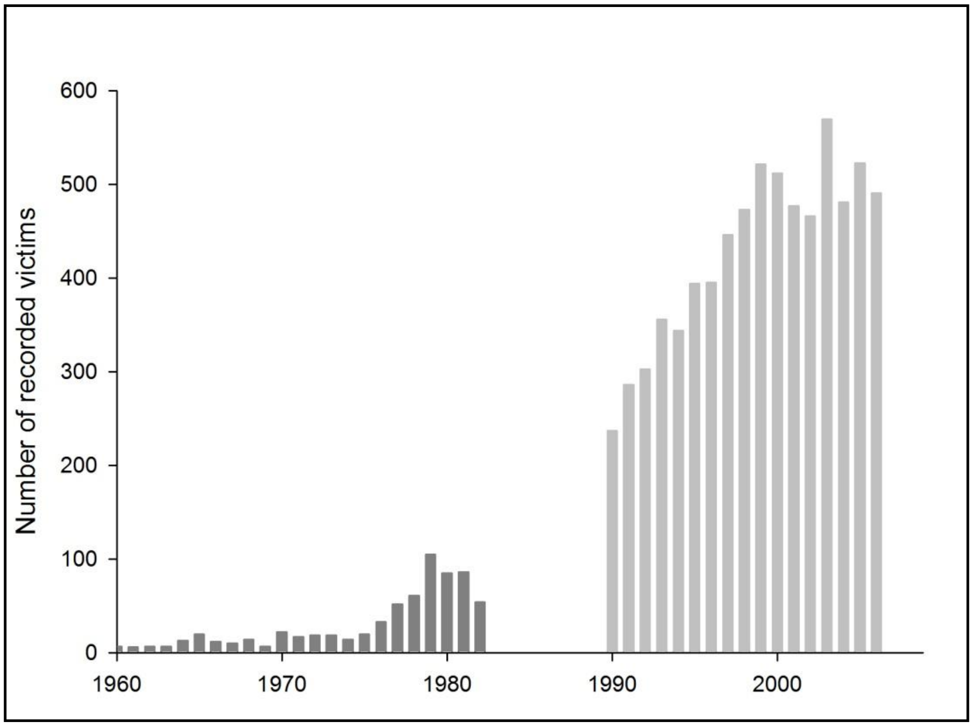


Figure 3. The number of recorded badger traffic victims in the period of 1960-1982 and 1990-2006. Dark grey: data from Wiertz & Vink (1989). Light grey: data from Das & Boom and Centre for Transport and Navigation. No data is available from 1983-1989.

Of the 7279 badger victims reported from 1990 until 2006, trains killed 142 animals. Another 140 victims in the dataset were badgers that had drowned in canals. These animals were not included in the analysis of the effect of mitigation measures on mortality.

The distribution of victims over the Netherlands generally follows the range of badgers, although some victims occur far outside the distribution (figures 4a and 4b). For example, in 1995 45 victims were found outside the known badger range.

In 1990, the recorded badger traffic victims are estimated to be 12% of the estimated Dutch badger population. In 1995, the estimated percentage of the population that is killed by traffic was higher than in 1990: 18%. In the 2000's, the estimated percentage declined again: 17% of the population was killed in 2001, and 13% in 2006 (figure 5).

Road types

In absolute terms, most victims fall at local roads, then at provincial roads and least at motorways (figure 6a). When corrected for the length of each road type in the distribution area of badgers in the Netherlands, a different pattern emerges: the lowest number of victims per kilometre of road occurs at local roads, and the most on provincial roads (figure 6b).

Effect of mitigation measures

We compared the number of victims two years before and 2 years after mitigation measures were taken in the badger range. At 56 measures, the same number of victims occurred before and after mitigation measures were implemented: zero victims. At 31 measures, more victims were found after than before measures were implemented. At 40 measures, fewer victims were found after the measure was implemented.

The generalised linear model shows that mitigation measures taken within the range of badgers resulted in a decrease of the number of traffic victims (table 1).

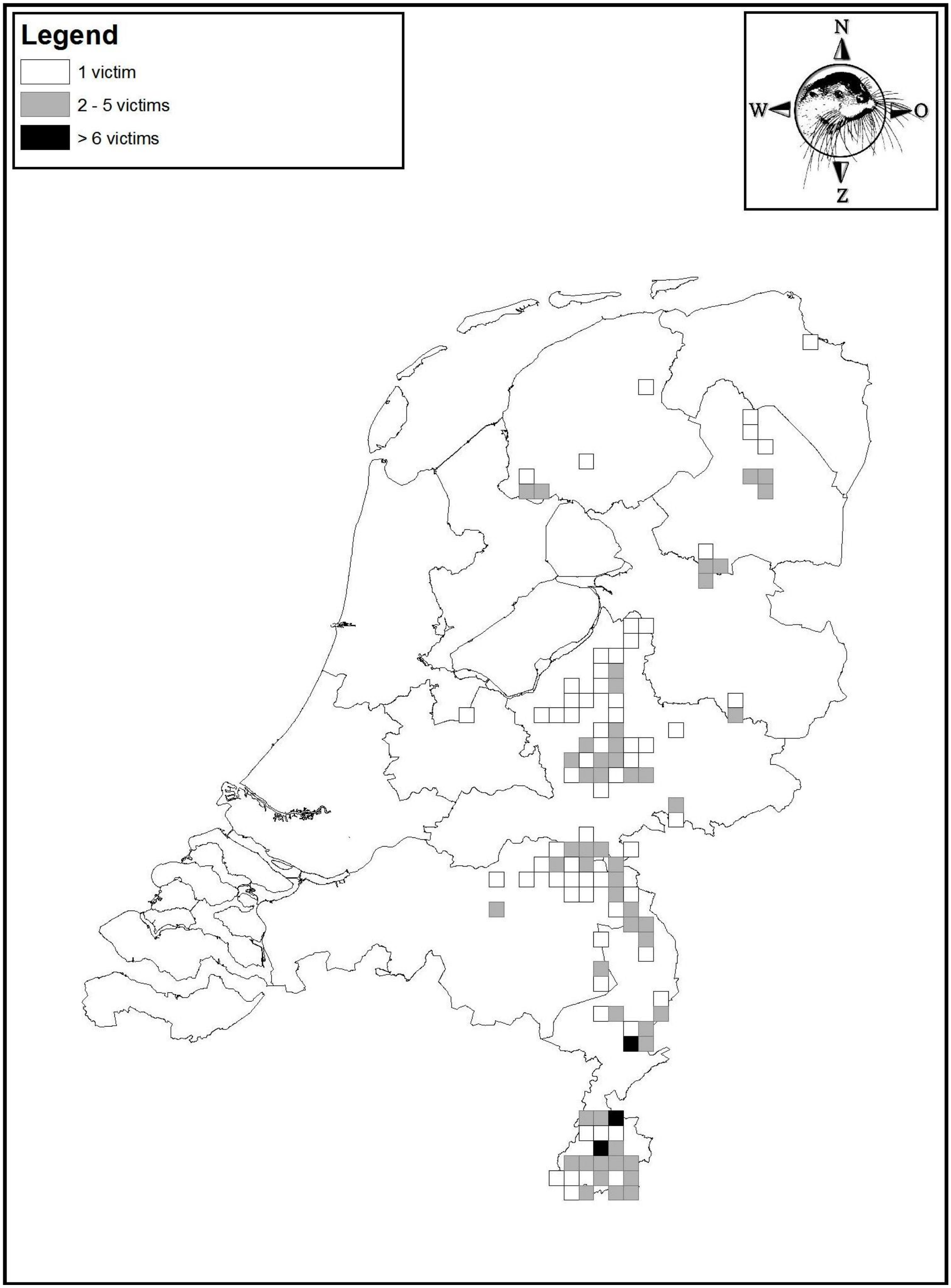


Figure 4a. Distribution of victims in 1990.

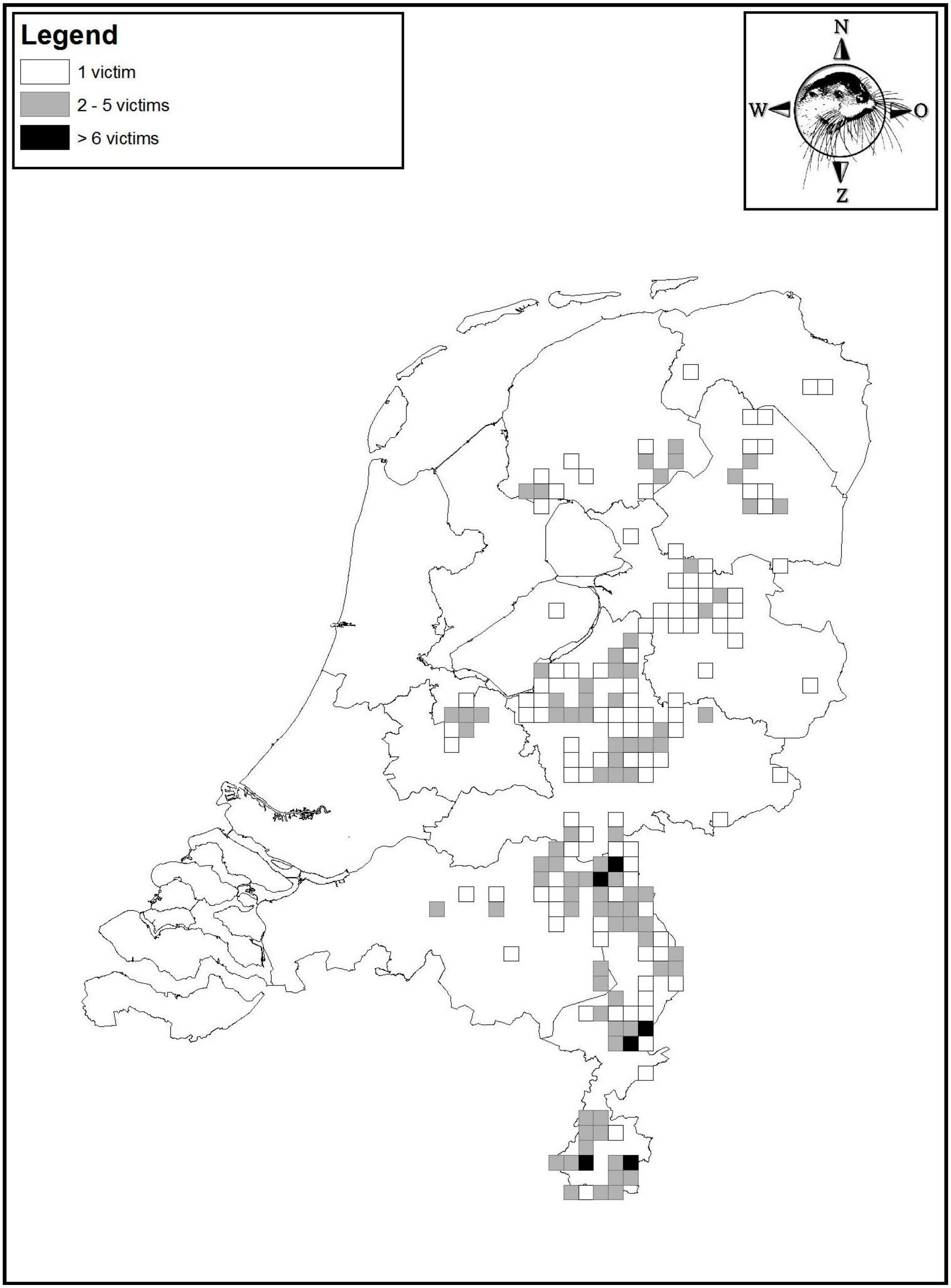


Figure 4b. Distribution of victims in 2006.

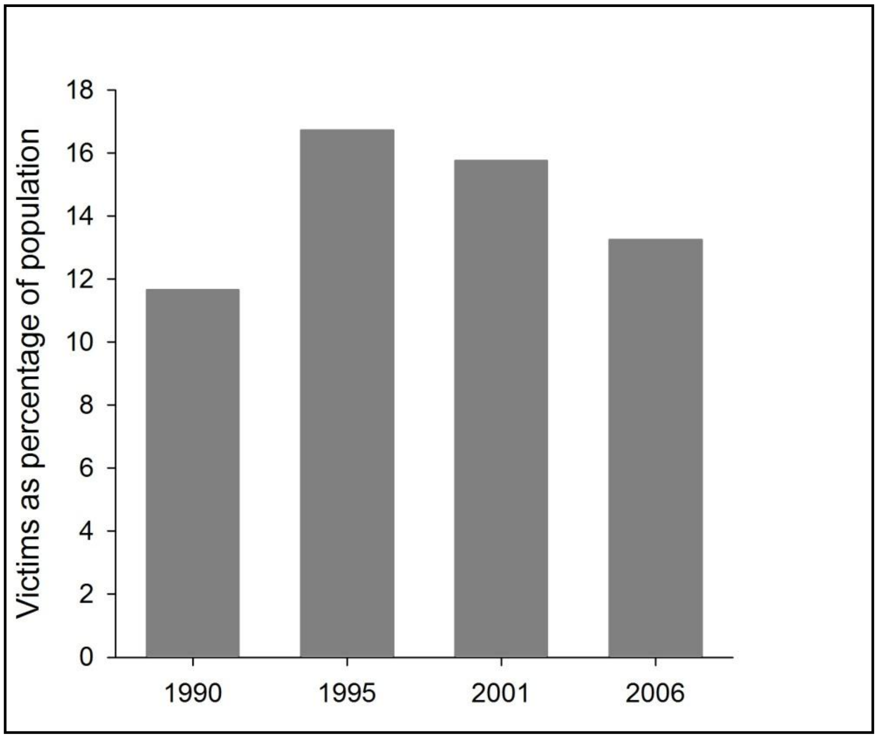
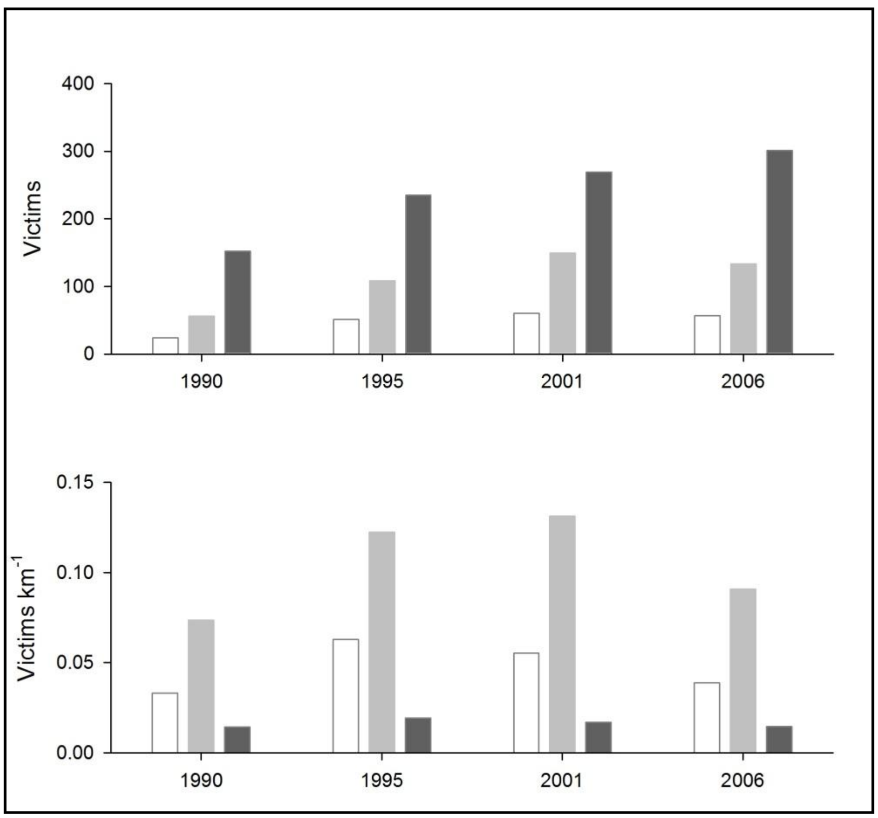


Figure 5. Estimate of the percentage of the Dutch badger population that is killed by traffic for census years.



Figures 6a and 6b. a) Absolute number of victims per road type. b) Number of victims per road type, divided by the total length of that road type in the badger's range. White: motorways, light grey: provincial roads, dark grey: local roads.

Coefficients of the Model	Estimate	Std. Error	z value	*p*
Site: absent	-1.128e-03	8.402e-05	-13.431	<0.001
Site: present	-1.173e-03	8.759e-05	-13.388	<0.001
Residual degrees of freedom: 1969; Null deviance: 2604.4 on 1971 degrees of freedom; Residual deviance: 2394.2 on 1969 degrees of freedom.				

Table 1. Output of GLM analyses. We modelled the number of victims at a site as a function of presence of mitigation measure as a factor, nested within sites.

Discussion

Victims

We estimate that at least between 12% and 18% of the Dutch badger population was killed yearly in the period 1990-2006. These percentages are an absolute minimum: possibly, not all victims that are found are reported. Animals that are hit by cars but not killed directly and move themselves away from the roadside will not be found. Also, the amount of juveniles that became orphans and subsequently died is of course not included in our estimates. This does not take into account losses of litters: Broekhuizen *et al* (1994) estimated that yearly at least 10% of all litters were lost because lactating females were killed at roads.

Road type

Most victims occurred on local roads. This is hardly surprising: this type of roads simply constitutes the most length in the range. This also makes it the hardest road type to manage for decreases in traffic victims. The number of victims per km of road is highest on the provincial roads. What's more, this number increased over the study period. We attribute this to the ease of access for wildlife on provincial roads and to the openness of major roads. In the Netherlands, major roads must be lined with an obstacle free zone of ten meters (Dienst Verkeerskunde 1992; Adviesdienst Verkeer en Vervoer 2006). This makes traffic more visible for wildlife and vice versa. In the south of the UK, most victims occurred on smaller roads as well, and much fewer on motorways (Clarke *et al*. 1998).

Policy-wise, management aimed at lowering numbers of badger traffic victims should be aimed primarily to the provincial roads: here, the number of victims per km of road is highest. The number of victims on the provincial roads and local roads could be lowered with management measures such as implementation and maintenance of road mitigation measures (Kruidering et al. 2005), lowering of speed limits, or by closing off certain stretches of roads (Jaarsma et al. 2007) during the night and/or in sensitive periods. To be most effective, measures should be planned at relevant landscape elements (ditches, tree lines, etc.), following a landscape-oriented approach (Kruidering et al. 2005).

Effect of mitigation measures

Mitigation measures have an effect on victim numbers at many locations: analyses of the full dataset showed fewer victims after mitigation measures were taken, and after implementation of measures there were fewer or equal numbers of victims at a number of sites. However, at other sites there were similar or more victims. These ambiguous results show that it is difficult to get full understanding when analyzing the effects of mitigation measures on victim numbers at a national scale only.

Aside from this, in these analyses there are some confounding factors. In our approach, the effects of the implementation of mitigation measures may have been obscured by the growth and expansion of the badger population in the Netherlands during the study period.

Van Apeldoorn et al (2006) and Vink et al. (2008) analyse a local, well-studied situation. This will give more insight in the effects of the measures on badger mortality. See Box 1.

<u>Box 1</u>; based at Vink, H.J., R.C. Van Apeldoorn, R.C. , G.J. Bekker, 2008.

For 24 years data on badger (Meles meles) and sett numbers were collected by direct observation of a local population in Eindegooi, in the provinces of Utrecht and Noord-Holland, the Netherlands. The population shows periods of slow but also exponential growth and spatial dynamics show colonization of the entire study area.

The expansion of the species throughout the area realised during the period of growth, which offset an increase in population density. At the same time the number of cars on all types of roads in the area also increased, but this did not result in higher traffic mortality, indirectly showing the positive effect of the protection measures that were taken. This is also illustrated by the fact that dead badgers were no longer found at locations where measures had been taken.

Analysis of the population dynamics in relation to de-fragmentation measures involving roads that were taken in the area suggests a positive contribution of tunnels and other measures. At low densities and during periods of slow growth these measures can increase the lifetime of reproducing individuals and help badgers to safely disperse and colonize new habitat patches. Their positive effect on the population is illustrated by a more or less constant individual chance to be killed by cars in spite of the increasing number of cars on motorways and provincial roads that dissect the study area.

Conclusion

In the Netherlands most victims fell on municipal roads, but when expressed per kilometre of road, most victims fell on county roads. Implementing mitigation measures resulted in a lower number of victims. There are several factors affecting the populations of Dutch badgers, so it is hard to say if only road management caused the recent increase of badgers in the Netherlands, but it is clear that mitigation measures decrease mortality in the Dutch badger. And, as has been argued by other authors, (Janssen 1997; Vereniging Das & Boom 2002; Ouden & Piepers 2006), it is important that these mitigation measures remain operational.

Most traffic victims are reported from provincial roads (in absolute numbers), and from local roads (in relative numbers). The victims occur over a huge length of these roads, especially in the case of local roads, making mitigation of their impact difficult. Still, some measures are feasible, for example decreasing speed limits or closing roads for through traffic (Jaarsma et al. 2007).

As traffic victims, badgers could be seen as a model species for all mustelids, and other terrestrial mammals. Implementation of more specific mitigation measures such as tunnels and fences require knowledge of the local badger population and of their spatial behaviour, for maximum effectiveness.

The dataset that was gathered by Das & Boom and the Centre for Transport and Navigation is a unique dataset. The dataset allows an in depth analyses of traffic victims and the possibly complex effects of road mortality on badger population dynamics. For example, mathematical models indicate that an increase of life expectancy of badgers will result in more females in the age of highest reproductive success, and therefore in a relatively big increase in the population (Seiler et al. 2003). However, this proposed mechanism has not been tested in the field. The challenge now lies in testing whether the decrease in mortality brought about by mitigation measures, together with the decrease in habitat fragmentation, indeed translates into positive effects on the population?

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Cost Justification and Examples of Cost-Benefit Analyses of Mitigation Measures Aimed at Reducing Collisions with Large Ungulates in the United States and Canada

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Abstract

Wildlife-vehicle collisions, especially with deer (*Odocoileus* spp.), elk (*Cervus elaphus*) and moose (*Alces alces*) are numerous and have shown an increasing trend over the last several decades in the United States and Canada. We calculated the costs associated with the average deer- ($6,617), elk- ($17,483) and moose-vehicle collision ($30,760), including vehicle repair costs, human injuries and fatalities, towing, accident attendance and investigation, monetary value to hunters of the animal killed in the collision, and cost of disposal of the animal carcass. In addition, we reviewed the effectiveness and costs of 13 mitigation measures considered effective in reducing collisions with large ungulates We conducted cost-benefit analyses over a 75-year period using discount rates of 1%, 3% and 7% to identify the threshold values (in 2007 $) above which individual mitigation measures start generating benefits in excess of costs. These threshold values were translated into the number of deer-, elk-, or moose-vehicle collisions that need to occur per kilometer per year for a mitigation measure to start generating economic benefits in excess of costs. For example, we calculated that wildlife exclusion fencing in combination with large mammal underpasses (one every 2 km) and wildlife jump-outs generates economic benefits if the pre-mitigation collisions are greater than 3.2 deer, 1.2 elk, or 0.7 moose per km per year (all at 3% discount rate). In addition, we calculated the costs associated with large ungulate-vehicle collisions on ten road sections throughout the United States and Canada and compared these to the threshold values. Finally, we conducted a more detailed cost analyses for one of these road sections to illustrate that even though the average costs for large ungulate-vehicle collisions per kilometer per year may not meet the thresholds of many of the mitigation measures, specific locations on a road section can still exceed thresholds. While the analyses can be expanded to include other parameters (e.g. the economic value of habitat connectivity or viable wildlife populations), we believe the cost-benefit model presented in this paper can be a valuable decision support tool for determining mitigation measures to reduce ungulate-vehicle collisions.

Introduction

Wildlife-vehicle collisions affect human safety, property and wildlife. The total number of large mammal-vehicle collisions has been estimated at one to two million in the United States and at 45,000 in Canada annually (Conover et al. 1995, Tardif & Associates Inc. 2003, Huijser et al. 2007). These numbers have increased even further over the last decade (Tardif & Associates Inc. 2003, Huijser et al. 2007). In the United States, these collisions were estimated to cause 211 human fatalities, 29,000 human injuries and over one billion US dollars in property damage annually (Conover et al. 1995). In most cases the animals die immediately or shortly after the collision (Allen and McCullough 1976). In some cases it is not just the individual animals that suffer. Road mortality may also affect some species on the population level (e.g. van der Zee et al. 1992, Huijser and Bergers 2000), and some species may even be faced with a serious reduction in population survival probability as a result of road mortality, habitat fragmentation and other negative effects associated with roads and traffic (Proctor 2003, Huijser et al. 2007; van der Grift et al. 2008). In addition, some species also represent a monetary value that is lost once an individual animal dies (Romin and Bissonette 1996, Conover 1997).

Over 40 types of mitigation measures aimed at reducing collisions with large ungulates have been described (see reviews in Knapp et al. 2004, Huijser et al. 2007). Examples include warning signs that alert drivers of potential animal crossings, wildlife warning reflectors or mirrors (e.g. Reeve and Anderson 1993, Ujvári et al. 1998), wildlife fences (Clevenger et al. 2001), and animal detection systems (Huijser et al. 2006). However, the effectiveness and costs of these mitigation measures vary greatly. When the effectiveness is evaluated in relation to the costs for the mitigation measure, important insight is obtained regarding which mitigation measures may be preferred, at least from a monetary perspective. Nonetheless, very few cost-benefit analyses exist (but see e.g. Reed et al. 1982), and while this may seem surprising, wildlife-vehicle collisions, at least until recently, are not always included in safety analyses by transportation agencies, let alone in cost-benefit analyses (Knapp and Witte 2006).

In this paper we provide a justification for the monetary costs and benefits of a range of mitigation measures aimed at reducing collisions with the most commonly reported large ungulates in the United States and Canada: deer (white-tailed deer (*Odocoileus virginianus*) and mule deer (*O. hemionus*) combined), elk (*Cervus elaphus*), and moose (*Alces alces*) (Huijser et al. accepted). We realize that the results of the associated cost-benefit analyses are directly dependent on the parameters included in the analyses and the assumptions and estimates required to conduct the analyses. For example, our cost-benefit analyses do not include passive use costs. However, we do evaluate each mitigation measure with regard to potential safe crossing opportunities for wildlife. Connectivity across roads for wildlife is also in the interest of human safety as animals are more likely to break through a barrier (e.g. wildlife fencing) if safe crossing opportunities are not provided or if they are too few, too small, or too far apart. Even if wildlife fencing is combined with safe crossing opportunities for wildlife, animals may still end up in between the fences, caught in the transportation corridor, and these animals pose a risk to human safety. For these reasons, it is considered good practice to accompany absolute barriers with safe crossing opportunities for wildlife and escape opportunities for animals that end up in between the barriers (e.g. wildlife jump-outs). For this paper we addressed the importance of safe crossing opportunities for wildlife by reviewing the individual mitigation measures for their potential barrier effect on the movements of large ungulates and including jump-outs with wildlife fencing.

The results of the cost-benefit analyses allow for much needed direction for transportation agencies and natural resource management agencies in the implementation and further research and development of mitigation measures aimed at reducing collisions with large ungulates.

Cost Benefit Analyses

We reviewed approximately 40 different types of mitigation measures or combinations of mitigation measures that aim to reduce collisions with large animals (deer and larger) (for full review see Huijser et al. 2007). Based on the available data, 13 of these measures were considered effective in reducing collisions with large animals (effectiveness >0%) (see section "Effectiveness and Costs of Mitigation Measures"). In addition, we estimated the costs (in 2007 US$) of these mitigation measures per year over a 75-year period (see section "Effectiveness and Costs of Mitigation Measures"). We also estimated the benefits generated by the 13 mitigation measures. The benefits are a combination of the effectiveness of the mitigation measures in reducing collisions with large ungulates and the costs associated with the average collision. The cost of a collision with a large ungulate typically increases with the size and weight of the species. For more details on methods see Huijser et al. (accepted).

Effectiveness and Costs of Mitigation Measures

We estimated the effectiveness of 13 types of mitigation measures for reducing collisions with large ungulates such as deer, elk and moose, and whether these mitigation measures still allow animals to cross the road (Table 1). Mitigation measures considered ineffective (effectiveness estimated at 0% (Huijser et al. 2007)), lacking effectiveness data, or having insufficient data were excluded from the cost-benefit analyses in this paper. If more than one estimate was available for the effectiveness of each of the 13 mitigation measures reviewed, the mean was calculated. Since the effectiveness of some of the mitigation measures is highly variable or based on only one study, additional studies may lead to an adjustment of these values at a later time. Of the 13 measures listed, only wildlife fencing is an absolute barrier for large ungulates (Table 1).

Each mitigation measure's suitability depends on the species concerned, the specific objectives of a project, and local circumstances. This paper does not discuss the advantages and disadvantages of each mitigation measure, but it is important to be aware that some mitigation measures may only be suited for very specific circumstances.

The estimated costs for each of the mitigation measures over a 75-year period vary greatly (Table 1). The following paragraphs provide a rationale for the estimated costs of the individual mitigation measures. The costs of the mitigation measures included design, construction or implementation, maintenance, and removal efforts. The 75-year period is equal to the longest lifespan of the mitigation measures reviewed (i.e. underpasses and overpasses).

We estimated the cost of the mitigation measures listed in Table 1 based on a review of the literature and interviews with researchers, manufacturers, and transportation agency personnel (for more detailed review see Huijser et al. 2007). The costs were standardized as costs per kilometer road length. Unless indicated otherwise, all cost estimates were expressed as US$ as reported in the cited work. For our analyses we converted all costs to 2007 US$ using the U.S. Consumer Price Index (U.S. Department of Labor 2008).

Mitigation measure	Effect-iveness	Crossing opportunity?	Source	Present value costs (US$)
Seasonal wildlife warning sign	26%	Yes	Sullivan et al. (2004): 51%; Rogers (2004): 0%	$3,728
Vegetation removal	38%	Yes	Jaren et al. (1991): 56%; Lavsund and Sandegren (1991): 20%	$16,272
Fence, gap, crosswalk	40%	Yes	Lehnert and Bissonette (1997): 42%, 37%	$300,468
Population culling	50%	Yes	Review in Huijser et al. 2007	$94,809
Relocation	50%	Yes	Review in Huijser et al. 2007	$391,870
Anti-fertility treatment	50%	Yes	Review in Huijser et al. 2007	$2,183,207
Fence (incl. dig barrier)	86%	No	Reed et al. (1982) 79%; Ward (1982): 90% Woods (1990): 94-97%; Clevenger et al. (2001): 80%; Dodd et al. (2007): 87%	$187,246
Fence, underpass, jump-out	86%	Yes	Reed et al. (1982) 79%; Ward (1982): 90% Woods (1990): 94-97%; Clevenger et al. (2001): 80%; Dodd et al. (2007): 87%	$538,273
Fence, under- and overpass, jump-out	86%	Yes	Reed et al. (1982) 79%; Ward (1982): 90% Woods (1990): 94-97%; Clevenger et al. (2001): 80%; Dodd et al. (2007): 87%	$719,667
Animal detection system (ADS)	87%	Yes	Mosler-Berger and Romer (2003): 82%; Dodd and Gagnon (2008): 91%	$1,099,370
Fence, gap, ADS	87%	Yes	Mosler-Berger and Romer (2003): 82%; Dodd and Gagnon (2008): 91%	$836,113
Elevated roadway	100%	Yes	Review in Huijser et al. 2007	$92,355,498
Road tunnel	100%	Yes	Review in Huijser et al. 2007	$147,954,696

Table 1. The estimated effectiveness, present value costs (in 2007 US$, 3% discount rate) of mitigation measures aimed at reducing collisions with large ungulates over a 75 year time period. The measures are ordered based on their estimated effectiveness.

Seasonal wildlife warning sign

Seasonal wildlife warning signs were estimated at US$400 for a large sign, and US$80 for two flashing lights (Sullivan et al. 2004). For these analyses we assumed that one sign and associated flashing lights is installed per km per travel direction. This brings the total costs to US$960 per km (US$1,053 in 2007 US$). The projected life span of the signs and warning lights was set at 10 years.

Vegetation removal

Vegetation removal alongside the road, consist of the removal of shrubs and trees to increase visibility for drivers and to reduce the attractiveness for certain species, e.g. moose. The costs were estimated at US$500 per km per year (US$530 in 2007 US$) (Andreassen et al. 2005).

Population culling, relocation and infertility treatment

The cost estimates for population culling, relocation and infertility treatment are typically expressed as cost per animal. For the purpose of our cost-benefit analyses we had to translate these costs to costs per km road length. For our analyses we set the treatment area in a zone parallel to, and on both sides, of a road. The width of the zone for each side of the road was based on the diameter of the home range (75 ha) of white-tailed deer in a suburban environment, 978 m (home range size estimated at 43-50-86-144 ha by Kilpatrick and Spohr (2000), Beringer et al. (2002), and Grund et al. (2002)). For both sides of the road this results in a treatment area of 195.4 ha per km road length. Population densities of (suburban) white-tailed deer that are considered a problem have been estimated at 50-88-91 individuals per km^2 (Porter and Underwood 1999, Kilpatrick et al. 2001). Assuming a population density of 70 individuals per km^2, there are 136.8 deer present in 195.4 ha. The cost for culling, relocation, and anti-fertility treatment was set at US$110 (US$132 in 2007 US$), US$450 (US$540 in 2007 US$), and US$1,128 (US$1,296 in 2007 US$) per deer (females only), respectively. The estimate for killing a deer was based on estimates for the use of professional sharpshooters; US$108-US$121-US$194 per deer for conservation officers, park rangers, and police officers, respectively (Doerr et al. 2001). Others estimated these costs at US$91-US$310 per deer (DeNicola et al. 2000). The estimate for relocating a deer was based on estimates by Beringer et al. (2002) (US$387 per relocated deer) and De Nicola et al. (2000) (US$431 or US$400-US$2,931 per deer). The estimate for giving a female deer an anti-fertility treatment was based on estimates by Walter et al. (2002) (US$1,128 per treated deer) (US$1,300 in 2007 US$). Assuming that a population can only be reduced by 50% before the culling, relocation, or anti-fertility treatment efforts become much more labor intensive, the one-time culling and relocation of 68.4 deer costs US$9,029 and US$36,936 respectively (reduction of 68.4 deer) (in 2007 US$). Suburban white-tailed deer populations can double their population size every 2-5 years, depending on the circumstances (DeNicola et al. 2000). Assuming a closed population (no immigration from adjacent areas) and a doubling of population size every 3 years, the culling and relocation effort would have to be repeated every 3 years. For the anti-fertility treatment, it was assumed that 80% of the females (80% of 68.4 female deer is 54.7 female deer, assuming an equal sex ratio), would have to be treated annually to stabilize or reduce the population density (DeNicola et al. 2000, Rudolph et al. 2000). This results in an annual cost for anti-fertility treatment of US$71,110 (in 2007 US$). For these mitigation measures there were no estimates available for elk and moose, and we used the same costs estimates for all three species.

Animal detection system

The purchasing cost for an animal detection system was estimated at US$65,000 per 1,609 m (1 mi) road length (both sides of the road) (Personal communication Lloyd Salsman, Sensor Technologies & Systems, December 2007). However, since roads often have curves and driveways or objects in the right-of-way, the distance between sensors may be shorter than the maximum range of their signal, potentially leading to cost increases. For these analyses we assumed the purchasing costs, including signs and power source or supply, were estimated at US$75,000 per km road length (both sides of the road). The planning costs were estimated at US$50,000 and the installation costs were estimated at US$50,000 per km road length (all in 2007 US$). Maintenance and operation costs were estimated at US$14,800 per km per year (US$10,000 for problem identification and problem solving, parts (US$3,000), vegetation management (US$1,500), and remote access to the system (US$300) (all in 2007 US$). The projected life span of the signs and warning lights was set at 10 years. System removal costs at the end of the life of the system were estimated at US$10,000 per km (in 2007 US$).

Wildlife fencing

The costs for 2.4 m (8 ft) high wildlife fencing along US Highway 93 on the Flathead Reservation in Montana varied depending on the road section concerned: US$26, US$38, US$41 per m in 2006 (material and installation combined) (Personal communication Pat Basting, Montana Department of Transportation). A finer mesh fence was dug into the soil and attached to the wildlife fence for some fence sections at an additional cost of US$12 per m (Personal communication Pat Basting, Montana Department of Transportation). For the cost-benefit analyses the cost of wildlife fencing, including a dig barrier, was set at US$47 per m (US$48 in 2007 US$). For both sides of a road this translates into US$96,000 per km road length (in 2007 US$). The projected life span of a wildlife fence was set at 25 years. Fences require maintenance, for example as a result of fallen trees, vehicles that have run off the road and into the fence, and animals that may have succeeded digging under the fence (Clevenger et al. 2002). Maintenance costs were set at US$500 per km per year and fence removal costs were set at US$10,000 per km road length (all in 2007 US$).

Safe crossing opportunities

Safe crossing opportunities and escape opportunities were not included in the cost estimates for wildlife fencing, but they are included in the mitigation measures discussed in the next paragraphs. The safe crossing opportunities and escape opportunities focus on serving large animals (deer size and larger). For our cost benefit analyses we set the number of safe crossing opportunities at one per 2 km (0.5 crossing opportunity per km) (0.3 per mi). This number is based on the actual number of crossing structures found at three long road sections (two lanes in each travel direction) that have wildlife fencing and crossing structures for large animals: 24 crossing structures over 64 km (0.38 structures per km) (Foster and Humphrey 1995); 24 crossing structures over 45 km (0.53 structures per km) (Clevenger et al. 2002); and (17 crossing structures over 31 km (0.56 structures per km) (Dodd et al. 2007). Note that this number is not based on what may be required to maintain viable wildlife populations in a landscape bisected by roads.

Jump-outs

For our cost-benefit analyses we used jump-outs or escape ramps as escape opportunities for large animals. The reported costs for one jump-out are US$11,000 (US$13,200 in 2007 US$) (Bissonette and Hammer 2000) and US$6,250 (2006) (US$6,425 in 2007 US$) (Personal communication Pat Basting, Montana Department of Transportation). We set the costs for a jump-out at US$9,813 (in 2007 US$) with a projected life span of 75 years.

Wildlife fencing in combination with gaps in the fence and crosswalks

Wildlife fencing in combination with gaps in the fence and crosswalks painted on the road at such gaps was studied by Lehnert and Bissonette (1997). The cost for a wildlife crosswalk across a four lane road (excluding wildlife fencing and escape from right-of-way measures) was US$28,000 (US$36,075 in 2007 US$) (US$18,037 per km) (Lehnert and Bissonette 1997). The projected life span of a crosswalk was set at 10 years. The costs for warning signs (76 cm x 76 cm), one for each travel direction, were set at US$62 per sign with a projected life span of seven years (USA Traffic Signs 2007). For this analyses we included 2 signs per gap (one for each travel direction), resulting in one sign per km. The width of the gap in the fence was set at 100 m (328 ft). However, the length of the fence was not reduced because of the gap as the fence may be angled towards the road to help direct animal movements. The cost for wildlife fencing was set at US$96,000 per km (see section on wildlife fencing). Fence maintenance costs were set at US$500 per km per year, and fence removal costs was set at US$10,000 per km road length. In addition to the gap in the fence a jump-out was provided every 317 m (1,040 ft) (5 per 2 km per roadside; 5 per km; US$49,065 per km).

Wildlife fencing in combination with gaps in the fence and animal detection systems

The cost for purchasing one section of a break-the-beam animal detection system was set at US$8,500 (Personal communication Lloyd Salsman, Sensor Technologies & Systems, December 2007). A gap requires a beam at each side of the road (US$17,000), but the costs for the second beam may be lower as there is only one control station required. The purchasing costs, including signs and power source or supply, were set at US$13,500 per km (in 2007 US$). The planning costs were estimated at US$25,000 and the installation costs were estimated at US$25,000 per km road length (all in 2007 US$). Maintenance and operation costs were estimated at US$11,800 per km per year (US$10,000 for problem identification and problem solving, parts (US$1,000), vegetation management (US$500), and remote access to the system (US$300). The projected life span of the signs and warning lights was set at 10 years. System removal costs were estimated at US$5,000 per km. The width of the gap in the fence with the animal detection system was set at 100 m (328 ft). However, the length of the fence was not reduced because of the gap as the fence may be angled towards the road to help direct animal movements. The cost for wildlife fencing was set at US$96,000 per km (see earlier section on wildlife fencing). Fence maintenance costs were set at US$500 per km per year, and fence removal costs was set at US$10,000 per km road length. In addition to the gap in the fence a jump-out was provided every 317 m (1,040 ft) (5 per 2 km per roadside; 5 per km; US$49,065 per km).

Wildlife fencing in combination with wildlife underpasses

For the purposes of our cost-benefit analyses for wildlife fencing in combination with wildlife underpasses, we provided a wildlife underpass every 2 km (1.2 mi). The cost for an underpass was set at US$500,000 (materials and construction). The cost for an underpass (elliptical culvert, about 7 m wide, 4-5 m high) was based on the US$650,000 paid for three large wildlife underpasses (about 7 m wide, 5 m high) under US Hwy 93 (two lanes) on the Flathead Reservation in Montana in 2006 (US$668,200 in 2007 US$) (Personal communication Pat Basting, Montana

Department of Transportation); the CanUS$225,000-CanUS$250,000 (exchange rate 1.36 CanUS$ for 1 US$ in 1996; US$218,731-US$243,034 in 2007 US$) for an underpass (7 m wide, 4 m wide) under the Trans Canada Highway (four lanes) in Banff National Park in 1996 (Personal communication Anthony P. Clevenger, Western Transportation Institute); the US$Can5,400 per m (road width) (exchange rate 1.36 CanUS$ for 1 US$ in 1996; US$5,428 per m in 2007 US$) for elliptical culverts (7 m wide, 4 m high) under the Trans Canada Highway in 1996 (Personal communication Terry McGuire, Parks Canada, unpublished data); and the €30,000-€50,000 per m (road width) (exchange rate 0.80 € for 1 US$ in 2004; US$41,136-US$68,560 per m in 2007 US$) for large underpasses (7-10 m wide) in 2004 in The Netherlands (Kruidering et al. 2005). The planning costs were estimated at US$50,000 per structure (US$25,000 per km) (in 2007 US$). Maintenance and operation costs were estimated at US$2,000 per structure per year (US$1,000 per km per year) (in 2007 US$). The projected life span of an underpass was set at 75 years. Structure removal costs were estimated at US$30,000 per structure (US$15,000) per km) (in 2007US$). The length of the fence was not reduced because of the gap as a result of the crossing structure, as the fence is angled towards the road and ties in with the crossing structure. The cost for wildlife fencing was set at US$96,000 per km (see earlier section on wildlife fencing). Fence maintenance costs were set at US$500 per km per year, and fence removal costs was set at US$10,000 per km road length (in 2007 US$). The number of escape ramps between crossing structures was set at 7 per roadside per 2 km (2 immediately next to a crossing structure (50 m on either side from the center of the structure), and an additional five escape ramps with 317 m (1,040 ft) intervals (7 per km; US$68,691 per km). The escape ramps on either side of a crossing structure are required because of the continuous nature of the wildlife fencing and the assumption that animals will want to cross the road most often at the location of the crossing structures, as that should be one of the most important criteria for the placement of these crossing structures.

Wildlife fencing in combination with wildlife underpasses and overpasses

For the purposes of our cost-benefit analyses for wildlife fencing in combination with wildlife underpasses and overpasses, we provided a wildlife underpass every 2 km, but every 12th underpass (once every 24 km) was replaced with an overpass. This resulted in 0.46 underpasses and 0.04 overpasses per km (0.29 and 0.02 per mi). The frequency for wildlife overpasses is based on the actual number of overpasses on a long road section (two lanes in each travel direction) that has wildlife fencing and crossing structures for large animals: 2 overpasses over 45 km (1 every 22.5 km) (Clevenger et al. 2002). For the costs of an underpass, see the previous paragraph. The cost for an overpass was set at US$5,000,000 in 2007 US$ (materials and construction). The cost for an overpass (about 50 m wide) was based on the CanUS$1,750,000 for an overpass (52 m wide) over the Trans Canada Highway (four lanes) in Banff National Park in 1996 (Personal communication Anthony P. Clevenger, Western Transportation Institute) (exchange rate 1.36 CanUS$ for 1 US$ in 1996; US$1,701,242 in 2007 US$); the €3,200,000 for an overpass (48 m wide) across the four lane motorway A28 (Leusderheide) in The Netherlands in 2004 (exchange rate 0.80 € for 1 US$ in 2004; US$4,387,866 in 2007 US$) (Kruidering et al. 2005). However, depending on the length (road width) and width of an overpass (15-50 m), and depending on the nature of the terrain, the costs for eight wildlife overpasses in The Netherlands ranged between €1,400.000 and €9,100,000 (exchange rate 0.80 € for 1 US$ in 2004; US$1,919,691-US$12,477,993 in 2007 US$) (Kruidering et al. 2005; Brabants Dagblad 2004). The planning costs were estimated at US$50,000 per structure (US$25,000 per km) (in 2007 US$). Maintenance and operation costs were estimated at US$2,000 per structure per year (US$1000 per km per year) (in 2007 US$). The projected life span of an overpass was set at 75 years. Structure removal costs were estimated at US$350,000 for an overpass (US$14,000 per km) and US$30,000 for an underpass (13,800 per km) (in 2007 US$). Fencing and escape ramp configuration and costs were identical to the previous paragraph.

Elevated roadway, road tunnel

The costs for an elevated roadway and road tunnel were set at US$60,000,000 and US$115,000,000 per km respectively (in 2007 US$). These estimates are based on a 200 m long elevated road way that cost CanUS$12,500,000 (1.06 CanUS$ for 1 US$ in 2007; US$11,792,453 in 2007 US$) and a 200 m long road tunnel that was constructed for CanUS$24,000,000 (1.06 CanUS$ for 1 US$ in 2007; US$22,641,509 in 2007 US$) in 2007 (Personal communication Anthony P. Clevenger, Western Transportation Institute – Montana State University). The planning costs were estimated at US$1,000,000 per km (in 2007 US$). Maintenance and operation costs were estimated at US$1,000,000 per km per year (in 2007 US$). The projected life span of an elevated roadway and road tunnel was set at 75 years. Structure removal costs were estimated at US$6,000,000 (elevated roadway) and US$11,500,000 (road tunnel) per km.

Cost Estimates for Deer-, Elk-, and Moose-Vehicle Collisions

The total estimated costs for the average deer-, elk-, and moose-vehicle collision is summarized in Table 2. Since we calculated the costs for an average collision, the costs of collisions that result in human injuries or fatalities, in addition to property damage, are higher than this average. The majority of the costs are associated with human injuries and fatalities (deer: 56.0%; elk: 69.1%; moose: 78.6%) rather than vehicle repair costs (deer: 39.6%; elk: 26.0%; moose: 18.2%). Based on a total estimate of one to two million collisions with large mammals per year in the United States (Huijser et al. 2007), and the estimate that 99.2% of all reported wildlife-vehicle collisions related to deer, 0.5% to elk and 0.3% to moose (see Huijser et al. accepted), the total estimated annual costs associated with ungulate-vehicle collisions is estimated at US$6,247,759,000- US$12,495,518,000. In Canada, with an estimated 45,000 large mammal-vehicle collisions, the estimated annual costs are US$281,149,155 (Tardif & Associates Inc. 2003).

Description	**Deer (US$)**	**Elk (US$)**	**Moose (US$)**
Vehicle repair costs per collision	$2,622	$4,550	$5,600
Human injuries per collision	$2,702	$5,403	$10,807
Human fatalities per collision	$1,002	$6,683	$13,366
Towing, accident attendance and investigation	$125	$375	$500
Hunting value animal per collision	$116	$397	$387
Carcass removal and disposal per collision	$50	$75	$100
Total	**$6,617**	**$17,483**	**$30,760**

Table 2. Summary of estimated costs (in 2007 US$) for the average deer-, elk-, and moose-vehicle collision.

The following sections provide a rationale for the cost estimates shown in Table 2. Unless indicated otherwise, all cost estimates were expressed as US$ as reported in the cited work. For our analyses we converted all costs to 2007 US$. The components included in our cost estimate were vehicle repair costs, costs associated with human injuries and fatalities, towing, accident attendance and investigation, the monetary value to hunters of the animal that was killed in the collision, and the cost of disposal of the animal carcass. Passive use costs were not included in our cost estimate.

Vehicle repair costs

In Nova Scotia, the percentage of collisions involving white-tailed deer which resulted in property damage was estimated at 90.2% – 3,524 collisions with property damage out of 3,905 collisions (Tardif & Associates Inc. 2003). In Utah this percentage was estimated at 94% (Romin and Bissonette 1996). There were no similar data available for elk and moose. For these analyses the percentage of collisions resulting in property damage was assumed to be 92% for collisions with deer and 100% for collisions with elk or moose. Current data from a major auto insurance company in the United States showed that in 2006-2007 the average vehicle repair costs were about US$2,900 for all species combined (Personal communication Dick Luedke, State Farm Insurance). The species specific costs were US$2,850 for deer (n = ±178,500), US$4,550 for elk (n = ± 900), and US$5,600 (moose; n = ±550) in 2006-2007 (Personal communication Dick Luedke, State Farm Insurance). Combined with the percentage of chance that a collision results in property damage, the average vehicle repair costs per collision were estimated at US$2,622 (deer), US$4,550 (elk), and US$5,600 (moose) (all in 2007 US$).

Human injures

The percentage of white-tailed deer-vehicle collisions resulting in human injuries was estimated at 2.8% in Michigan (12 injuries from 60,875 collisions) (SEMCOG 2007), 3.8% in the US Midwest (4,724 injuries from 125,608 collisions) (Knapp et al. 2004); 4% in Ohio (review in Schwabe et al. 2002), 4% (review in Conover et al. 1995), 7.7% in Ohio (10,983 injuries from 143,016 collisions) (Schwabe et al. 2002); and 9.7% in Nova Scotia (378 injuries from 3,905 collisions) (Tardif & Associates Inc. 2003). Similar data could not be retrieved for elk. The percentage of moose-vehicle collisions resulting in human injuries was estimated at 18% in Newfoundland and Labrador (Government of Newfoundland and Labrador 1997); 21.8% in Newfoundland (363 injuries from 1,662 collisions) (Tardif & Associates Inc. 2003); 20% in rural Alaska (Thomas 1995); 23% in Maine (Huijser et al. 2007); and, 23% in Anchorage, Alaska (158 injuries from 519 collisions) (Garrett and Conway 1999). The ratio of moose-vehicle collisions to human injuries was estimated at 1:0.201 in Newfoundland (Rattey and Turner 1991) and 1:0.304 in Anchorage, Alaska (Garrett and Conway 1999). The ratios are higher than the percentages because more than one person may be present in a car, and multiple people may be injured as a result of one collision. Based on the data presented above, it was assumed that an animal-vehicle collision resulted in an average of 0.05 human injuries for deer, 0.10 for elk, and 0.20 for moose. When these proportions are combined with the relative frequency for each of the three injury categories distinguished in the General Estimates System for animal-vehicle collisions, (51.4% for possible human injuries, 38.4% for evident human injuries, and 10.3 % for incapacitating or severe human injuries (Huijser et al. 2007)) and the standard costs associated with each injury category, (US$24,418 for possible human injuries, US$46,266 for evident human injuries, and US$231,332 for incapacitating or severe human injuries (U.S. Department of Transportation 1994, Huijser et al. 2007)), it results in species specific cost estimates for human injuries (Table 3).

Type of human injury	Deer (US$)	Elk (US$)	Moose (US$)
Possible	$627	$1,254	$2,508
Evident	$887	$1,775	$3,550
Incapacitating/severe	$1,187	$2,374	$4,749
Total	**$2,702**	**$5,403**	**$10,807**

Table 3. Estimated costs (in 2007 US$) per type of human injury for the average deer-, elk-, and moose-vehicle collision.

Human fatalities

The percentage of white-tailed deer-vehicle collisions resulting in human fatalities was estimated at 0.009% in Ohio (14 collisions with human fatalities from 143,016 collisions) (Schwabe et al. 2002); 0.020% (12 fatalities from 60,875 collisions) (SEMCOG 2007); 0.029% in North America (review in Schwabe et al. 2002); 0.03% in the US Midwest (33 collisions with human fatalities from 125,608 collisions) (Knapp et al. 2004); and 0.05% in Nova Scotia (2 collisions with human fatalities from 3,905 collisions) (Tardif & Associates Inc. 2003). Similar data could not be retrieved for elk. The percentage of moose-vehicle collisions resulting in human fatalities was estimated at 0% in Anchorage, Alaska (0 fatalities from 519 collisions) (Garrett and Conway 1999); 0.26% in Newfoundland (14 fatalities from 5,422 collisions) (Joyce and Mahoney 2001), 0.36% in Newfoundland (6 collisions with human fatalities from 1662 collisions) (Tardif & Associates Inc. 2003), 0.45% in Newfoundland (3 fatalities from 661 collisions) (Rattey and Turner 1991); 0.43% in Maine (Huijser et al. 2007); and 0.50% in rural Alaska (Thomas 1995). Based on the data presented above, it was assumed that an animal-vehicle collision resulted in an average of 0.0003 (deer), 0.0020 (elk), and 0.0040 (moose) human fatalities. When these proportions are combined with the costs associated with a human fatality (US$3,341,468 (U.S. Department of Transportation 1994, Huijser et al. 2007)), it results in a cost estimate for human fatalities of US$1,002 (deer), US$6,683 (elk), and US$13,366 (moose) for each collision (all in 2007 US$).

Towing, accident attendance and investigation

Not all wildlife-vehicle collisions require the towing of a vehicle, and attendance or investigation by medical personnel, fire department personnel, or police. When they do, the cost for these efforts was estimated to vary between Can$100 and Can$550 (Clayton Resources Ltd. & Glen Smith Wildlife Consultants 1989). Note that the cost for the actual medical assistance is included in the cost estimates for human injuries calculated earlier. Based on the data presented above, it was assumed that the cost of towing, and accident attendance or investigation is US$500, but these services are only required or provided in 25% (deer), 75% (elk) and 100% (moose) of the collisions. These assumptions result in an average cost for towing, accident attendance and investigation of US$125 (deer), US$375 (elk), and US$500 (moose) for each collision (all in 2007 US$).

Monetary value of animals

The monetary value of animals can include benefits associated with hunting or viewing the animal or with the passive use values for the existence of the given animal. Passive use values are likely to be location and population specific, and the literature on wildlife viewing values is not extensive. Therefore we only included hunting-related values in our analyses. These values are measured by what the hunter would be willing to pay over and above the costs of the hunt, for example to access a hunting area. For the U.S. and Canada access for hunting on most private and public lands is free. However, what the maximum amount the hunter would be willing to pay for access if necessary is a measure of the net benefit or hunter "willingness-to-pay" for the hunt (Ward and Duffield 1992).

These net benefits are also referred to as “consumer surplus”. For the application to collisions, the foregone expected value related to hunting would be the hunting value per animal times the probability that it would have been harvested. The hunting value per animal can be derived from the hunter willingness to pay for a season of hunting divided by the success rate per hunt. There is extensive literature on net economic values for hunting, usually based on travel cost or contingent valuation methods (for example, see Ward and Duffield 1992), but most of these are location (e.g. hunt district or perhaps state) specific. The most comprehensive hunting value estimates have been developed by the U.S. Fish and Wildlife Service in their periodic national fishing and hunting surveys. The most recent values available for hunter willingness to pay for a season of hunting are for 2001 (U.S. Fish and Wildlife Service 2003), and in 2001 dollars averaged US$377 for deer, US$579 for moose (just Alaska) and for elk hunting (CO, ID, MT, OR, WY) were US$380 for resident hunters and US$556 for nonresident hunters or a weighted average (based on the number of resident and nonresident big game hunters for these states (U.S. Fish and Wildlife Service 2002)) of US$424. Corrected to 2007 price levels, these values are US$441 for deer, US$496 for elk, and US$678 for moose. Success rates for these species are not reported in each survey year, but were estimated by U.S. Fish and Wildlife Service (1998) for 1996 at 0.61 for deer, 0.20 for elk, and 0.14 for moose. This implies the value of a successful hunting season for these species, respectively, as US$723, US$2,480, and US$4,843. Crête and Daigle (1999) provide estimates of 1995-1996 hunting harvest as a share of pre-harvest populations for these species in North America as 0.16 for deer (whitetail and mule deer combined) and elk, and 0.08 for moose. Given this probability that a given animal will be harvested by a hunter, the implied foregone hunting value associated with the average collision is US$116 for deer, US$397 for elk, and US$387 for moose (Table 2).

Removal and disposal costs of deer carcasses

In Canada, the clean-up, removal and disposal costs for animal carcasses were estimated at Can$100 for deer and Can$350 for moose (Sielecki 2004). In Pennsylvania, the average for deer carcass removal and disposal in a certified facility was US$30.50 per deer for contractors and US$52.46 per deer for the Pennsylvania Department of Transportation in 2003-2004 (Personal communication Jon Fleming, Pennsylvania Department of Transportation). Based on the data presented above, it was assumed that the removal and disposal costs of animal carcasses were US$50 (deer), US$75 (elk) and US$100 (moose) (all in 2007 US$).

Threshold Values

Huijser et al. (accepted) show the results of cost-benefit analyses over a 75-year period using discount rates of 1%, 3% and 7% and identifies the threshold values (in 2007 $) above which individual mitigation measures start generating benefits in excess of costs. These threshold values were translated into the number of deer-, elk-, or moose-vehicle collisions that need to occur per kilometer per year for a mitigation measure to start generating economic benefits in excess of costs. For example, it was calculated that wildlife exclusion fencing in combination with large mammal underpasses (one every 2 km) and wildlife jump-outs generates economic benefits if the pre-mitigation collisions are greater than 3.2 deer, 1.2 elk, or 0.7 moose per km per year (all at 3% discount rate).

Real World Example

We calculated the costs associated with large ungulate-vehicle collisions on ten road sections throughout the United States and Canada and compared these to the threshold values (see Huijser et al. accepted). The costs associated with deer-, elk-, and moose-vehicle collisions for ten road sections in the United States and Canada varied between US$3,636 and US$46,155 per kilometer per year (Huijser et al. accepted). While these numbers may not seem high in relation to the costs per kilometer per year for many of the mitigation measures (Table 1), it is important to realize that the costs associated with collisions on the ten road sections are averaged out over relatively long road sections and that specific locations on a road section can still exceed thresholds. To illustrate this concept we conducted a more detailed cost analyses for one of these road sections (Figure 1). For example, the benefits of animal detection systems as a stand-alone mitigation measure exceed the costs on 3.9% of an 8.2 km (5.1 mi) long road section on I-90 west of Missoula, MT (Ninemile area). Similarly, this percentage is 25.5% for wildlife fencing with gaps and animal detection systems in these gaps, and jump-outs; 27.5% for wildlife fencing with under- and overpasses, and jump-outs; and 56.9% for wildlife fencing with underpasses, and jump-outs (Figure 1).

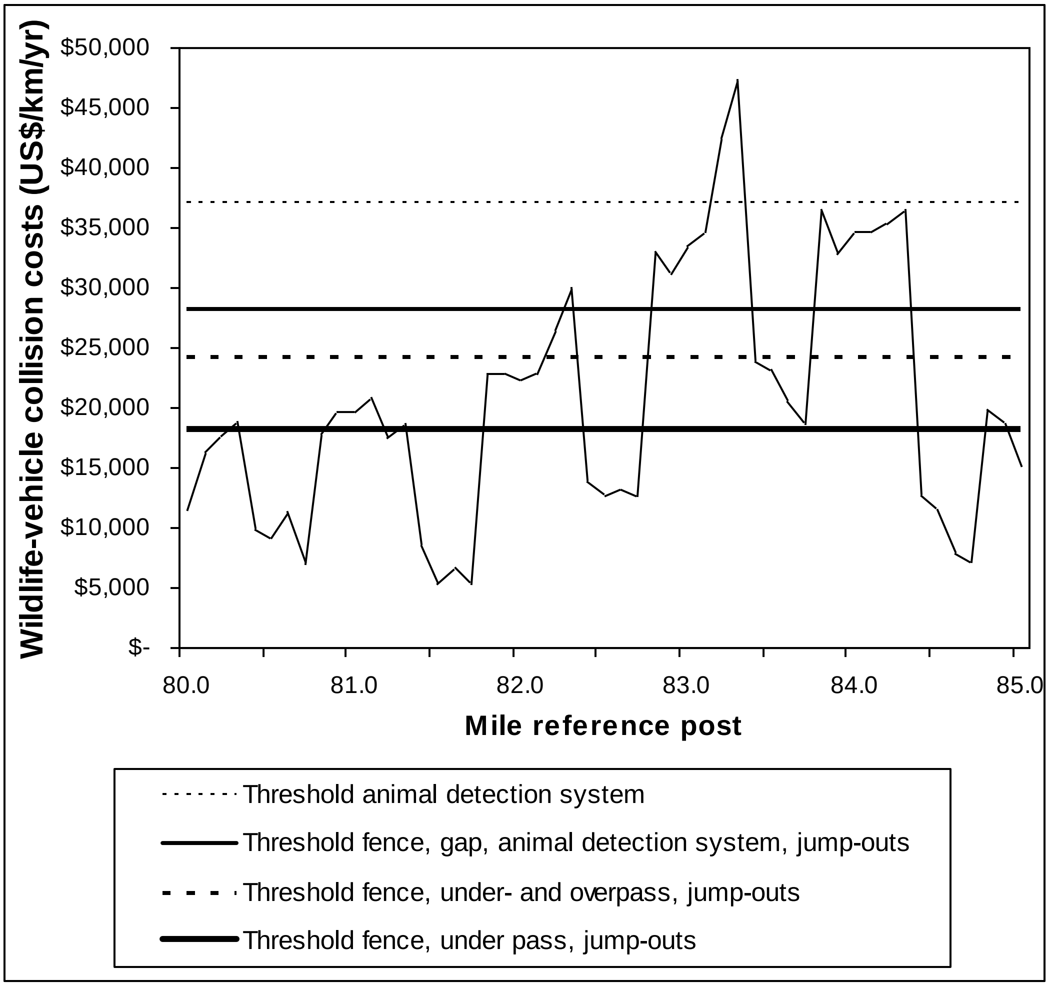

Figure 1. I-90 Ninemile area, west of Missoula, MT, USA. The costs (in 2007 US$) associated with wildlife-vehicle collisions (white-tailed deer, mule deer, and 2 black bears and 1 wolf (black bears and wolves conservatively were estimated to have equal cost as deer) along the 4-lane I-90 (mi reference posts 80.0-85.0) per year (average 1998-2008), and the threshold values (at 3% discount rate) that need to be met in order to have the benefits of individual mitigation measures exceed the costs over a 75 year long time period. Note that the costs at each 0.1 mi concerned and five adjacent 0.1 mi units were summed (0.6 mi = 1 km) to estimate the costs per kilometer.

Discussion and Conclusion

The costs associated with deer-, elk-, and moose-vehicle collisions are substantial. The majority of the costs are associated with human injuries and fatalities (deer 56.0%; elk 69.1%; moose: 78.6%) rather than vehicle repair costs (deer: 39.6%; elk: 26.0%; moose: 18.2%). Of the approximately 40 different types of mitigation measures reviewed, only 13 were considered to effective in reducing collisions with large ungulates. However, the degree of effectiveness and the costs of these 13 mitigation measures vary greatly and, as a consequence, there are substantial differences in the threshold values between the individual mitigation measures above which the benefits of a mitigation measure exceed the costs (see Huijser et al. accepted). Collision and carcass data from ten road sections throughout the United States and Canada showed that some road sections easily meet the threshold values for some of the mitigation measures. This means that the benefits of implementing such mitigation measures over the full length of the road sections concerned exceed the costs and that the implementation of mitigation measures would be economically feasible. However, when calculating the average costs of wildlife-vehicle collisions over relatively long road sections, potential concentrations of wildlife-vehicle collisions are ignored. Therefore it is important that more detailed analyses are carried out at a finer spatial scale (e.g. at 0.1-1.0 km or 0.1-1.0 mi resolution) to identify road sections where the benefits of mitigation measures may exceed the costs.

While it may appear attractive to implement mitigation measures that have relatively low threshold values, not all mitigation measures reduce wildlife-vehicle collisions substantially. Therefore, while mitigation measures with relatively low threshold values and with limited effectiveness may be considered for longer road sections with relatively few wildlife-vehicle collisions, mitigation measures with higher threshold values and higher effectiveness may be considered for shorter road sections that have relatively many wildlife-vehicle collisions.

Wildlife fencing as a stand-alone mitigation measure has relatively low threshold values and reduces wildlife-vehicle collisions substantially. However, we strongly advise against increasing the barrier effect of roads and traffic without providing for safe crossing opportunities at appropriate intervals (see e.g. Bissonette and Adair 2008, Huijser et al. 2008). The reason wildlife fencing has relatively low thresholds is that connectivity for wildlife (a passive use cost) was not included in our cost-benefit analyses. However, depending on the species and local population structure, connectivity across the landscape, including roads, can be critical for the long term population viability of the species concerned, and perhaps especially for species that may not be frequently hit by cars and that have low population density in the area (e.g. Jaeger and Fahrig 2004). Future cost-benefit analyses may include a monetary value for having viable populations of different species, as well as other passive use values.

We believe that the cost-benefit model presented in this paper can be a valuable decision support tool for transportation agencies and natural resource management agencies when deciding on the implementation of mitigation measures to reduce ungulate-vehicle collisions. The tool allows for the selection of the appropriate road sections as well as the type of mitigation measure. The results suggest that there must be many road sections in the United States and Canada where the benefits of mitigation measures exceed the costs and where the mitigation measures would help society save money and improve road safety for humans and wildlife. Mitigation measures that include safe crossing opportunities for wildlife may not only substantially reduce road mortality, but also allow for wildlife movements across the road. This connectivity is essential to the survival probability of the fragmented populations for some species in some regions.

Biographical Sketches

Marcel Huijser received his M.S. in population ecology (1992) and his Ph.D. in road ecology (2000) at Wageningen University in Wageningen, The Netherlands. He studied plant-herbivore interactions in wetlands for the Dutch Ministry of Transport, Public Works and Water Management (1992-1995), hedgehog traffic victims and mitigation strategies in an anthropogenic landscape for the Dutch Society for the Study and Conservation of Mammals (1995-1999), and multifunctional land use issues on agricultural lands for the Research Institute for Animal Husbandry at Wageningen University and Research Centre (1999-2002). Currently Marcel works on wildlife-transportation issues for the Western Transportation Institute at Montana State University (2002-present). He is a member of the Transportation Research Board (TRB) Committee on Ecology and Transportation and co-chairs the TRB Subcommittee on Animal-Vehicle Collisions.

John Duffield is an economist at the University of Montana where he has taught and conducted research for the last 35 years. He has a Ph.D. (1974) in economics from Yale and a B.A. (1968) in economics and math from Northwestern University. His field is natural resource economics, with an emphasis on nonmarket values for fish, wildlife and water resources. He has worked on a broad range of policy issues including energy modeling and forecasting (coal development on the Northern Great Plains), hydroelectric development issues (electricity versus the values of free flowing rivers) and on many issues relating to recreation management and valuation. His primary current project is estimating ecosystem values for the Grand Canyon to inform water allocation and management in the Colorado River. Much of his work has been on endangered species, including critical habitat analysis for bull trout in the Columbia and Klamath River Basins. In 1992 he coauthored a book on natural resource damage assessment and has worked on a number of significant cases including serving as the lead economist for the Alaska natives in the Exxon Valdez oil spill case. He has long been involved in policies relating to fish, wildlife and hydroelectric energy development and currently serves on the Independent Economic Advisory Board for the Northwest Power and Conservation Council, based in Portland, Oregon.

Tony Clevenger has carried out research during the last 12 years assessing the performance of mitigation measures designed to reduce habitat fragmentation on the Trans-Canada Highway (TCH) in Banff National Park, Alberta. Since 2002, he has been a research wildlife biologist for the Western Transportation Institute (WTI) at Montana State University. Tony is currently a member of the U.S. National Academy of Sciences Committee on Effects of Highways on Natural Communities and Ecosystems. Since 1986, he has published over 40 articles in peer-reviewed scientific journals and has co-authored three books including, Road Ecology: Science and Solutions (Island Press, 2003).

Rob Ament, M.Sc., Biological Sciences, is the Road Ecology Program Manager at the Western Transportation Institute at Montana State University. He has more than 25 years of experience in field ecology, natural resource management, environmental policy and organizational development. He manages nine road ecologists with over 20 active research projects throughout North America, three of which he is the principal investigator.

Pat McGowen obtained his B.S. and M.S. in Civil Engineering from Montana State University, and his Ph.D. from University of California Irvine in Transportation Systems Engineering. He has been a licensed professional civil engineer in Montana since April 2000. He is an assistant professor jointly appointed between the Western Transportation Institute (WTI) and Civil Engineering Department at Montana State University where he has worked on projects relating to rural ITS, transportation impacts to wildlife, safety and travel and tourism. Dr. McGowen is a national expert on highway-wildlife interactions. He developed the Artemis Clearinghouse, a wildlife-vehicle collision mitigation web-based clearinghouse. He has been involved in projects including the Roadside Animal Detection System Testbed, the National Wildlife Vehicle Collisions Study, and Habitat Connectivity and Rural Context Sensitive Design. Dr. McGowen is the founder and co-chair of the TRB subcommittee on Animal Vehicle Collisions (ANB20-2). Dr. McGowen, along with other colleagues at WTI was awarded the 2008 Best of ITS Award from the Intelligent Transportation Society of America for Best New Innovative Practices for Partnerships for Deploying Animal Vehicle Crash Mitigation Strategies.

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An Analysis of the Efficacy and Comparative Costs of Using Flow Devices to Resolve Conflicts with North American Beavers Along Roadways in the Coastal Plain of Virginia

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An Analysis of the Efficacy and Comparative Costs of Using Flow Devices to Resolve Conflicts with North American Beavers Along Roadways in the Coastal Plain of Virginia

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Abstract: Road damage caused by beavers is a costly problem for transportation departments in the U.S. Population control and dam destruction are the most widely used methods to reduce road damage caused by beavers, but the benefits of such measures in some situations are often very short-term. At chronic damage sites, it may be more effective and cost-beneficial to use flow devices to protect road structures and critical areas adjacent to roads. To determine the potential benefits of using flow devices at chronic beaver damage sites, from June 2004 to March 2006 we installed 40 flow devices at 21 sites identified by transportation department personnel as chronic damage sites in Virginia's Coastal Plain. Following installations, study sites were monitored to determine flow device performance and any required maintenance and repairs. Between March 2006 and August 2007, transportation department personnel were surveyed to collect data on flow device efficacy and comparative costs. As of August 2007, transportation department personnel indicated that 39 of the 40 flow devices installed were functioning properly and meeting management objectives. The costs to install and maintain flow devices were significantly lower than preventative road maintenance, damage repairs, and/or population control costs at these sites prior to flow device installations. Prior to flow device installations, the transportation department saved \$0.39 for every \$1.00 spent per year on preventative maintenance, road repairs, and beaver population control. Following flow device installations, the transportation department saved \$8.37 for every \$1.00 spent to install, monitor, and maintain flow devices. Given the demonstrated low costs to build and maintain flow devices, transportation agencies may substantially reduce road maintenance costs by installing and maintaining flow devices at chronic beaver damage sites.

Key Words: beaver, Beaver Deceivers™, *Castor canadensis*, Castor Masters™, economics, flow devices, Round Fences™, water flow control devices

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INTRODUCTION

The recovery of the North American beaver (*Castor canadensis*) is one of the conservation movement's greatest success stories, but the re-colonization of a massive historical range that is now widely inhabited by humans has led to inevitable conflicts. Beavers fell trees and shrubs and impound waters that flood agricultural lands, timberlands, structures, buildings and roads. Arner and Dubose (1979) estimated that economic losses attributed to beaver activity exceeded \$4 billion in the southeastern U.S. over the previous 40 years, and Miller (1983) estimated that annual damage was between \$75 and \$100 million in the U.S.

Road damage caused by beavers is a costly problem for many transportation departments in the U.S. Beaver damming behavior is believed to be stimulated by the sound and feel of running water. As water flows through narrow channels and/or road culverts, especially metal culverts, which resonate the sound of flowing water, beavers respond by damming channels and culverts, impounding water against roadbeds, and ultimately causing roads to flood and/or wash out (Langlois and Decker 1997). Plugged culverts are difficult, dangerous, and expensive to clear, and over time if they remain "plugged," saturated roadbeds settle, become unstable, and potholes form. Eventually, the road may wash out altogether, resulting in expensive, time-consuming road repairs (Jensen et al. 1999).

Trapping and dam destruction are widely considered the most effective and economical methods for reducing and eliminating road damage caused by beavers. In cases where it is unlikely that immigrants will re-occupy trapped sites, removing beavers and dams may be the most cost-effective approach to mitigating beaver damage. However, in areas with dense concentrations of beavers, dams are quickly re-built due to rapid beaver immigration and recolonization. For example, Houston et al. (1995) reported that beavers in a bottomland forest in southwest Tennessee immediately and repeatedly re-colonized idle colony sites following eradication, because the area still maintained preferred habitat. Removing or breaching dams is also an immediate but temporary solution to flooding problems caused by beaver. Demolishing dams, with explosives or by hand, is dangerous, expensive (Arner 1964), and futile, as beavers usually rebuild the dams within days (Miller 1977). In situations where removing beavers and dams provides only short-term solutions to problems associated with beaver activity, it may be more effective and affordable for transportation departments to identify chronic beaver damage sites and take proactive measures to protect road culverts and critical areas adjacent to roads.

The installation and maintenance of water flow control devices, designed to prevent problems associated with beaver damming activity, is an alternative that is potentially a more efficient and cost-effective approach to managing beaver conflict along roadways than the expense of annual beaver population control, repeated road maintenance and repairs, and damage to property and buildings due to flooding and washouts. Over the years, state, federal, and tribal agencies have developed, described, and installed several types of effective water flow control devices (Arner 1964; Laramie 1963; Lisle 1996, 2001; Roblee 1987; Wood et. al 1994). This includes the Penobscot Indian Nation Department of Natural Resources in Old Town, ME, which initiated a program in the 1990s to develop and install water flow control devices on tribal lands to prevent road damage caused by beaver activity and to create and enhance wildlife habitat (Lisle 1999). The results of these efforts led to the development of innovative flow device concepts known as Beaver Deceivers™, Castor Masters™, and Round Fences™.

There are generally two categories of beaver damage sites: 1) narrow outlets, such as road culverts, that direct water through a manmade barrier (e.g., an embankment or roadbed), and 2) beaver dams that are not attached to manmade structures. To prevent beavers from damming road culverts, the Penobscot Nation created the Beaver Deceiver™, a rugged, wooden-framed fence constructed of braced wooden posts and 4-gauge steel mesh fencing installed on the upstream end of road culverts. Because beaver damming behavior is stimulated by the sound and feel of running water, Beaver Deceivers™ are designed to not only deny beaver access to culverts, but to reduce or eliminate the "feel" of running water by spreading stream flow over a long perimeter. The perimeter of a Beaver Deceiver™ frame typically ranges from 40 to 120 ft and generally increases with stream and culvert size.

Beaver Deceivers™ are also strategically shaped to discourage damming behavior; their frames may be square, rectangular or pentagonal, but trapezoidal designs, 4-sided with 2 parallel sides and 2 non-parallel sides, tend to be the most effective. From the road, trapezoid-shape Beaver Deceivers™ resemble upside-down triangles. Once in place, beavers may swim around the Beaver Deceiver™ and attempt to dam the corners of the fence closest to the culvert due to visual, auditory, and tactile cues (e.g., the sight, sound, and feel of water running through a metal culvert). The sides of the fence direct beavers away from the upstream side of the culvert at an unusual angle, and as the beavers work to dam the area, the fence side forces them away from the culvert opening, discouraging damming behavior.

To address flooding problems that occur with beaver build dams that are not attached to manmade structures, the Penobscot Nation invented the Castor Master™, a pipe system that is used with a filter called the Round Fence™ to control water flow through an existing beaver dam (Lisle 2003). A Castor Master™ consists of one or several 12-in × 20-ft polyethylene pipes submerged and placed through an existing beaver dam, with the upstream and downstream sides of the pipes protected with filters. Round Fences™ are filters made of 4-gauge steel mesh fencing, typically between 2 to 4 ft height and 4 to 8 ft in diameter. Filters such as Round Fences™ prevent beavers and debris from plugging the pipe directing water through the dam, and they disperse flowing water over a broad area so that it is difficult for beavers to detect (Lisle 2003).

Beaver Deceivers™, Castor Masters™, and Round Fences™ have been used successfully to reduce and prevent damage to roads and other manmade structures at numerous beaver damage sites in the U.S., but few studies have been conducted to determine the effectiveness and cost benefits of using these devices. Over a period of 7 years, Lisle (1999 and unpubl. data) significantly reduced and/or eliminated preventative maintenance at 20 damage sites in Maine near un-trapped beaver colonies, where beavers frequently plugged culverts and flooded roads. In another study, Callahan (2003) reported that of 277 conflict sites, beaver damming was effectively controlled at 83% of sites where devices similar to a Caster Masters™ and Round Fences™ were installed, and at 95% of sites where devices similar to a Beaver Deceivers™ were installed. The purpose of this study was to evaluate the efficacy and cost-effectiveness of using Beaver Deceivers™, Castor Masters™, and Round Fences™ to resolve conflicts with beavers on roadways in the Commonwealth of Virginia.

METHODS

Study Area

Our study was conducted at chronic beaver damage sites along roadways in 7 counties within the 3 Virginia Department of Transportation (VDOT) districts located in the Coastal Plain of Virginia. VDOT districts in the Coastal Plain of Virginia were selected for this study because of the high number of reported beaver damage sites compared with Piedmont, Blue Ridge, Ridge and Valley, and Appalachian Plateau Districts (USDA-WS 2002, 2003, 2004, 2005), and to evaluate the premise that flow devices are effective in streams with higher gradients (e.g., Piedmont and Mountain regions) but are less effective in streams with low gradients (e.g., Coastal Plain).

Site Selection

To maintain objectivity, VDOT environmental and maintenance personnel from 3 districts with counties located in the Coastal Plain of Virginia– Hampton Roads, Fredericksburg and Richmond– selected chronic beaver damage sites, which were defined as sites where removing beavers and/or dams did not significantly reduce and/or prevent road maintenance, road repairs or beaver population control costs attributed to beaver activity along roadways. A total of 14 sites were initially selected for flow device installations: 4 in the Hampton Roads District, 5 in the Fredericksburg District, and 5 in the Richmond District.

In November 2005, we used data provided by USDA-Wildlife Services (USDA-WS) to identify and select 7 additional chronic beaver damage sites where maintenance records showed that beaver population control activities and/or preventative maintenance had been conducted more than once over a 5-year period. We ranked the sites by frequency of required population control and/or preventative maintenance (i.e., a damage site where population control activities were conducted 5 times in 5 years was given priority over a site that had been trapped twice) and then treated the sites by installing a total of 7 flow devices.

Flow Device Installation

Selected beaver damage sites generally consisted of plugged culverts and/or high water resulting from free-standing beaver dams located upstream and/or downstream of affected roads. Between June 2004 and November 2005, with the assistance of the principal investigator and several undergraduate students, wildlife biologist and flow device consultant Skip Lisle designed, constructed, and installed 33 flow devices at 14 study sites. Between November 2005 and March 2006, Mr. Lisle installed 7 flow devices at an additional 7 study sites. Beaver Deceivers™ were recommended primarily for treating plugged road culverts, and Castor Masters™ were installed to lower high water impounded by free-standing dams. In some cases, Castor Masters™ were installed with Beaver Deceivers™ to enhance flow efficiency.

Table 1. Data from surveys conducted with Virginia Department of Transportation personnel and adjacent landowners before flow device installations at 14 beaver damage study sites in the Coastal Plain of Virginia. For each site, individuals surveyed reported whether flooding occurred prior to flow device installations (yes [Y] and no [N]), and the costs per year for maintenance, road repairs and beaver removal due to beaver activity.

Study Sites	Prior Flooding	Maintenance Cost/Yr	Repair Costs/Yr	Beaver Removal Costs/Yr
Lake Cohoon	Y	$43,500.00		$1,891.44
Kingsale Swamp	Y	$6,000.00		$1,891.44
Corrowaugh Swamp (South)	Y	$7,000.00		$763.25
Corrowaugh Swamp (North)	Y	$7,000.00		$799.05
Craney Creek	Y	$5,600.00	$1,000.00	
Briary Swamp	Y	$10,800.00	$300.00	
Pope's Creek (South)	Y	$21,600.00	$132,500.00	$117.89
Pope's Creek (North)	Y	$21,600.00		
Newtons Pond	Y	$400.00		
Winterpock Creek	Y	$11,000.00		
Swift Creek	Y	$4,000.00	$10,000.00	$506.32
Blackwater Swamp	Y	$3,600.00		
Second Swamp	Y	$4,800.00		
Indian Swamp	Y	$3,000.00	$1,200.00	
Totals		**$149,900.00**	**$145,000.00**	**$5,969.40**

Monitoring and Maintenance

Following installations, study sites were monitored by principal investigators and/or VDOT personnel and inspected at least once every 4 months to determine if the flow devices were functioning properly, to note any specific damage to the device or changes in the landscape, and if necessary, to remove any accumulated debris obstructing the Beaver Deceivers™ and/or Round Fences™. Any time spent manually removing debris from the site was recorded as less than 15 minutes, less than 30 minutes, less than 45 minutes, or less 60 minutes. If time spent cleaning the device exceeded 60 minutes, actual time cleaning the device was recorded.

Surveys

We surveyed VDOT personnel from all 3 cooperating districts, as well as several landowners with property adjacent to study sites, to gather general data on what, if any, effect flow device installations had on previous flooding frequency, road maintenance, repair, or beaver management costs. Information recorded included when the devices were installed, the status of the flow devices (including any flooding, road maintenance and/or repairs, beaver damage/population control activities, and any efforts made by VDOT and/or the landowner to maintain the devices following installation), and whether management objectives for the study site had been met.

Comparative Cost Analysis

A cost-benefit ratio formula utilized by USDA-WS (2003) to compare beaver management expenditures to VDOT resources saved was used to test the differences in the costs to manage beavers and repairs roads before and after the installation of flow devices at 14 of the 21 selected study sites. (Comparative cost data collected for the 7 beaver damage sites treated between November 2005 and March 2006 has not yet been analyzed). For the purposes of this study, the estimated cost-benefit will be considered favorable if the ratio of expenditures to resources saved is greater than 1 to 2, or for $1 spent on beaver management activities or road repairs, $2 in VDOT resources are saved.

RESULTS

VDOT Personnel and Landowner Surveys

VDOT personnel and landowners reported that flooding occurred and preventative maintenance was conducted at all 14 sites prior to installation of flow devices at a total cost of $149,900.00 for preventative maintenance, or an average cost of $10,707 per site (Table 1). Beaver population control activities were conducted at 10 of 14 sites prior to installations at an average cost of $5,969 per year, or $994.90 per site, at the 6 sites where VDOT paid for beaver population control activities (Table 1). Following preventative maintenance and beaver population control efforts, all of the study sites were re-occupied by beavers. VDOT personnel and landowners also reported that road repairs attributed to beaver-related damage were carried out at 5 sites prior to installations at a total cost of $145,000 and an average cost of $29,000 per site.

From June 2004 to November 2005, 33 flow devices– 18 Beaver Deceivers™ and 15 Castor Masters™– were installed at 14 beaver damage sites in 7 counties in 3 VDOT districts in the Coastal Plain of Virginia. Installation costs per site ranged from $1,359 to $5,572 at an average cost of $3,160 per site and a total cost of $44,245 for installations at all 14 study sites (Table 2). Total installation time ranged from 10 to 50 hours with a total of 390 hours and an average installation time of 28 hours per site. The total costs for labor at these 14 study sites was $39,000 or $2,786 per site, and the total costs for materials was $5,244.52 or $374.61 per site.

Flow device maintenance time ranged from 1.0 to 4.75 hours per year and required a total of 19.75 hours per year, or 1.4 hours per site, and at $14.00 an hour, cost a total of $276.50 or $19.75 per site (Table 2). At the time that VDOT personnel and landowner surveys were conducted in April 2006, length of time following installations ranged from 6 months to 22 months with an average length of time following installations of 15 months per site.

After flow device installations, VDOT personnel and

Table 2. Data from surveys conducted with Virginia Department of Transportation personnel and adjacent landowners following flow device installations at 14 beaver damage study sites in the Coastal Plain of Virginia. For each site, individuals surveyed reported whether flooding occurred following flow device installations (yes [Y] and no [N]), the total cost for materials and labor to install flow devices, maintenance costs per year following installations.

Study Site	Current Flooding	Installation Costs	Maintenance Costs/Yr*
Lake Cohoon	N	$2,371.05	$17.50
Kingsale Swamp	N	$1,825.32	$31.50
Corrowaugh Swamp (S)	N	$1,340.13	$14.00
Corrowaugh Swamp(N)	N	$1,359.41	$14.00
Craney Creek	N	$3,829.81	$14.00
Briary Swamp	N	$3,329.79	$14.00
Pope's Creek (S)	N	$5,571.76	$14.00
Pope's Creek (N)	N	$3,882.31	$14.00
Newtons Pond	N	$2,800.55	$14.00
Winterpock Creek	N	$4,464.43	$21.00
Swift Creek	N	$1,752.28	$14.00
Blackwater Swamp	N	$4,841.68	$14.00
Second Swamp	N	$2,344.70	$14.00
Indian Swamp	N	$4,531.30	$66.50
Total		**$44,244.52**	**$276.50**

* based on an average wage of $14.00/hour

landowners reported that the study sites had not flooded, that road maintenance, flow device maintenance, and beaver population control activities had not been required or conducted, and that overall they were satisfied with the performance of the flow devices (Table 2). VDOT personnel surveys were also conducted for the 7 beaver damage sites treated from November 2005 and March 2006. As stated previously, comparative cost data collected for these sites has not yet been analyzed, but the preliminary efficacy results show that 6 of the 7 devices are functioning properly and meeting VDOT management objectives (Table 3).

Table 3. Data from surveys conducted with Virginia Department of Transportation personnel and adjacent landowners before flow device installations at 7 beaver damage study sites in the Coastal Plain of Virginia. For each site, individuals surveyed reported whether flooding occurred prior to and following flow device installations (yes [Y] and no [N]).

Study Sites	Prior Flooding	Current Flooding
Mill Creek	Y	N
Monroe Bay	Y	Y
Jones Hole Swamp (A)	Y	N
Jones Hole Swamp (B)	Y	N
Miles Creek	Y	N
John H. Kerr Reservoir	Y	N
Proctors Creek	Y	N

Comparative Cost Analysis

Prior to flow device installations, the estimated beaver management costs at the first 14 study sites, including preventative maintenance and population control activities, was $155,869 and the estimated beaver damage repair cost was $145,000, for a total cost to VDOT of $300,869 per year (Table 4). Following flow device installations, the estimated beaver management costs, including flow device installations and maintenance costs, was $44,526, and the estimated beaver damage repair cost was $0 for a total cost to VDOT of $44,526 per year (Table 4). The resources saved were estimated at $71,639, based on calculations in USDA-WS (2003) (Table 4). We assumed that the same resources were saved after installation of flow devices. The total resources saved prior to flow device installations included resources saved ($71,639) in addition to funds VDOT saved by not installing flow devices ($44,526), for a total resources saved of $116,165.

Table 4. The ratio of total resources saved to total costs per year for beaver management and damage repairs before and with the installation of flow devices at 14 beaver damage sites in the Coastal Plain of Virginia. Total costs are the sum of beaver management costs (preventative maintenance and/or flow device installations and beaver population control activities), and beaver damage repair (funds used to repair roads). Total resources saved before flow devices is the sum of potential resources saved and the total costs with flow devices. The total resources saved with flow devices is the sum of potential resources saved and the total costs before flow devices.

Beaver Management Costs/Yr.	Before Flow Devies	With Flow Devices
Beaver management	$155,869.00	$44,526.00
Beaver damage repair	$145,000.00	$0.00
Total costs	**$300,869.00**	**$44,526.00**
Potential resources saved*	$71,639.00	$71,639.00
Total resources saved	**$116,165.00**	**$372,508.00**
Total resources saved/ Total costs	**$0.39**	**$8.37**

* based on data published by USDA-Wildlife Services (2003)

Total resources saved following flow device installations included resources saved ($71,639) in addition to funds VDOT saved in beaver management costs ($155,869) and road repair costs ($145,000) saved by installing flow devices, for a total resources saved of $372,508.

The cost-benefit ratio at these 14 study sites (total costs divided by total resources saved) prior to flow device installations was 1 to 0.39, or $0.39 in resources saved for every $1 VDOT spent. Following flow device installations, the estimated cost-benefit ratio was 1 to 8.37, or for every $1 spent, VDOT saved $8.37.

DISCUSSION

The results of our study show that flow devices such as Beaver Deceivers™, Castor Masters™, and Round Fences™ can be efficient, cost-beneficial tools for resolving conflicts with beavers along roadways in the Coastal Plain of Virginia. To date, based on the most current survey information, all 33 devices installed at 14 beaver damage sites from June 2004 to November 2005, including 18 Beaver Deceivers™ and 15 Castor Masters™, are functioning properly and are meeting VDOT and landowner beaver management objectives. Of the 7 devices installed at 7 chronic damage sites from November 2005 to March 2006, 6 are functioning properly.

These results concur with data published by Callahan (2005), who reported an 87% success rate using Flexible Pond Levelers (devices with designs similar to Castor Masters™) at 156 beaver damage sites in New York and Massachusetts, and a 97% success rate using upright trapezoidal or rectangular culvert fences (devices similar to Beaver Deceivers™) at 227 sites in the same geographic region. Several factors may have contributed to the slightly higher flow device success rates in our study, the most influential of which may have been our study's relatively small sample size (21 sites) compared to Callahan's study (383 sites). Climate, weather, topographic, and landscape differences may also have contributed to differences in success rates, since our study was conducted in the Coastal Plain of Virginia and Callahan's devices were installed throughout New England. Nonetheless, the flow device success rates reported in both studies were significantly higher than rates reported by other researchers who conducted similar studies on other flow device designs (Nolte et al. 2001, Hamelin and Lamendola 2001).

Although Callahan reported high flow device success rates, flow devices did fail at a small percentage of sites for a variety of reasons. At 383 sites managed with flow devices from November 1998 to February 2005, pond leveler failure rate was 13.5%, while culvert fence failure rate was only 3.1%. Pond levelers generally failed due to the construction of new dams downstream by beavers (11 sites or 7.1%), insufficient pipe capacity (6 sites or 3.8%), lack of maintenance (2 sites or 1.3%), and dammed fencing (2 sites or 1.3%). Culvert fences failed due to lack of maintenance (4 sites or 1.8%), dammed fencing (2 sites or 0.9%), and vandalism (1 site or 0.4%). Other factors that contributed to failure included inexperienced installers, poor site selection, and/or flow device design (Callahan 2003). Results of a previous study conducted by Callahan (2003) also showed that when flow devices did fail, they failed within the first 2 to 12 months following installation, but as of 2003, 221 successful devices in Callahan's study had been in place longer than 12 months.

The results of our study also demonstrated that the flow devices we used can be extremely cost-beneficial due to relatively low installation and maintenance costs compared to the time and expense of repeated road maintenance, repair of road damage, and annual beaver population control required for other flow device designs. The comparative cost analysis revealed that for every $1 VDOT spent on preventive maintenance, road repairs, and beaver population control activities at the 14 study sites prior to the installation our flow devices, the agency saved $0.39 in resources; whereas, after installing and maintaining our flow devices, VDOT saved $8.37 for every $1 spent, for a total of $372,508 of resources saved per year (Table 4). Additionally, the cost-benefit comparison represents both actual damages that occurred at a site 12 months prior to installations and potential damages expected to occur within 12 months without flow device installations. Since the predicted life expectancy for each successful device is at least 10 years (Callahan 2005), with an average maintenance cost of $19.75 at each site per year compared to $21,490.64 per site per year for maintenance, repairs, and beaver population control prior to the installation of our flow devices, we believe the value of resources saved by installing flow devices at these sites will continue to increase over time.

During the course of our study, we also discovered several benefits to using flow devices that are difficult to quantify, but nonetheless significant. For instance, opening blocked culverts– manually, or by using heavy equipment– is an expensive, arduous, and potentially dangerous endeavor, compared to the routine maintenance required for Beaver Deceivers™. VDOT personnel noted that culverts are often damaged in the process of clearing with heavy equipment, decreasing the life expectancy of these road structures and forcing the transportation department to replace them more frequently.

Moreover, clearing a culvert manually generally involves having one or more people inside the culvert disassembling the dam using their hands or hand tools (a cultivator, for instance) to remove the blockage piece by piece, until the pressure of the dammed-up water finally pushes the remainder of the dam out the downstream side of the culvert. Under these circumstances, the dam could easily give way while a worker is in the culvert and could lead to serious, life-threatening injuries. Compared to clearing a plugged culvert, routine maintenance on a Beaver Deceiver™ is relatively easy and safe, as it simply requires removing any leaves, sticks, twigs, or branches that have accumulated on the upstream side of the receiver fence once or twice a year. Maintenance workers are never subject to the risk of an unpredicted release of large volumes of dammed water.

One potential concern for us when using flow devices to manage beavers near roadways is the development of new conflict sites following installations. In 2003, Callahan published data showing that of the 177 beaver colonies present where flow devices were installed in New England between 1998 and 2003, there were 277 conflict sites, or an average of 1.56 conflict sites per beaver colony. Since data published 2 years later in 2005 showed the average conflict sites per colony remained constant, Callahan concluded that by using flow devices to treat a small number of critical beaver conflict sites, a large watershed can be managed without contributing to the development of new problem sites or removing beavers from the community.

In the future, to test Callahan's findings, it may be beneficial to generate data on the ratio of beaver conflict sites per colony at our study sites in Virginia. In the meantime, to assist transportation agencies in the decision-making process for selecting chronic beaver damage management sites for flow device installation, we intend to develop a projected cost-benefit analysis model based on current and future collected comparative cost data. We also plan to create guidelines for identifying chronic damage sites where flow device use is both preferable and feasible, and the criteria necessary for designing and installing the devices.

As stated previously, Callahan's data indicated that there are sites where flow device installations are not workable, but it would be helpful to determine what, if anything, these sites have in common so that wildlife damage control managers can make educated decisions on the most effective, cost-beneficial strategies for beaver conflict resolution at particular damage sites. We also know, for instance, that a Beaver Deceiver™ frame is typically trapezoid-shaped and that the perimeter ranges from 40 to 120 feet and generally increases with stream and culvert size, but specific standard dimensions and instructions should be developed for transportation departments and wildlife damage control operators to use when designing, installing, monitoring, and maintaining these devices.

Given the demonstrated low costs to install and maintain flow devices compared to the high costs of preventative maintenance, road repairs, and beaver population control activities, a compelling case can be made to install flow devices in freestanding dams near roads or to protect culverts that beavers could potentially plug. Nevertheless, a more prudent approach may be for transportation agencies to install flow devices at sites that have the largest impact on road maintenance and beaver management budgets.

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PRIORITIZING ROAD CROSSING IMPROVEMENT TO RESTORE STREAM CONNECTIVITY FOR STREAM-RESIDENT FISH

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Abstract

Road crossings over streams can act as barriers to movement of aquatic organisms, and may thereby prevent recovery of populations following disturbance and increase extinction risk by fragmenting populations. Reconstruction of existing crossings can facilitate passage of organisms, and has the potential to be one of the most efficient ways of improving habitat because management action at a very small scale – the width of a road – can lead to very large extents of connected habitat. However, because there are so many existing crossings (e.g., >60,000 in Wisconsin), methods are needed to prioritize restoration efforts. The objective of this study was to create a method for identifying road crossings whose reconstruction would most benefit stream fishes by restoring stream network connectivity.

We demonstrate the method through a case study in the 2,500 km^2 Pine-Popple watershed in Wisconsin. We first designed a new metric for quantifying stream connectivity status for stream-resident fishes. We then conducted a comprehensive field survey of road crossings in the watershed to identify crossings that are likely to impede fish movement. We used a GIS to evaluate the influence of each crossing on the mean connectivity status of all streams in the watershed. This measure is an index of the potential benefit of eliminating each barrier. The benefit index was then divided by a reconstruction cost estimate to create a benefit/cost ratio that could be used to prioritize projects.

Sixty-seven percent of the 169 surveyed road crossings were determined to be a barrier to movement of at least some species or life stages of fish. The most common problem was a low constriction ratio (structure width/stream width). The probability of a crossing being a barrier was strongly negatively related to the size of the stream at the crossing. The distribution of benefit/cost ratios was strongly skewed, which provides support for the utility of prioritizing projects in this watershed. The methods developed in this study can be applied elsewhere using widely available spatial data, and commonly used GIS and database software.

Introduction

There are millions of places where roads cross streams and rivers in the United States. Proper design, construction, maintenance, and periodic replacement of these crossings are critical for maintaining the safety and continuity of our road network. It is becoming increasingly recognized that these same activities strongly influence the continuity and health of our flowing water resources. Poorly designed or maintained road crossings can block fish migration and deposit excessive sediment in stream channels. Recently, innovative crossing designs have been developed that minimize these negative effects and are generally only slightly more costly than traditional designs (Hansen, Nieber, and Lenhart 2009). However, there are far too many problem crossings in many areas to address in the short term. Furthermore, some crossings have a disproportionate effect on stream connectivity. Together, these factors mean that prioritizing reconstruction projects is a potentially useful approach.

Prioritization requires a method for assessing the condition of a crossing structure and for quantifying the relative benefit to stream ecosystems that would result from the removal of each problem crossing. There are several existing examples of both of these types of methods. However, existing methods for crossing assessment are either overly simplistic and qualitative (i.e., do not distinguish varying degrees of passability) or require too much time and effort to be applicable to watershed-scale assessments (e.g., FishXing software; Furniss et al. 2008). Existing metrics for quantifying connectivity status and prioritizing barrier removal (O'Hanley and Tomberlin 2005) are oriented toward migratory fishes and do not capture the movement needs of stream-resident fishes. This report describes a field protocol for estimating a continuous measure of passability that represents the proportion of individual fish that are able to pass through a crossing. It also describes the development and implementation of a series of connectivity metrics oriented toward stream-resident fishes.

The methods presented in this report were developed as part of a pilot stream connectivity project in the Pine-Popple watershed in northeastern Wisconsin. This project was sponsored by The Nature Conservancy, the US Fish and Wildlife Service, and the USDA Forest Service, and was conducted in cooperation with researchers at the University of

Wisconsin-Madison. The objective of this project was to develop methods that could be used to quantify connectivity patterns and prioritize remediation efforts across the Great Lakes Basin. The Pine-Popple watershed case study illustrates the application of these methods and provides a first look at watershed-scale patterns of stream connectivity that are functionally relevant for stream-resident fishes. We hope that as these methods are applied across larger areas, we may begin to understand the broad scope of influence that road crossings have on stream connectivity, and to make progress toward remediating the most significant negative effects.

Road Crossing in the Pine-Popple Watershed

The Pine and Popple watersheds (hereafter Pine-Popple) cover 2500 km^2 of mostly forest and wetland in northeastern Wisconsin. The two mainstem rivers (the Pine and the Popple) were designated by the state of Wisconsin in 1965 as wild and scenic rivers, to be protected from development and kept in a natural, free-flowing condition. There is only one major dam in the watershed, a hydroelectric facility on the Pine River. Because watershed land use is predominantly natural, road crossings have the potential to be one of the most significant anthropogenic influences on aquatic species and habitats.

Several road crossings in the watershed had been reconstructed with "fish-friendly" structures prior to this project. Most of these projects were coordinated by the USDA Forest Service and were implemented on roads managed by the Forest Service. However, many more problem crossings have been identified, and many crossings had not been surveyed prior to this project. To conduct a watershed-wide prioritization of road crossing reconstruction projects, we deemed it necessary to survey as many crossings as possible. We later conducted a sensitivity analysis to determine whether a GIS-based analysis would produce similar results (Fig. 10).

A comprehensive survey of road crossings in the Pine-Popple watershed was conducted in summer 2008. The purpose of this survey was to collect enough information on each crossing to estimate its passability by fish, and for problem crossings, to estimate the cost of replacing the existing structure with a fully passable structure. The estimate of passability was designed to represent the proportion of individual fish of all species and life stages that could pass the structure going upstream. Table 1 contains the classification criteria, which are based on swimming ability information (from the FishXing program; Furniss et al. 2008) of fish species that commonly occur in the Pine-Popple watershed. This passability classification approach is a compromise between a binary passability determination and a detailed hydraulic analysis. If this approach is used elsewhere, the specific criteria should be modified to match the swimming ability of resident species.

To plan the surveys, probable road crossings were mapped as the intersection of 1:24,000 scale hydrography (WDNR 2003) and three road layers: TIGER roads, Nicolet National Forest roads, and International Paper logging roads. This mapping procedure produced 281 locations. Sixty-seven percent of these locations were identified in the field as actual road crossings. In the remaining 33% of cases, there was either no stream or no road present.

The survey protocol was adapted from an existing protocol used by The Nature Conservancy.
Each crossing took 15-30 minutes to survey. Three two-person field crews completed the bulk of the field work in approximately 20 crew-days.

A Microsoft Access database was created to store and analyze the survey data. The database also includes a function for estimating the cost of replacing the existing crossing structure with one that is fully passable by fish. The database template and other supplementary materials, including a computer program for calculating connectivity metrics, are available upon request from the authors.

<u>Passability = 0</u> (Most species and life stages cannot pass at most stream flows.) The outlet of the structure is perched, or The ratio of the structure water depth to the stream water depth is less than 0.1, or The water velocity in the structure is greater than 3 ft/s during baseflow.
<u>Passability = 0.5</u> (Some species and/or life stages cannot pass at most stream flows.) The water depth in the structure is less than 0.2 feet, or The water velocity in the structure is 2-3 ft/s during baseflow, or The structure is longer than 30 ft and does not have natural substrate through its entire length.
<u>Passability = 0.9</u> (Barrier at high flows.) The constriction ratio (structure width/bankfull stream width) is less than 0.5, or There is a scour pool below the structure.
<u>Passability = 1</u> (No passage problem.) The outlet of the structure is not perched, and The water depth in the structure is greater than 0.2 feet, and The ratio of the structure water depth to the stream water depth is greater than 0.1, and The water velocity in the structure is less than 2 ft/s during baseflow, and The constriction ratio is greater than 0.5, and There is no scour pool below the structure, and The structure is longer than 30 feet and has natural substrate through its entire length, or The structure is shorter than 30 feet and may not have natural substrate through its entire length.

Table 1. Criteria for determining passability of road crossings.

<u>Survey Findings</u>

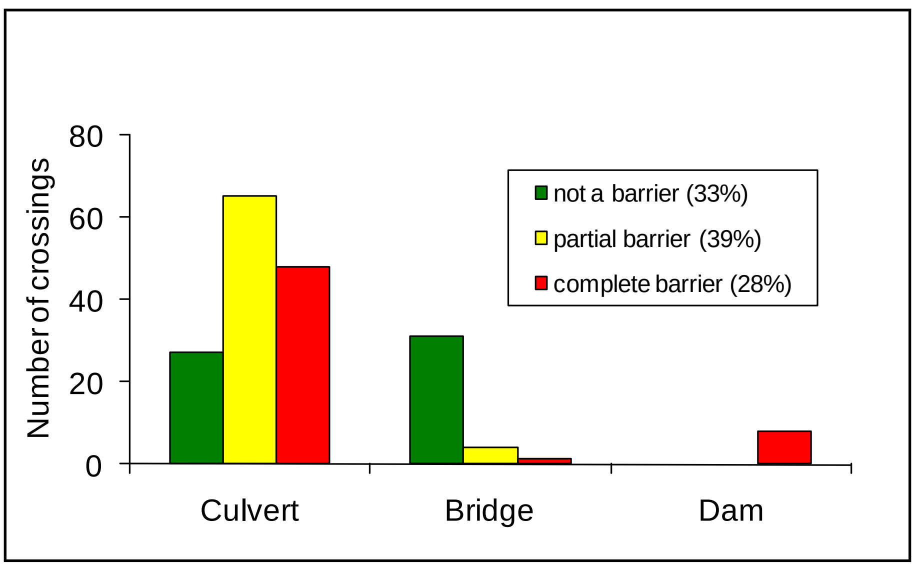

Figure 1. There are 192 road crossings on the 611 miles of mapped streams in the Pine-Popple watershed (an average of one crossing every 3.2 miles of stream). 67% of road crossings were at least a partial barrier to fish passage. In this watershed, road crossings (culverts, in particular) are a more significant impediment to fish movement than dams.

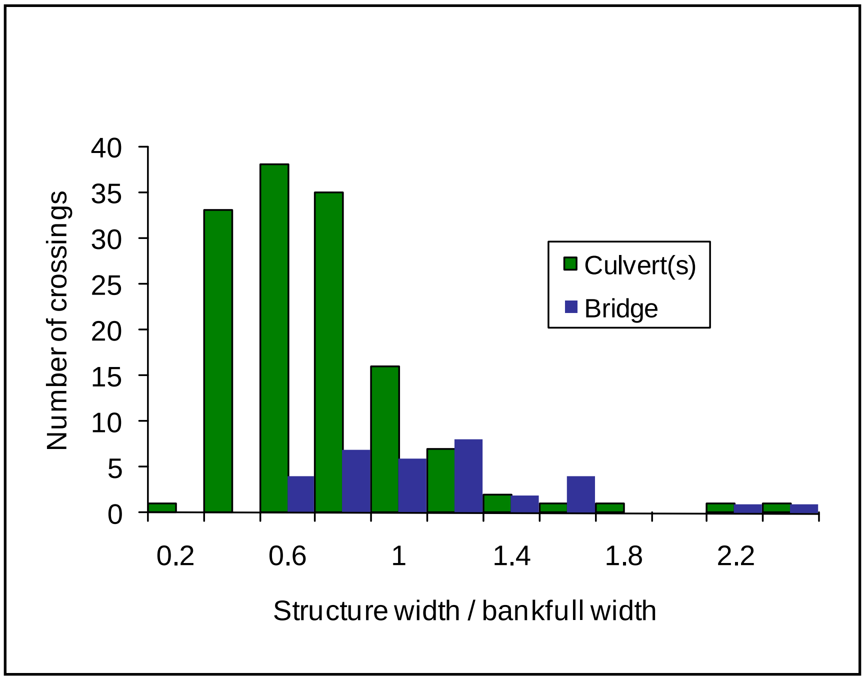

Figure 2. 77% of crossing structures are narrower than the streams they carry. Stream constriction was the most common design flaw. Culverts were much more likely than bridges to be significant constrictions.

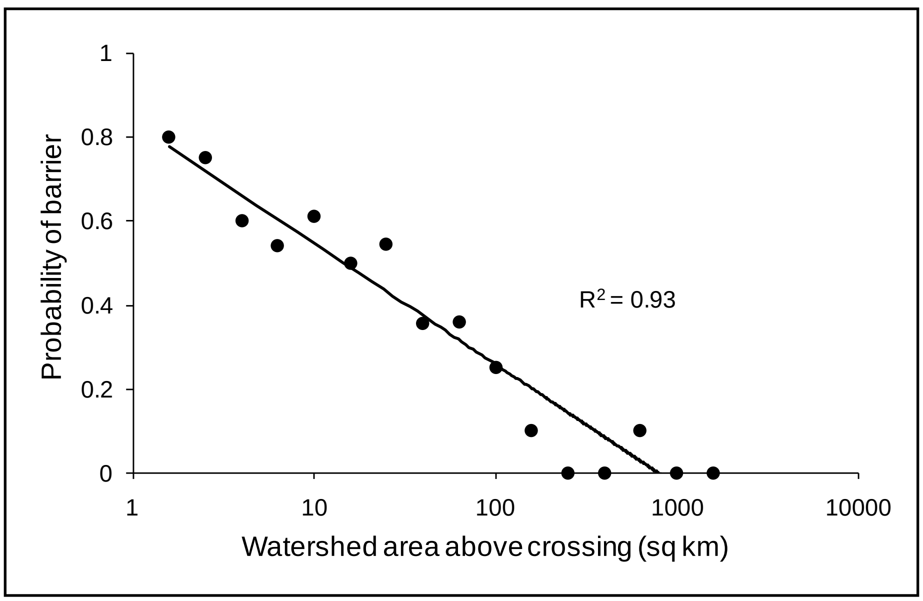

Figure 3. The probability that a crossing is a barrier is largely a function of the size of the stream at the crossing (represented by watershed area).

Quantifying Connectivity Status and Improvement for Stream-Resident Fishes

The field survey described in Section 1 identified barriers to fish passage in the Pine-Popple watershed. If only a few crossings had been barriers, it would have been reasonable to fix all of them. However, 121 crossings and dams were at least partial barriers, which justified prioritizing remediation projects.

Our prioritization approach is a benefit/cost analysis. The road crossing database associated with this report can be used to estimate the cost of reconstructing a crossing to one that is fully passable by fish. To quantify the benefit of removing a particular barrier, we designed a series of new metrics, which are described in this section. These metrics are designed to capture the movement needs of stream-resident fishes, which are qualitatively different than the movement needs of anadromous species, such as salmon.

The most common movements that most stream-resident fish make are among seasonal habitats (e.g., spring spawning in headwaters, summer feeding in mid-order streams, and over-wintering in deep pools of larger rivers). We assume that free access among this range of habitat types will also provide access to refuge during a disturbance such as a flood. There may be connectivity scenarios where these classes of needs are met, but where long range movements that lead to genetic exchange among populations are limited.

Detailed Methods

We define the connectivity status (*C*) of a focal stream segment *j* as a function of the degree of access to and from the range of seasonal habitat types (*t*) that a fish uses. Connectivity status can be defined for either an individual species whose habitat needs are well known, or for the fish community as a whole, whose combined needs will often encompass a greater range of habitat types. Once C is calculated for all the segments in a watershed, it can be summarized to describe watershed connectivity status. The change in watershed connectivity status that results from a barrier removal can be used to prioritize barrier removal projects.

Even in a watershed with no barriers, the amount of each habitat type that is accessible from each stream segment varies. This is because some habitat types are more common than others, because distance limits movement between some pairs of segments, and because degradation of habitat quality in some segments effectively reduces the contribution of those segments to the pool of available habitat. Natural barriers (e.g., waterfalls) also limit connectivity for some segments. Evaluation of barrier-limited habitat availability must first account for these sources of background variation. We define the baseline (*b*) (no artificial barriers) availability (*A*) of habitat type *t* from segment *j* as:

(1) $$A_{jt}^{b} = \sum_{i=1}^{n} \left(S_{it} \cdot P_{itj}^{n} \cdot D_{itj} \cdot Q_{it} \right)$$

Where S_{it} is the length of segment *i*, the natural barrier passability (P^n) is the product of the individual passabilities ($0 \le P \le 1$) of all natural barriers encountered when traveling from the focal segment *j* to segment *i* and back. The quality index (*Q*) equates habitat degradation with a reduction in habitat availability. For the Pine-Popple analysis, *Q* was defined as 1-*H*, where *H* is the sum of the proportions of urban and agricultural land uses in the watershed of segment *i*. D_{itj} is the value from an inverse distance weighting function which scales the accessibility of nearby segments toward one and distant segments toward zero:

(2) $$D_{itj} = \frac{1}{1 + \left(\frac{d}{d_m} \right)^2}$$

Where *d* is the distance along the stream network between the centroids of two segments and d_m is the distance at which the weight equals 0.5. For the Pine-Popple analysis, d_m was set to 20 km, which approximates the typical spatial autocorrelation function from the distributions of several stream fish species in Wisconsin (Diebel et al. in review). Ideally, the variable d_m should be set so that the distance weighting function resembles a frequency distribution of seasonal movement distances of the focal species in an unimpeded stream network.

We then expand equation 1 to include effects of artificial barriers on *A*:

(3) $$A_{jt} = \sum_{i=1}^{n} \left(S_{it} \cdot P_{itj}^{n} \cdot P_{itj}^{a} \cdot D_{itj} \cdot Q_{it} \right)$$

Where the artificial barrier passability (P^a) is the product of the individual passability ($0 \le P \le 1$) of all road crossings and dams encountered when traveling from the focal segment *j* to segment *i* and back.

The overall connectivity status of a stream segment *j* is calculated as:

$$(4)\quad C_j^{ind} = \frac{\sum_{t=1}^{m}\left(\frac{A_{jt}}{A_{jt}^{b}}\right)}{m}$$

Where *m* is the number of habitat types for which there is some baseline availability (A_{jt}^{b} > 0). In watersheds with no natural barriers, *m* will equal the number of habitat types for all segments. In watersheds with natural barriers that isolate some segments from one or more habitat types, *m* serves to normalize the connectivity status of each segment to its expected maximum for that segment.

In equation 4, the availability of each habitat type to a focal segment is assessed in relation to its baseline availability for that same individual (*ind*) segment. This approach may attribute undue importance to a small to moderate reduction in habitat availability on segments where the baseline availability is particularly high. A more conservative measure of connectivity status compares the existing habitat availability (A_{jt}) to the lesser of A_{jt}^{b} or $\overline{A}_{t't}^{b}$, where *t'* is the habitat type of the focal segment and $A_{t't}^{b}$ is the set of all pairs of segments in the study area with habitat types *t* and *t'*:

$$(5)\quad C_j^{avg} = \frac{\sum_{t=1}^{m}\left(\max\left(1, \frac{A_{jt}}{\min(A_{jt}^{b}, \overline{A}_{t't}^{b})}\right)\right)}{m}$$

C^{ind} and C^{avg} provide different ways of answering the question: How much connectivity is enough? C^{ind} sets a standard that varies among segments and is an aggressive goal, whereas the C^{avg} standard only varies among habitat types and is a more modest goal. C^{ind} can only equal 1 when there are no artificial barriers in the watershed, whereas C^{avg} equals 1 as long as artificial barriers do not reduce the availability of each habitat type below its watershed average availability in the baseline scenario.

For the Pine-Popple watershed analysis, we used Strahler stream order for the habitat type classification. Changes in stream order are usually accompanied by changes in habitat characteristics such as depth, current velocity, substrate, and temperature. Another advantage of using stream order is that it is an existing attribute in many hydrographic data layers. Other habitat classifications that focus more directly on the life-history needs of fish should be substituted when available.

The overall connectivity status of a watershed ($\overline{C}$) is the length-weighted average *C* (*ind* or *avg*) of all segments:

$$(6)\quad \overline{C} = \frac{\sum_{j=1}^{n}(C_j \cdot L_j)}{\sum_{j=1}^{n} L_j}$$

The difference between $\overline{C}^{ind}$ and $\overline{C}^{avg}$ will generally increase as the number of natural barriers increases in a watershed.

The overall connectivity effect of removing barrier *k* ($\Delta\overline{C}$) is simply $\overline{C}_{\text{post-removal}}$ - $\overline{C}_{\text{pre-removal}}$, or:

$$(7)\quad \Delta\overline{C}_k = \frac{\sum_{j=1}^{n}(\Delta_k C_j \cdot L_j)}{\sum_{j=1}^{n} L_j}$$

The metrics described here take a similar perspective to the recently-developed Dendritic Connectivity Index (Cote et al. 2008). This study presents two variations of this metric: DCI_d (diadromous version) and DCI_p (potadromous version). DCI_p is analogous to C^{ind}, but does not differentiate among habitat types, and does not include a distance-weighting or a quality function. In simple terms, it is the length-weighted average connectivity among all pairs of segments in a watershed. DCI_d is essentially the percentage of the whole stream network that is connected to the watershed outlet. In most cases, these metrics will indicate a lower connectivity status than C^{ind} or C^{avg}. Table 2 summarizes the four metrics discussed here.

Metric	Application	Summary description
C^{ind}	Stream resident species	Compares the availability of each habitat type from a focal segment to its availability from that same segment without artificial barriers. Availability is based on segment length, distance, quality, and passability.
C^{avg}	Stream resident species	Compares the availability of each habitat type from a focal segment to its availability from the average segment without artificial barriers. Availability is based on segment length, distance, quality, and passability.
DCI_p	Stream resident species	The average size of the connected stream network from all points in the watershed as a proportion of the total network length.
DCI_d	Diadromous species	The proportion of the whole stream network that is connected to the watershed outlet.

Table 2. Comparison of four connectivity metrics:
DCI_d and DCI_p (Cote et al. 2008) and C^{ind} and C^{avg} (this study).

Results of the Connectivity Assessment of the Pine-Popple Watershed

Connectivity Status

The connectivity status of the Pine-Popple watershed for stream-resident fish is 0.574 (C^{ind}) or 0.630 (C^{avg}) out of 1. This means that the average stream segment has a little more than half as much connected habitat as it would without artificial barriers. This baseline scenario was calculated with the distance weighting parameter (d_m) set to 20 km. Varying d_m to reflect differences in the spatial range of target species had a moderate effect on the value of connectivity status (Fig. 4). Species with larger ranges will find connectivity more impaired than those with smaller ranges.

The connectivity status of individual segments varies from almost completely isolated to almost fully connected; C^{ind} ranges from 0.001 to 0.84 and C^{avg} ranges from 0.001 to 0.94 (Fig. 5). The frequency distribution of connectivity status is somewhat bimodal; streams tend to fall toward one end of the spectrum or the other, with fewer intermediate values. Connectivity status varied among stream orders. In general, small and large streams and lakes are more isolated than mid-sized streams (Fig. 6).

C^{avg} paints a more favorable picture of connectivity status than C^{ind} (Figs. 4, 5, 6). This will be the case in any watershed, but the watershed-level difference will be greater where there are more natural barriers, and the segment-level difference will be greatest where there is a moderate reduction in habitat availability to a segment whose baseline availability is particularly high.

Connectivity Improvement

The improvement in connectivity status that results from the removal of barrier *k* ($\Delta\overline{C}_k$) can be used to prioritize crossing reconstruction projects. However, $\Delta\overline{C}_k$ may not be static when multiple barriers are removed and the efficiency of a given project also depends on its cost. Administrative factors such as allocation of decision-making responsibility and the timeline of funding availability should also be considered when selecting a prioritization method. Table 3 describes three possible prioritization approaches, and discusses conditions and limitations of their use.

We ran the sequence optimization described in Table 3 on the all artificial barriers in the Pine-Popple watershed, using both C^{ind} and C^{avg}. The resulting sequences of projects are displayed in Figure 7. These sequences are particularly efficient at low budgets. For example, the same connectivity improvement caused by the removal of all completely impassable road crossings can be achieved for less than half the cost through sequence optimization.

Figure 7 can be used to balance overall expenditures with watershed-scale targets for connectivity restoration. For example, a C^{ind} target of 0.8 could be achieved for $2 million through prioritization, but would cost approximately $6 million with random project selection.

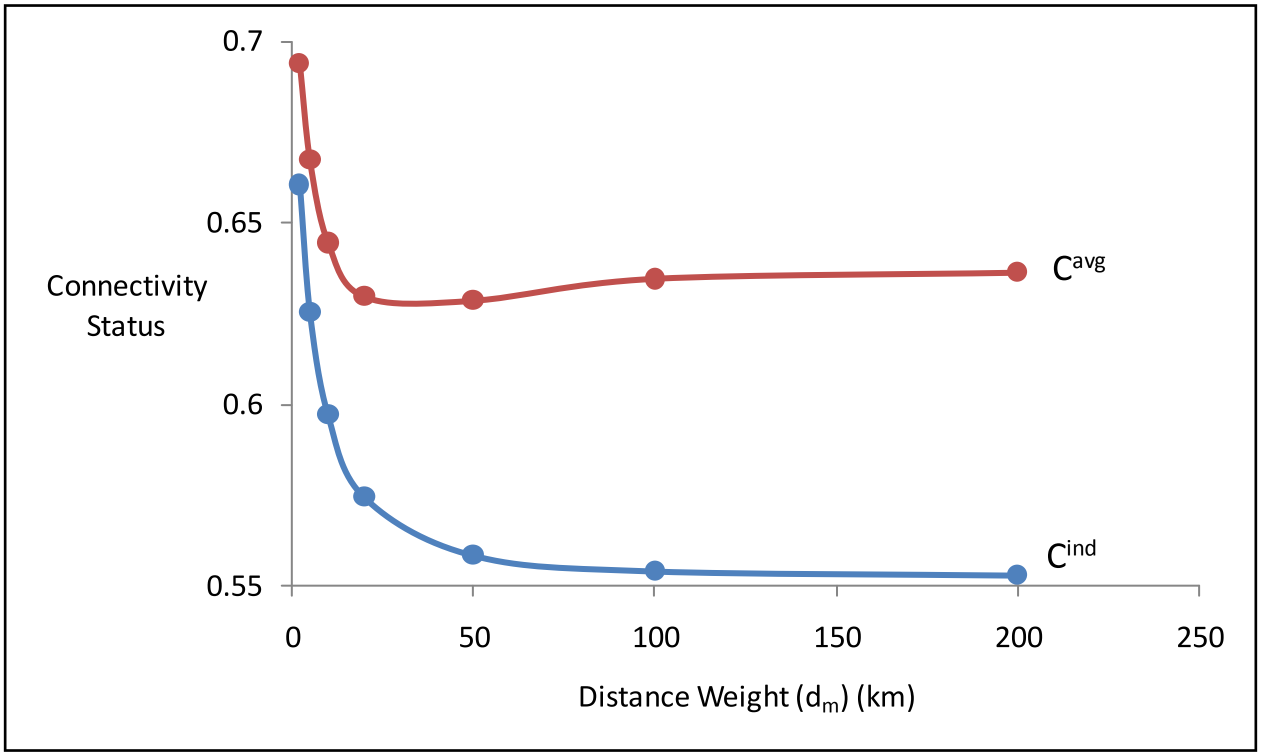

Figure 4. Varying the distance-weighting parameter (d_m) to reflect differences in the expected spatial range of target species changes estimates of connectivity status. Species with greater ranges will find connectivity more impaired than those with smaller ranges.

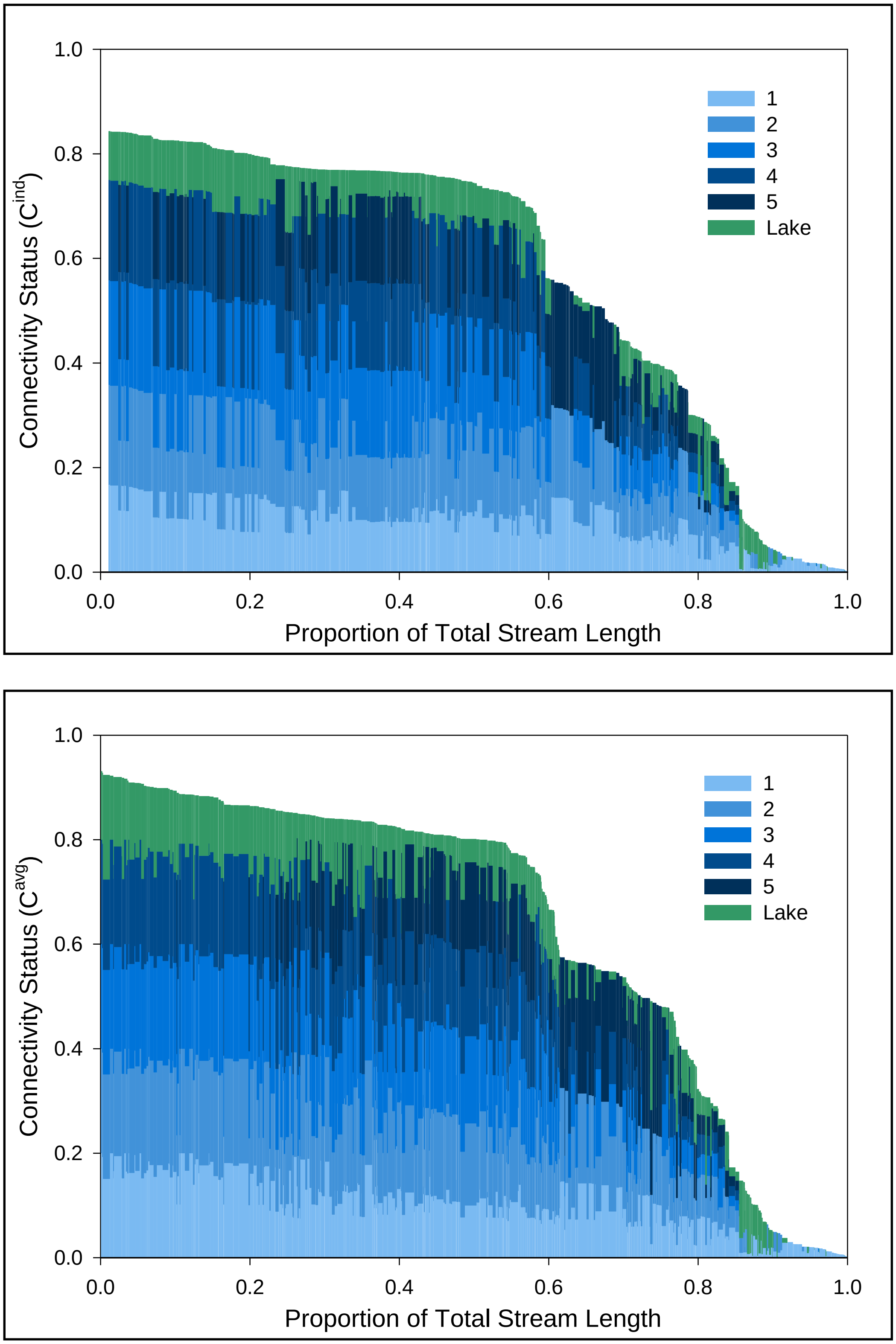

Figure 5. The connectivity status of all streams in the Pine-Popple watershed is summarized on these two plots (C^{ind} and C^{avg}). In each plot, stream segments are arranged in descending order of connectivity status from left to right. The color bands indicate habitat types (stream orders). The filled plot area is equal to the connectivity status of the watershed

($\overline{C}^{ind}$ = 0.574, $\overline{C}^{avg}$ = 0.630).

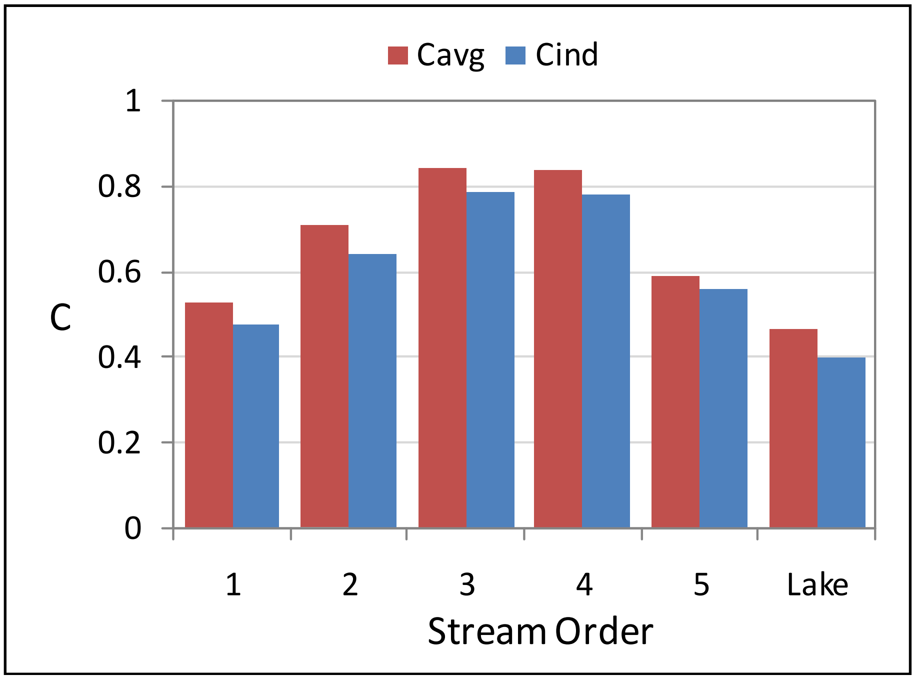

Figure 6. Connectivity varies by stream order. In the Pine-Popple watershed, small and large streams and lakes tend to be more isolated than mid-sized streams.

Approach	Procedure	Conditions	Limitations
Manual scenario comparison	1. Select several feasible combinations of barrier removals. 2. Run scenarios (program available from authors). 3. Select the best scenario based on the value(s) of connectivity metrics and other factors (e.g., age of structures, safety concerns).	• A limited number of crossings are feasible to reconstruct. • Decision making will require negotiation among multiple managing authorities.	• Because scenarios are selected manually, the most efficient scenario(s) may not be evaluated.
Sequence optimization	1. Run barrier removal sequence optimization (program available from authors). 2. Select barriers for reconstruction in the order of the results.	• Most crossings are feasible to reconstruct. • Projects will be completed one or a few at a time over a long time span.	• Cumulative efficiency may not be optimal at some points in the sequence. • Skipping some projects in the sequence may significantly reduce cumulative efficiency.
Budget optimization	1. Specify the total project budget. 2. Run the budget optimization routine (in development) to select the optimal set of projects for the specified budget.	• Most crossings are feasible to reconstruct. • Decisions are mostly made by one managing authority. • Several projects will be completed in one or a few bursts of activity.	• The set of projects selected by this routine is only guaranteed optimal if all projects are completed.

Table 3. Comparison of three barrier removal prioritization approaches.

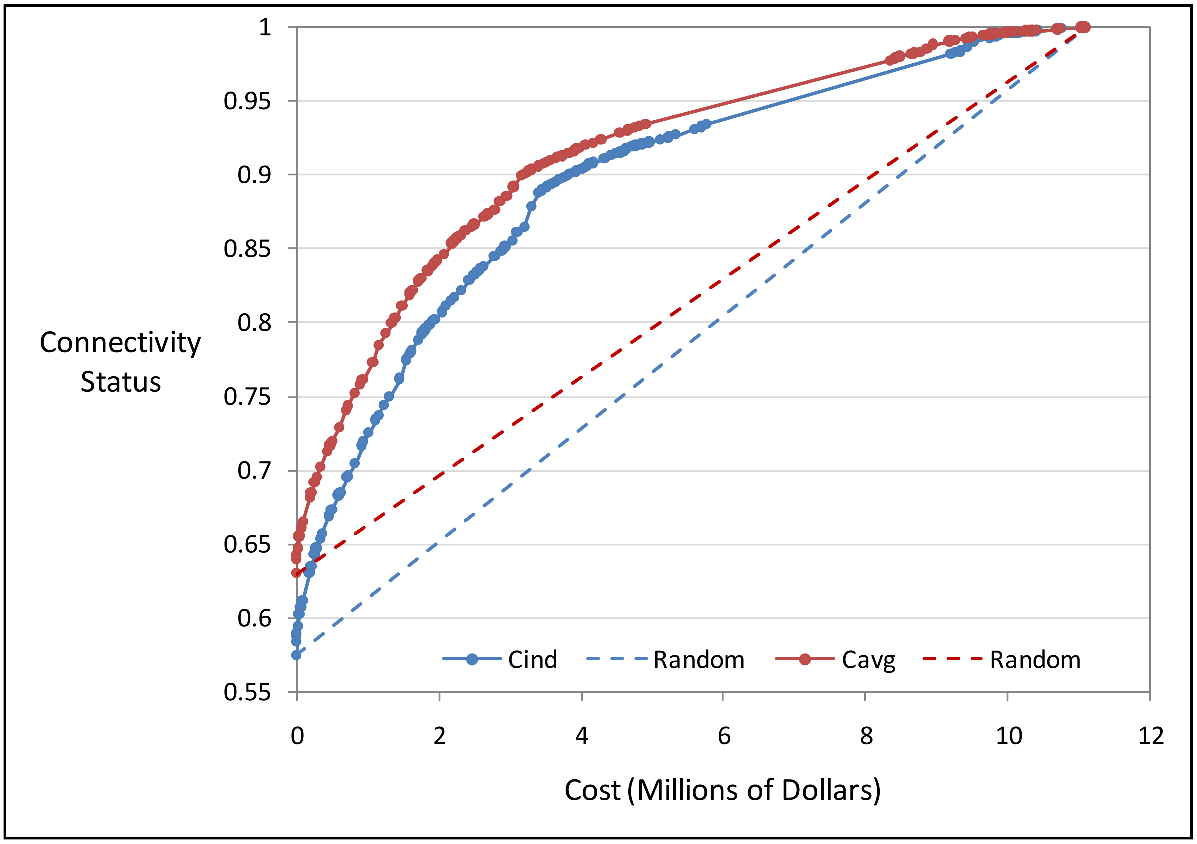

Figure 7. A plot of the two types of watershed connectivity status as a function of cumulative cost. This type of figure can be used to balance overall expenditures with watershed-scale targets for connectivity restoration. For example, a C^{ind} target of 0.8 could be achieved for $2 million through prioritization, but would cost approximately $6 million with random project selection.

Effect of Connectivity Status on Fish Communities

An existing dataset of fish surveys in the Pine-Popple watershed was used to examine how connectivity status affects fish community composition. Fish surveys were conducted on 97 stream segments between 1970 and 2003, primarily by the Wisconsin Department of Natural Resources, using standard stream survey methods, including electrofishing, netting, and trapping. Survey reach length was typically 20 × mean wetted width. Fish species richness was calculated for each segment as the number of species with at least one individual present.

We expected that fish species richness would be influenced by both stream size and connectivity status. Larger streams provide more diverse habitat and more space for a greater number of species. Well-connected streams are likely to support the resilience of populations of resident species, which should result in fewer incidences of stochastic absences (e.g., following disturbance). Well-connected streams should also contain more transient species, although the identity of these species may change through time due to asynchronous movement patterns.

The analysis was limited to smaller streams (watershed area < 50 km^2), because nearly all of the sampled locations on larger streams were well-connected. In contrast, the sampled smaller streams spanned the full range of connectivity status. Species richness varied from 2 to 19 in the sampled streams. As expected, species richness was positively correlated with both the size of the stream and its connectivity status (Table 4, Fig. 9). Regression goodness of fit measures were nearly identical with C^{ind} and C^{avg}; thus, this analysis does not provide any empirical basis for selecting one measure over another.

We then divided the species into three groups to determine whether connectivity was influencing some types more than others. The groups were warmwater species, cold/coolwater species and rare species. The richness of warmwater species was most strongly related to both watershed area and connectivity status (Table 4). In the Pine-Popple watershed, warmwater species are most likely to be benefitted by strategic barrier removal that increases the connectivity status of portions of the stream network.

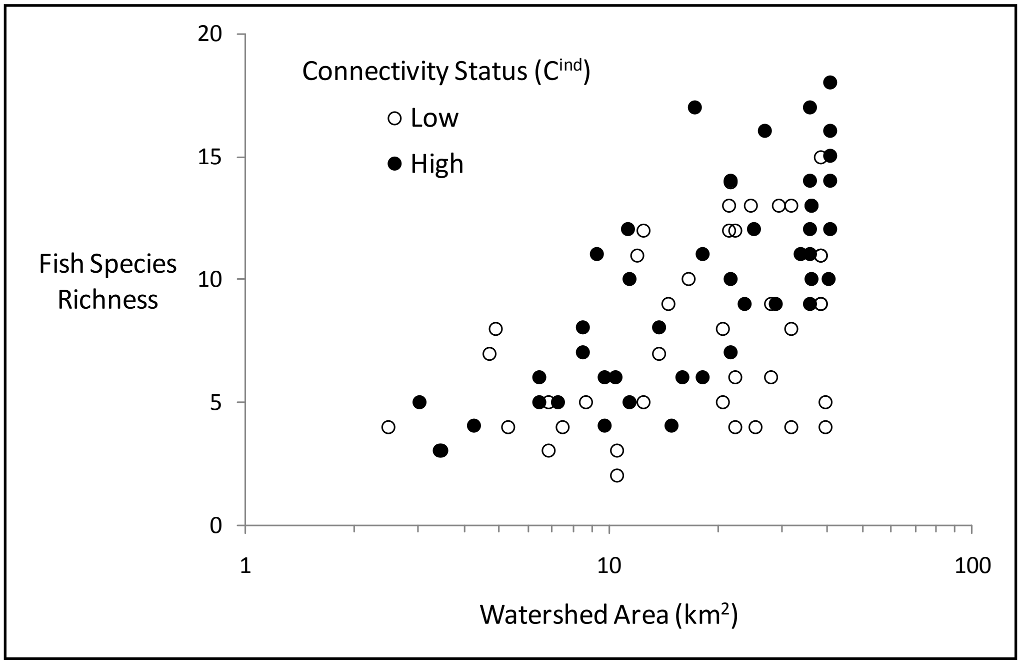

Figure 9. Fish species richness estimated by electrofishing survey is positively related to stream size. Significant residual variation in this relationship is explained by connectivity status; for a given size, streams that are better connected had more fish species.

		Constant		LWSA		CIND	
Response Variable	R^2	Coef.	p-value	Coef.	p-value	Coef.	p-value
All species	0.40	-2.0	0.16	7.5	<0.001	3.0	0.007
Warmwater species	0.51	-2.4	0.002	4.4	<0.001	2.6	<0.001
Coldwater species	0.10	0.8	0.19	1.2	0.01	1.0	0.03
Rare species	0.09	-0.5	0.57	1.9	0.003	-0.7	0.29

Table 4. Results of regression analyses relating fish species richness to stream size (log watershed area; LWSA) and connectivity status (CIND).

Future Directions

A connectivity assessment can play a key role in prioritizing road crossing and other barrier reconstruction or removal efforts. However, road crossings can also affect the geomorphic condition of streams, and the severity of these effects should be considered when selecting reconstruction projects. Road crossing repairs are typically first prioritized based on roadway safety. Often, however, there are many crossings in similar condition. A connectivity assessment can provide a basis for determining which of these safety-oriented repairs will create the greatest ancillary benefits. In some cases, connectivity improvement may have negative ecosystem effects, such as by allowing range expansion of invasive species. Further work should try to integrate these factors into a more holistic prioritization approach.

Connectivity assessments at very large geographic scales will be challenging, mostly due to the difficulty of surveying very large numbers of crossings. Desktop methods for identifying likely problem crossings would be useful if they were reasonably accurate. Figure 10 shows a comparison of barrier reconstruction sequences determined through the full protocol described here, and one where passability is modeled as a function of stream size, using the relationship in Figure 3. This analysis shows that a desktop analysis can improve the selection of projects over random selection, but it is significantly inferior to the survey-based approach.

The results of a connectivity analysis should not go into a static report; they should be continually updated as barriers are removed, and can serve as an indicator of watershed condition, much like watershed land cover and geomorphic condition. Biological metrics, such as fish community composition, should be monitored to determine whether connectivity changes actually cause biological changes. These methods could also be adapted to evaluate the potential effects of barrier additions, such as new hydropower dams, and could help identify locations that would minimize additional connectivity impairments.

This analysis provides a first look at watershed-scale patterns of stream connectivity that are functionally relevant for stream-resident fishes. Future assessments elsewhere can help determine whether the patterns observed in the Pine-Popple watershed are common. The following features will be worth comparing among watersheds:

1. **Watershed connectivity status**. This is the best single metric for comparing watersheds. It could be used to map connectivity patterns at large geographic scales.
2. **The distribution of connectivity status among segments within a watershed**. Barriers are not randomly distributed within watersheds. Is connectivity status typically bimodal among segments, or does it sometimes follow other frequency distributions?
3. **The shape of the benefit/cost curve from the sequence optimization**. The initial steepness of the benefit/cost curve could be used to identify watersheds where connectivity restoration is likely to be particularly cost-effective.

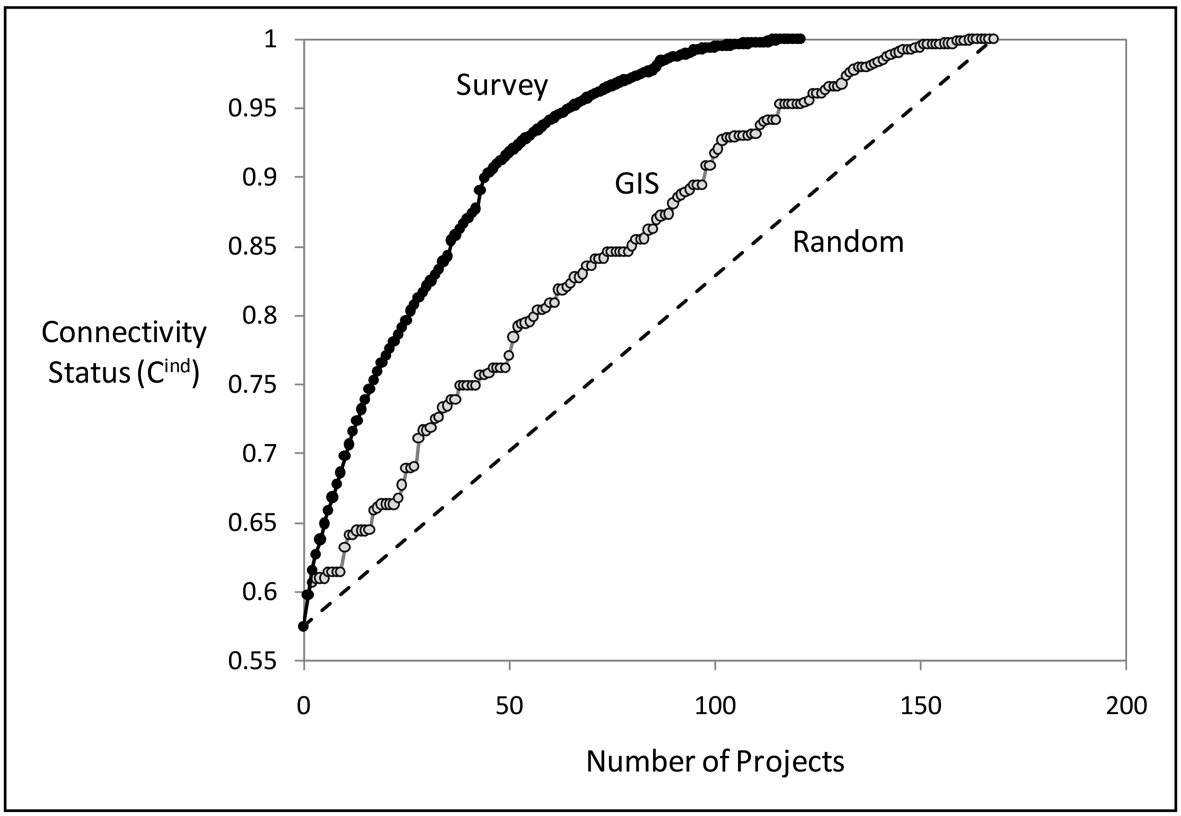

Figure 10. The cumulative gain in connectivity status with additional reconstruction projects chosen with survey and GIS-based estimates of passability. For the GIS analysis, a "predicted passability" value was first calculated for each crossing based on the watershed area – passability relationship shown in Figure 3.

The barrier removal sequence optimization (maximize $\Delta\overline{C}$ version) was then run using the predicted passability values. Crossings were then removed in the sequence selected to determine the C^{ind} trajectory that would have resulted from this imperfect information.

Biographical Sketches

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MULTI-SCALE HABITAT-RESISTANCE MODELS FOR PREDICTING ROAD MORTALITY "HOTSPOTS" FOR REPTILES AND AMPHIBIANS

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Abstract

As road networks and traffic volumes increase, road-effects on animal populations are becoming more prevalent. Our goal was to identify herpetofaunal crossing hotspots on roads and to use this information to prioritize deployment of mitigation efforts. Our focus was New York State where in a collaborative effort between ecologists and the New York State Department of Transportation we synthesized available literature to predict patterns of habitat use by 10 species of herpetofauna. A geographic information system was then used to develop habitat resistance-based models to predict hotspots of herpetofaunal abundance on roads. We developed three approaches for prioritizing model output for transportation planners: (1) Categorizing occurrence indices based on five quantiles; (2) overlaying the arterial classification code (a measure of traffic intensity) over model outputs, and (3) using the contiguous length of road remaining within specified high occurrence index values. Models were evaluated using field data derived from road surveys. Our models showed clear differences in the predicted occurrence of species of herpetofauna on roads depending on life-history strategies. Wide-ranging habitat generalists were predicted to have at least some probability of occurrence on most roads in the study area, for example the common snapping turtle, *Chelydra serpentina*, was predicted to occur on 98% of roads. Conversely, species with limited movement ranges and specific aquatic and terrestrial habitat had more limited distributions, for example the wood frog, *Rana sylcatica*, was predicted to occur on 43% of roads. Validation data indicated that models were effective tools for predicting occurrence of species with specialized habitat requirements, but that predictions for wide-ranging generalists were less accurate. These data also demonstrated that the use of quantiles and the length of continuous hotspot were effective approaches to prioritizing the deployment of mitigation for habitat specialists, with higher densities of animals occurring where there was a higher occurrence index and in longer sections of continuous high occurrence. Our modeling approach is an effective tool for identifying road-hotspots for herpetofauna, allowing predictions to be made over large spatial extents and with readily available data sources. Our results suggest that effective mitigation for movement-limited habitat specialists may include spatially and/or temporally targeted approaches such as road-underpasses or temporary signage. For widespread generalist species it is extremely difficult to determine exact locations for mitigation, thus broader-scale approaches such as driver education are likely to be more effective.

Introduction

A wealth of research has shown that roads can affect animal populations, both through direct mortality (Smith & Dodd 2003), and through habitat fragmentation, degradation and loss (Forman & Deblinger 2000; Trombulak & Frissell 2000; Vos & Chardon 1998). As road-networks and traffic volumes increase, agencies managing roads have an increasingly challenging task: how to build and maintain a system that facilitates the flow of people and commerce, while minimizing the effects on biodiversity. Balancing these objectives can be greatly enabled by understanding where roads are of most concern to animal populations. By identifying these "hotspots" of road-effects, transportation managers can prioritize mitigation efforts when re-engineering existing roads and minimize the likely effects of new roads.

Herpetofauna represent an important target for modeling hotspots as they are particularly vulnerable to road-effects. Many species of amphibians and reptiles make annual migrations between aquatic and terrestrial habitat, increasing the probability that an individual will encounter roads. When crossing roads, the slow rates of movement of many species of herpetofauna make them extremely susceptible to road-mortality (Ashley & Robinson 1996; Hels & Buchwald 2001). High road-mortality of herpetofauna during terrestrial movement is of particular concern as these individuals are members of later life-history stages (juveniles and adults) (Aresco 2005; Gibbs & Shriver 2002). Changes in survival of these stages, which typically have high survival relative to earlier life-history stages in undisturbed populations, are likely to drive overall population dynamics (Biek et al. 2002; Vonesh & De la Cruz 2002). Because many species of herpetofauna rely on aquatic habitats, have high adult philopatry (Berven & Grudzien 1990) and limited terrestrial vagility (Patrick et al. 2006; Smith & Green 2005), populations tend to be spatially structured. Depending on the composition of wetlands, local populations may be centered around single or small groups of wetlands, with rare dispersal events connecting these local populations in regional or meta-populations (Marsh & Trenham 2001; Sjogren Gulve 1994). Maintaining the viability of herpetofaunal populations is therefore reliant on conservation efforts that focus on maintaining both local and regional viability (Semlitsch 2008). Road-effects can influence population dynamics at both these scales; at the local level, primarily by influencing survival of adults and philopatric juveniles that migrate to and from the same aquatic sites; and at the regional population levels by altering the frequency of juvenile dispersal between local populations.

To predict hotspots of road-effects for herpetofauna we must first be able to predict the distribution of animals in the landscape. A number of approaches have been used to model patterns of spatial distribution. Dispersal kernels represent one of the simplest forms, where the distribution of individuals away from a source (for example a pond) is typically calculated from empirical data (Worton 1989). This approach, however, fails to consider the role of habitat heterogeneity in determining habitat use (Ricketts 2001). The application of resistance surfaces/friction modeling in Geographic Information Systems (GIS) offers a means to include variation in habitat suitability. With this technique, each habitat type in a landscape is assigned a “friction” value based on the willingness of animals to cross the habitat type, the physiological cost incurred during this crossing, and the reduction in survival for the individual (Joly et al. 2003; Ray et al. 2002). Research has now combined friction modeling with information on the movement behavior of different species (Compton et al. 2007; Popescu 2007). These hybrid approaches weight the friction cost to movement by the Euclidean distance from the source of animals (e.g., a breeding pond), making it is more costly to move farther and through less suitable habitat. This provides a more realistic assessment of the probability of an individual being present at any point in the landscape.

This newly developed approach to predicting patterns of spatial distribution provides a valuable tool for modeling likely hotspots of road-effects for herpetofauna. Specifically, by using a mechanistic understanding of species-habitat relationships based on readily-available data to derive hotspot models, we are able to offer a valuable addition to current modeling efforts that are primarily phenomenistic (Langen et al. 2009). This information is of particular benefit when recommending how to reduce the effects of newly constructed roads on herpetofauna and for making predictions over wide geographic areas. Under these circumstances, hotspot modeling based solely on empirical studies is difficult; one cannot sample a road that does not exist yet and predictions based on observations in a limited suite of field-conditions are often inaccurate when applied to novel circumstances.

The goal of this study was to pilot the use of habitat-resistance modeling to map hotspots of herpetofaunal road mortality in New York State. Our objectives were: (1) To develop maps of predicted herpetofaunal occurrence for species with a variety of life-history traits; (2) to develop means of prioritizing these hotspots for mitigation efforts; (3) to validate models using empirical data; and (4) to develop a strong working collaboration with transportation management agencies, to build the capacity of both research scientists and managers, and to ensure that we provide the most useful and relevant information for mitigation efforts. To meet these objectives, this applied modeling project was developed in concert with transportation managers. We modeled 10 species with a variety of life-history traits allowing us to extend our results to additional species. We also looked at the effects of roads at multiple scales by developing separate hotspot models for local and regional populations of amphibian species (the only herpetofaunal taxa for which sufficient data were available). We validated our models post hoc by sampling herpetofauna on roads in a select area of New York State.

Methods

We developed models for twelve counties in New York State: Cayuga, Cortland, Chenango, Onondaga, Madison, Oswego, Oneida, Delaware, Otsego, Schoharie, Albany, and Greene. This ~67450 km2 area has a network of public roads ~85303 km in length and encompasses gradients from rural-urban and agriculture-forest as well as including a variety of topography from the alluvial plains on the south of Lake Ontario to the steep glacial valleys of the Allegheny Plateau. Areas within these counties were excluded if no National Wetlands Inventory (NWI) data were available.

Study species were chosen based on incorporating a range of life-history traits, availability of literature data, and targeting species of specific conservation concern in New York State. Amphibian species included three ranids: the wood frog, *Rana sylvatica*, green frog, *R. clamitans*, and northern leopard frog, *R. pipiens*; one bufonid, the american toad, *Bufo americanus*, one ambystomatid salamander: the spotted salamander, *Ambystoma maculatum,* and one true salamander, the eastern red-spotted newt, *Notophthalmus viridescens*. Reptile species included four turtle species: snapping turtle, *Chelydra serpentina*, spotted turtle, *Clemmys guttata*, Eastern painted turtle, *Chrysemys pictus pictus*, and wood turtle, *Glyptemys inscuplta*.

All GIS layers were set to a common coordinate system (Universal Transverse Mercator Zone 18 North), and datum (North American Datum 1983). All analyses were performed using ArcGIS 9.0 (ESRI, Redlands, CA). Creating the friction models for herpetofauna involved a 7-step process: (1) Determine potential suitable aquatic habitat for each species from which to initiate calculation of cumulative cost to movement; (2) Assess which of these aquatic sites has sufficient forest cover required by some amphibian species for population persistence and remove aquatic sites that do not meet these requirements; (3) Assign friction costs to each land-cover type in our study area for each species (and for migrating adults and dispersing juveniles separately in the case of amphibians); (4) Create circular movement buffers around each of the potential aquatic sites for each species representing the maximum known movement distance (separated into migration and dispersal for amphibians); (5) Use the "Cost-Distance" procedure in ArcGIS 9.0 to calculate the cumulative cost distance within these movement buffers; (6) Rescale these cumulative costs to the probability of a species being present; and (7) Extract the probability of presence for the existing road network in the study area.

We assigned the aquatic habitats for each of the species (the loci on which resistance surfaces were centered) based on literature data (references listed in Appendix A). NWI wetland classes were grouped based on system and subsystem categories within Cowardin's wetland classification index (Cowardin et al. 1979). For the initial land-cover map (for which resistance values were assigned), we combined the National Land Cover Database (NLCD 2001) and NWI, replacing NLCD wetland categories with the more precise NWI classifications. Friction costs assigned to each land-cover type for each species were based on literature data rather than expert knowledge. Our friction index ranged from 0 (most suitable) to 50 (least suitable). A value of 0 (i.e., no cost) was used for the most suitable habitat, as it was considered to actually facilitate movement (Popescu 2007).

Persistence of populations of three of our focal amphibian species, the wood frog, spotted salamander, and eastern newt have been shown to be dependent on forest cover (Guerry & Hunter Jr. 2002; Herrmann et al. 2005; Homan et al. 2004). Estimates of the amount of forest cover needed by these species vary between studies, regions, and species. We set a minimum threshold for site occupancy by these species as 40% forest cover (deciduous and coniferous but excluding the shrub/scrub category in the NLCD [2001]) within the known migration or dispersal distance from the aquatic site. Although this figure does not take into consideration landscape configuration, it represents a best estimate based on the results from these previous studies.

To assign friction values, we divided the available literature data into two groups: (1) research that generally describes habitat suitability for study species; and (2) research that specifically quantified the proportion of individuals choosing certain habitats when faced with a range of choices. The latter research affords a more accurate estimation of relative habitat resistance values but was not available for all species or habitats. Additionally, two studies have previously reported friction values for amphibians: Popescu (2007) focused on mink frog, *Rana septentrionalis*, in northern New York State, and Compton et al. (2007) juvenile marbled salamanders, *A. opacum*, and adult spotted salamanders in Massachusetts. We used these studies as benchmarks to compare our own estimates for anurans and spotted salamanders respectively.

Because of the important role played by moisture in habitat selection by herpetofauna (Reagan 1974; Wyman 1988), we further adjusted friction values by a topographic wetness index (TWI). The TWI combines a measure of the upslope area and slope to predict the hydrology of a given location (Sorenson et al. 2005), and is defined as $\ln(a/\tan\beta)$ where a is the local upslope area draining through a specified point per unit contour length and $\tan\beta$ is the local slope. Initially the TWI was rescaled to range from 0-5 (dry-wet). This index was then used to alter resistance values, resulting in the wettest areas having a resistance value 5 points lower than the driest areas.

Movement buffers for amphibians were based on the maximum migration and dispersal distances reported for adults and juveniles. We were conservative in these estimates, discounting studies where movement was calculated based on displaced individuals, or where movement was inferred from unmarked individuals. We used the maximum distance reported in any study rather than mean values as limited data for some species meant that mean distances were often much lower than maximums.

Once resistance surfaces had been generated for each species (and life stage in case of amphibians), we extracted the cells that represented the locations of roads. The roads used in models were derived from the New York State Office of Cyber Security and Critical Infrastructure Coordination (CSCIC) as part of the Accident Location Information System (ALIS). This provided us with a relative measure of the probability of an animal crossing each 30 m long section of road. As road mortality has been shown to increase with traffic intensity (Carr & Fahrig 2001; Gibbs & Shriver 2005), we also developed models where we classified roads/hotspots according to their Arterial Classification Code (ACC). This scale from 1-6 represents the relative importance of roads to the overall transportation network as measured by the volume of traffic carried, the capacity of the road to handle traffic (for example the number of lanes and the maximum speed on the road), and the purpose of the road. For example, ACC class 1 represents the largest/longest highways connecting major cities with a maximum speed of 65+ mph, whereas class 6 represents residential roads with either one or two lanes and a maximum speed of 15-25 mph (http://www.nysgis.state.ny.us/gisdata/inventories/details.cfm?DSID=932).

Output Metrics and Prioritizing Hotspots

We generated 15 initial models of the predicted occurrence index across the study area. These represented 10 focal species and included both migrating and dispersing individuals for all amphibians except red-spotted newts.

We derived three means of prioritizing hotspots. In the first, we classified occurrence indices based on quantiles in ArcView using 5 divisions. We chose this method rather than an equal interval approach as the distribution of the occurrence index for each model tended to be highly left-skewed (i.e., many more occurrence rasters with a high rather than low predicted probability of occurrence). In the second approach, we initially selected occurrence index values in the range of 0-2 for each model (i.e., the highest probability of occurrence) then reclassified hotspots based on the length of continuous hotspot that remained within these occurrence index values. For the third approach to prioritization, we overlaid the ACC for roads over our occurrence indices, allowing hotspots to be identified based on traffic intensity.

Model Validation

To validate the accuracy of our models, we selected an area of road network within our study region (in the vicinity of Labrador Hollow State Unique Area, approximately 20 miles south of Syracuse, New York, hereafter call “Labrador Hollow”) that encompassed the same land-cover gradients as our full model within a small geographic region. This 20 mile-long road network was sampled in its entirety on rainy nights from 31st March to 2nd May 2008 between dusk and 12 pm. Sampling consisted of driving slowly (<30 mph) along the road and recording all live and dead animals, including details of age and sex where possible and the exact position of the animal using a global positioning system. A single route was established on which to sample all sites.

We also conducted a more intensive sampling session on a shorter section of road within an agricultural region approximately 15 miles south of Syracuse New York, hereafter called the “Tully Valley.” This 12 mile-long section of road was sampled seven times on rainy nights from May 27- August 23 2007. Sampling was conducted using a bicycle riding at 8 mph, ensuring that most animals on the road including juveniles were detected.

We used 30m road segments as our sampling unit for model validation (i.e., the minimum resolution of our hotspot model output) and focused on predictions and field-data for migrating adults of three species of amphibians; the spotted salamander, green frog, and American toad. One of these species, the American toad was sufficiently abundant on both survey routes to allow model validation. Green frogs were only observed in sufficient numbers on the Tully Valley route and spotted salamanders on the Labrador Hollow route.

To compare the ability of our models to predict the locations of animals crossing roads in general, we examined whether more observations of animals were made in high occurrence index rasters, with a null hypothesis that observations occurred randomly and thus in the same proportions as the proportions of each occurrence index value. We reclassified rasters based on the occurrence index into 4 categories: (1) Rasters on the route that were predicted as non-occurrence; and rasters with an occurrence index of (2) 0-5; (3) 6-10; and (4) >10. Chi square tests were used to compare the observed distribution of occurrences with a null hypothesis of animals being randomly distributed along the route.

To compare the use of the length of contiguous high occurrence index values (i.e., 0-2), we assessed the number of observations per 30-m raster in 4 length categories: (1) Rasters on the route that were either non-occurrence or had an occurrence index of >2; (2) short sections of road [length <100m]; (3) medium [length 100-500m]; and (4) long [length >500m]. For these analyses, we compared the observed distribution of occurrences within rasters of these length classifications to that expected under a null hypothesis of a random pattern of occurrences.

Results

As expected, our models predicted that amphibians and reptiles were more likely to be found on roads closer to suitable aquatic habitat and in high-quality terrestrial habitat. The occurrence indices tended to be left-skewed. This skew is a result of high-quality terrestrial habitats such as forested wetlands being assigned a resistance value of 0. Because of the abundance of wetlands in our study area, and as our models were designed to predict any probability of occurrence, no matter how slight, most road-segments had some probability of at least one of our study species being present.

Differences between Species

The predicted occurrence of species on roads in New York State clearly differed. The range of aquatic habitats species used, estimated maximum movement distances, and their relative sensitivity to terrestrial habitat change caused these differences. Figure 1 illustrates the occurrence index model outputs (for all terrestrial habitat rather than just roads) for a wide-ranging generalist species, the common snapping turtle, compared with migrating spotted salamander, a species with relatively specialized aquatic habitat requirements and high sensitivity to terrestrial habitat changes associated with development, urbanization and agriculture.

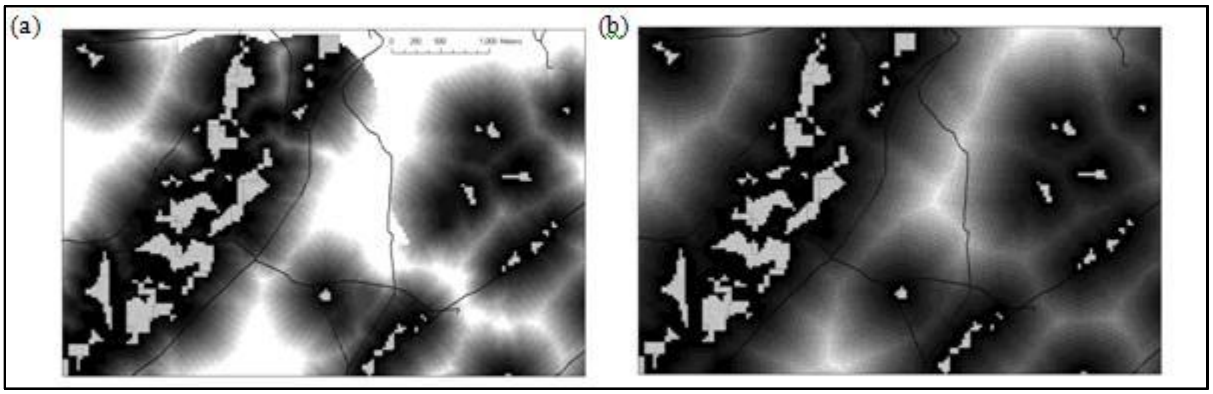

Figure 1. Example of the occurrence index output for all terrestrial habitat (rather than just roads), for (a) migrating spotted salamanders and (b) common snapping turtles with a darker color representing a higher probability of occurrence, aquatic habitat denoted by stippling (in this area aquatic habitat was suitable for both species) and roads indicated as dark lines.

Differences between Life-History Stages: Migration versus Dispersal

Models for migrating adults compared with dispersing juvenile amphibians differed depending on the maximum movement distance for the two life-history stages and the relative sensitivity to terrestrial habitat change. For example, documents differences between migrating adult wood frogs, which tend to remain closer to aquatic sites but are relatively more tolerant of terrestrial habitat change, and the wide ranging but relatively sensitive juvenile dispersers.

Prioritization

Figure 2 illustrates typical output for our target species (using migrating wood frogs as an example) based on two of the three methods of prioritization we developed: (1) classifying the occurrence index values based on 5 quantiles; and (2) using the arterial classification code (ACC)

The proportion of the total length of the road network in our study area that was encompassed by different prioritization metrics varied by species: Migrating adult wood frogs with specific habitat requirements and a maximum movement range of 430 m were predicted to have at least some probability of occurrence on 43.3% of the road network, with 8.7% of the road network being classified in the highest occurrence index quantile (top 20%). When using the length of continuous high-occurrence as a metric, 28.4% of the road network fell in the 'long' length category of >500 m continuous high occurrence. Snapping turtles, a habitat generalist with a maximum reported movement of 2020 m had at least some probability of occurrence on 97.6% of the road network, with 19.5% of the road network being classified in the highest occurrence index quantile. When using the length of continuous high-occurrence as a metric, 35% of the road network fell in the 'long' length category of >500 m continuous high occurrence.

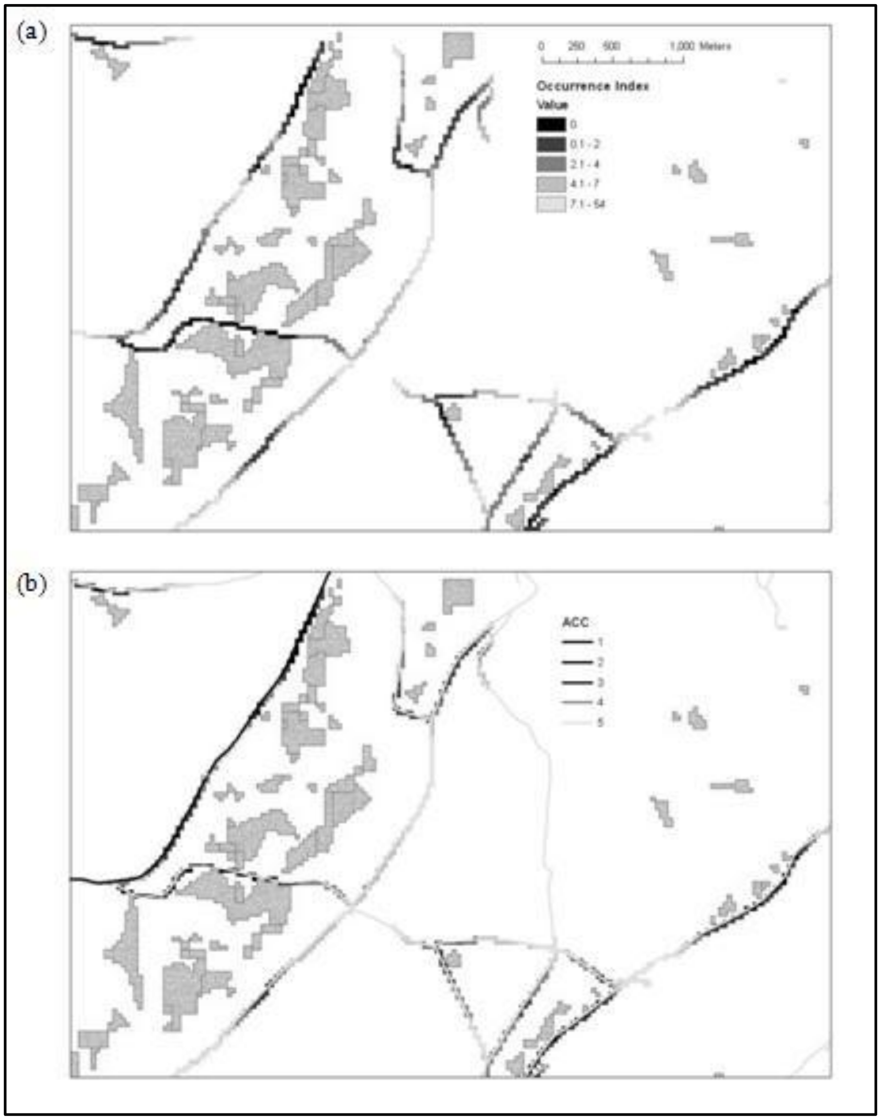

Figure 2. Illustration of three methods employed to prioritize hotspots of herpetofaunal occurrence on roads in New York State using migrating wood frogs as an example: (a) classifying occurrence index values based on 5 quantiles; (b) with the arterial classification code for roads overlaid (ACC); and (c) using the length of continuous high-occurrence rasters (divided into 3 categories based on length: short sections of road [length <100m]; (3) medium [length 100-500m]; and (4) long [length >500m]).

Model Validation

We observed 330 animals on the 20-mile stretch of road surveyed by car in the vicinity of Labrador Hollow, representing 8 species. Four of these species were relatively abundant (spotted salamander, n = 206; American toad, n = 38; wood frog, n = 35; and eastern red-spotted newt, n = 40), with the remaining species being relatively rare (n < 8). We observed 260 animals on roads during our bicycle surveys of the agricultural Tully Valley, representing 14 species (3 snake species, 2 salamander, and 8 anuran). These species can be loosely grouped into two categories; abundant species represented by green frogs (n = 138) and American toads (n = 91), and rarely observed species (all other species, n < 7).

Of the three species we used for model validation, the observed distributions of spotted salamanders and green frogs differed significantly from the null hypothesis of a random pattern of occurrences in relation to both the overall occurrence index (Table 1) and the length of high occurrence areas (Table 2).

Survey route	Species	Chi-square statistic	*P*-value
Labrador Hollow	Spotted salamander	75.599	0.001<*P*
Labrador Hollow	American toad	3.594	0.5<*P*<0.25
Tully Valley	American toad	0.195	0.99<*P*<0.975
Tully Valley	Green frog	32.819	0.001<*P*

Table 1. Comparison of the observed occurrences of individuals of focal species along road-validation survey routes in central New York (Labrador Hollow and Tully Valley). Chi square tests were used to compare the observed distribution of occurrences with a null hypothesis of animals being randomly distributed along the route.

Survey route	Species	Chi-square statistic	P-value
Labrador Hollow	Spotted salamander	26.539	0.001<P
Labrador Hollow	American toad	2.227	0.75<P<0.5
Tully Valley	American toad	3.320	0.5<P<0.25
Tully Valley	Green frog	21.395	0.001<P

Table 2. Comparison of the observed occurrences of individuals of focal species along road-validation survey routes in central New York (Labrador Hollow and Tully Valley) with locations grouped according to the length of contiguous high occurrence road in which they occurred [n = 4 groups].

In the case of spotted salamanders, the null hypothesis predicted that 9.4% of observations should occur in non-occurrence rasters, with 2.5% of actual observations seen in these locations. For the highest occurrence index category (occurrence indices from 0-5), 53.5% of observations were predicted, with an actual occurrence of 84.2%. For the two lower occurrence index categories (6-10 and >10), fewer animals were observed than predicted. When comparing observed versus expected observations of spotted salamanders per 30-m section of road in relation to road length, more animals were observed on road sections in the longest length category, >500m, than expected under the null hypothesis (14.1% expected, 26.6% observed), with fewer observations than expected in the other categories (shorter lengths of road and those predicted as either non-occurring or with an occurrence index of >2).

Because of the large movement distances of green frogs, no sections of road were predicted as non-occurrence, i.e., we were not able to evaluate the commission error of our models. When comparing observed versus expected occurrences for this species, model performance was poor; in the highest occurrence index category (0-5), 67.9% of occurrences were predicted with 61.6% observed. Similar patterns were seen in the medium occurrence index category (30.8% predicted with 31.9% observed). In the lowest occurrence index category (>10), more animals were observed than predicted (1.2% predicted with 6.5% observed). The latter result drove the statistically significant difference in the overall comparison of observed versus expected. When comparing observed versus expected distributions of this species in relation to the length of predicted hotspot, models also performed poorly, with more animals observed in the short and medium length categories than expected (for roads <100m, 0.9% expected and 3.6% observed; for roads 100-500m, 11.7% expected and 16.5% observed), and fewer animals on the longest hotspots (11.6% expected and 3.6% observed). Observed versus expected observations in areas predicted as either non-occurring or with an occurrence index of >2 were similar (75.8% expected, 76.3% observed).

Although no overall significant difference was seen when comparing the observed versus expected distributions of American toads, more animals occurred in the highest occurrence index category at Labrador Hollow (61.9% expected and 77% observed) with fewer observations than expected in all other categories. The same trend was seen on the Tully Valley route, although with less of a pronounced difference between observed and expected (for the highest occurrence index category, 59.6% expected, 61.8% observed). When comparing observed versus expected in relation to the length of hotspot, more animals were observed in the longest length category at Labrador Hollow (30.9% expected, 37.1% observed) with fewer in all other categories. In Tully Valley, however, fewer animals were observed in the longest length category (8.3% expected, 5.5% observed, with more observations in the medium (7.4% expected, 10.0% observed) and either non-occurring or with an occurrence index of >2 category (82.4% expected, 84.4% observed).

Discussion

Our models predict a widespread occurrence of herpetofauna on roads in New York State with most sections of road having at least some probability of occurrence for at least one of our focal species. This phenomenon is likely a function of the abundance of wetlands found in this region as well as our focus on a range of species that differ in their preference for aquatic and terrestrial habitats. Similar to the results of other studies, particularly high concentrations of animals are found on roads that run adjacent to large wetland complexes (where breeding habitat for a variety of different species are found) and/or through areas of undisturbed terrestrial habitat (Compton et al. 2007; Langen et al. 2007). Despite the coarseness and broad assumptions of the study, the strength of our approach lies in the use of a large spatial extent, readily available datasets, and relatively simple prioritization methods, which can be easily replicated in other parts of the state.

Differences between Species

Differences between the predicted patterns of occurrence of species on roads have clear implications for mitigation. For species such as the spotted salamander or wood frog characterized by relatively limited terrestrial vagility, specific aquatic habitat requirements, and high sensitivity to anthropogenic changes in terrestrial habitat, our models identify discrete locations in which mitigation can be focused. Many of these species are also considered ‘explosive’ migrators, with the majority of individuals crossing roads simultaneously at predictable points during the year (for example the spring migration of adult amphibians into ponds to breed (Paton & Crouch 2002). For species that have this type of life-history strategy, approaches to mitigation such as culverts, signage and potentially road-closures may be valuable and represent a feasible balance between the needs of road-users and biodiversity. Conversely, wide-ranging species such as spotted turtle characterized by low population densities and relatively continuous movement throughout the active season (although see (Beaudry 2007) may present a greater challenge to mitigation. Although these species have a relatively low probability of occurring on any one stretch of road and thus being vulnerable to road-mortality, their life-history strategy characterized by late reproductive maturity and high adult survival under natural conditions makes populations extremely vulnerable to any increase in adult mortality. Bearing this in mind, mitigation focused on single point locations, for example culverts, is unlikely to be enough to maintain the long-term viability of populations of species such as this. Broader-scale measures deployed at crossing hotspots, for example seasonally reduced speeds, and population-level measures such as driver education may be more appropriate (Beaudry 2007), with the best strategy for long-term conservation of these species likely to be maintaining contiguous areas with low road and traffic densities of sufficient size to maintain viable populations.

Differences between Life-History Stages: Migration versus Dispersal

The differences seen in model outputs for migrating versus dispersing amphibians are analogous to the inter-specific differences observed in other models. There are, however, important differences when considering mitigation. The fact that for many species of amphibians, juveniles are the dispersing life-history stage and range farther than migratory adults is reflected in our model outputs, where the predicted patterns of occurrences of juveniles cover a much greater area of the road network. Thus, juvenile amphibians can be considered to present similar issues for mitigation as the wide-ranging species discussed above. The role played by juveniles in population dynamics is important to consider, however, with these individuals providing connectivity between spatially separate populations. Maintenance of this connectivity has been demonstrated as vitally important to the long-term persistence of amphibian species such as the wood frog (Harper et al. 2008).

Prioritization

Bearing in mind the widespread occurrence of many of our study species on roads in New York State, and the limited resources available for mitigation along with a road network encompassing more than 228,000 km, there is a clear need for prioritizing efforts by transportation planners. The three methods we have highlighted — the use of quantiles in the data to identify where animals are most likely to occur on roads, the length of continuous hotspot, and classifying occurrence based on traffic intensity — represent useful metrics for transportation agencies. There are however a variety of different ways of prioritizing hotspots that can be readily generated from our model output. These include identifying zones of connectivity between populations and identifying likely areas of high abundance of animals on roads (for example selecting contiguous areas of high occurrence). From a jurisdictional standpoint, there are a number of different agencies responsible for managing roads in New York State including the State Department of Transportation, County Departments of Transportation and local town and villages as well as New York Thruway Authority (responsible for the State’s main toll highway). Each of these agencies varies in terms of their capacity for deploying mitigation and the mandates given to them by their constituents. If we are to see the results of our models effectively implemented, understanding these differences and providing information at a relevant spatial scale and technical level is vital.

Model validation

Bearing in mind the limited number of species and spatial and temporal scale over which validation occurred, the model validation we conducted demonstrated that our models are effective tools for predicting occurrences of species with limited movement ranges and relatively specific habitat requirements, for example the spotted salamander. Our models were less effective in predicting occurrences of generalist species with larger movement ranges such as the American toad and green frog. These results were expected and support the recommendations we have made for mitigation, i.e., that targeted mitigation such as crossing structures is only likely to be effective for habitat specialists. Our validation data also show that the use of the length of contiguous hotspot is a good indicator of the likely abundance of these habitat specialists on roads, and that if reducing the abundance of mortality on roads is the goal of mitigation, targeting these locations may be an effective approach.

Use of Models in Transportation Planning and Mitigation

Our models were designed to meet a specific purpose, i.e., to inform transportation managers as to where roads in the New York State are most likely to detrimentally affect populations of amphibians and reptiles. We believe that our models effectively meet this goal, especially given that before their development, the Department of Transportation had no large-scale data on which to base their decisions. There are a number of important caveats when applying our models to mitigation, however. As with all models, the reliability of the output is dependent on the quality and accuracy of the data used in development. There are three principle sources of error in our model development. The first is knowledge of the ecology of our focal species: For most species of herpetofauna there are large gaps in our understanding of their ecology, especially in the terrestrial environment. Although we used sufficient literature data as one of the criterion when selecting species, inevitably some of our estimates of habitat suitability, movement distances etc., were based on limited data, or from studies conducted outside of our region.

The second potential source of error is the remote sensing data we used. The categorical NLCD and NWI data miss some of the finer scale differences within each category of habitat. For species that are sensitive to change in aquatic or terrestrial habitat, this variation can be the difference between occurrence and non-occurrence. Similarly, certain habitat features are omitted from these data. An important example is the smaller ephemeral wetlands used by some of our study species such as the wood frog and spotted salamander. Lastly, landscapes are dynamic and as time progresses since the NLCD and NWI were assessed there is an increasing chance that habitat will no longer be the same.

The third potential source of error is that models were based on the presumption that populations would be located wherever suitable aquatic habitat and sufficient terrestrial habitat for certain species were found. This certainly led to an overestimation of the occurrence of some species on New York roads. In areas with high traffic intensity/road densities, the resulting mortality may have already led to the extirpation of these local populations.

Bearing in mind these caveats, the results of our models can be used to generate a number of specific recommendations for mitigating the effects of existing roads and constructing new roads with the minimum effect on animal movement: (1) the highest abundance of animals is likely to be found where roads run in close proximity to large wetland complexes. In these locations, a combination of directional fences and crossing structures is likely to be effective (Aresco 2005); (2) transportation managers should avoid constructing roads that run in close proximity to wetlands, especially where the road is likely to create a division between two critical habitat types, for example aquatic sites and nesting habitat for turtles and aquatic breeding sites and terrestrial foraging areas for amphibians; (3) for species with specific habitat requirements and predictable seasonal movement patterns, mitigation efforts focused on specific points in space and time are likely to be effective, whereas for species with more generalized habitat use and patterns of movement, mitigation also needs to include broader strategies such as traffic calming, reduced speed limits, and driver education; (4) the use of field-surveys to ground-truth model predictions is more likely to be an effective tool for species for which mortality is predictably concentrated in space and time; and (5) in limited circumstances, where animals are crossing a road to access a vital resource and sustaining high mortality in the process, moving the habitat rather than the road (for example constructing artificial nesting habitat or regenerating woodland), coupled with the use of a roadside barrier to movement may be appropriate. This last approach should not be viewed as a panacea, or as a proactive approach to issues with future road construction, but may be an effective option for existing roads.

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Appendix A: References Used to Gather Life-History Characteristics of the Focal Study Species.

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Green frog	(Carr & Fahrig 2001; Guerry & Hunter Jr. 2002; Lamoureux et al. 2002; Livingston Birchfield 2002; Martof 1953, 1956; Patrick et al. 2006; Schroeder 1976)
N. leopard frog	(Carr & Fahrig 2001; Dole 1965, 1967, 1971; Merrell 1970; Patrick et al. 2006; Pope 2000; Seburn et al. 1997)
American toad	(Breden 1987; deMaynadier & Hunter 1998; Holomuzki 1995; Petranka et al. 1994; Rothermel & Semlitsch 2002; Wyman 1998)
Spotted salamander	(deMaynadier & Hunter 1998; Douglas 1981; Faccio 2003; Gibbs 1998b; Guerry & Hunter Jr. 2002; Kleeberger & Werner 1983; Madison 1997; McDonough & Paton 2007; Patrick et al. 2008; Rothermel & Semlitsch 2002; Wyman 1998)
E. spotted newt	(Gibbs 1998a; Gill 1978; Hurlbert 1969)
Snapping turtle	(Brown & Brooks 1994; Pettit et al. 1995; Ultsch 2006)
Spotted turtle	(Ernst 1976; Joyal et al. 2001; Milam & Melvin 2001; Ultsch 2006)
Painted turtle	(Baldwin et al. 2004; Christens & Bider 1987; Rowe 2003; Ultsch 2006)
Wood turtle	(Arvisais et al. 2002; Compton et al. 2002; Kaufmann 1992; Quinn & Tate 1991; Saumure et al. 2007; Walde et al. 2003; Walde et al. 2007)

Integrating Ecosystem Needs with Transportation Facility Design: Design Engineering Challenges of the I-90 Snoqualmie Pass East Project

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Abstract

The Washington State Department of Transportation's I-90 Snoqualmie Pass East Project (I-90 Project) presents unique engineering design challenges and constraints due to its location along a high mountain pass in Washington State's Central Cascades. The topography is one of mountainous peaks and valleys. These steep mountain slopes contain bedrock at varying depths that are subject to deep fissures and cracks with weakened slip planes, which when combined with high annual precipitation and freeze thaw conditions, makes them susceptible to landslides, debris flow, and avalanches.

For the first six miles of the project area, I-90 runs along a narrow corridor between the shores of Keechelus Lake and steep cliffs. Since Keechelus Lake is used as an irrigation reservoir, WSDOT must be careful to not impact the lake storage volume. WSDOT must also design work around lake elevation levels that vary by approximately 80 feet, depending on irrigation needs and the annual snow pack. To mitigate lake storage impacts, WSDOT has a no-net loss agreement with the US Bureau of Reclamation (USBR). WSDOT will excavate materials from the lake, which will later be incorporated into the project, to allow for construction. WSDOT also researched historical lake level averages and designed around those variables.

WSDOT has been conducting geotechnical drilling on the mountain slopes and in the lakebed to collect data to finalize roadway designs. Early results indicate that there are areas of stable rock and favorable sediment, while other areas contain soft frangible rock and liquefiable soil conditions. As a result, WSDOT altered engineering designs to include replacement stone columns, modified structure foundations, and elevated the road profile in the westbound direction.

WSDOT has also committed to address the issue of ecological connectivity as a project need. I-90 has been identified as a physical barrier to the north-south movement of fish and wildlife. Wildlife attempting to cross over the interstate present a safety concern to motorists, and the barrier I-90 forms between upstream and downstream aquatic habitats affects fish passage and hydrologic processes. To meet ecological connectivity needs, WSDOT has worked with many agencies that manage land and resources in the project area to help identify target species, habitat needs, and project constraints. Data gained from these partnerships allowed WSDOT to design bridges and culverts that improve wildlife connections, stream channel migration, fish passage, and habitat designs. In addition, the engineering team has been testing various prototypes of wildlife exclusionary fencing, intended to redirect wildlife away from the interstate to crossing structures, in order to find a design that will withstand winter weather conditions and maintenance operations.

Other general engineering challenges include designing the project around the area's extreme temperatures and heavy snowfall, which limits the construction season to approximately six months a year, and creating construction detour routes in the narrow project corridor. WSDOT plans to keep two lanes open in each direction during peak travel times as a commitment to the freight community and traveling public.

The I-90 Project corridor topography, geology, weather, ecological connectivity commitments, and traffic constraints have presented challenges when trying to integrate transportation objectives with ecological needs. In order to achieve a balance in objectives, the project team will continue to work with other agencies to resolve environmental and design challenges.

Introduction

The Washington State Department of Transportation's (WSDOT) I-90 Snoqualmie Pass East Project (I-90 Project) is a 15-mile highway improvement project that will ensure the continued availability of Interstate 90 as a primary statewide corridor. Through the I-90 Project, WSDOT will improve the safety and reliability of this corridor by reducing avalanche risks to the traveling public, minimizing road closures required for avalanche control work, and reducing the risk of rock and debris falling onto the interstate from unstable slopes. WSDOT will also fix structural deficiencies and provide for the recent and predicted increases in traffic volume. Ecological connectivity is another important project component. WSDOT will work to reduce wildlife / vehicle collisions by re-connecting habitat across I-90 and improving mobility of aquatic species and wildlife.

Plans for the project include widening the existing four lane interstate to six lanes, replacing deteriorated concrete pavement, straightening sharp roadway curves, stabilizing unstable rock slopes, building a new, more efficient snowshed (a concrete shed covering the roadway to provide permanent protection from avalanches and other falling debris to travelers passing through Snoqualmie Pass), and constructing wildlife crossings structures.

The first five miles of the I-90 Project from Hyak to Keechelus Dam received funding in 2005 from the Washington State Legislature through the Transportation Partnership Account – a 9.5 cent increase in the gas tax – in the amount of $595 million. The remaining 10 project miles from Keechelus Dam to Easton remain unfunded.

The I-90 Project corridor is located high along a mountain pass in the Central Cascades. The area's extreme weather conditions and inherent geographical and geotechnical complexities has presented WSDOT I-90 Project engineers with many challenges when designing this improvement project. Integrating ecological connectivity objectives with transportation objectives has also presented challenges. Conflicts in objectives regarding crossing structure designs often surfaced that required the I-90 Project design team and partnering resource agencies to compromise and accept trade-offs in order to move the project forward. Finding the right designs to optimize benefits required a great deal of collaboration, technical investigation, and engineering review.

In the following paper, several case studies will be provided depicting how conflicts in design between WSDOT engineers and various resource agencies, inter-disciplinary teams, and technical committees were managed to resolve issues and reach compromises with satisfactory outcomes.

However, in order to better understand how WSDOT and project stakeholders integrated transportation and ecological connectivity objectives into the I-90 Project, it's first necessary to understand the environment in which we're working and the process for developing the project's purpose and need.

I-90 Project Corridor Attributes

I-90 spans 300 miles in Washington state from the Port of Seattle to the Idaho State line, and then continues east across the United States to Boston, MA. I-90 is the major east-west transportation corridor across Washington and is vital to the state's economy (Washington State Department of Transportation Final EIS 2008, 1-1).

Figure 1. A map of Washington State, highlighting I-90 and the I-90 Project area

The I-90 Project improves a 15-mile portion of I-90, beginning on the eastern side of Snoqualmie Pass at milepost 55.1, just east of the Hyak Interchange, where the existing highway narrows from six lanes to four lanes. The project end point is at milepost 70.3 at the West Easton Interchange, where the terrain becomes flatter and the highway is straighter. This 15-mile stretch of I-90 is in Kittitas County, WA, and is predominately located on federal land within the Okanogan-Wenatchee National Forest.

The project corridor is located along a high mountain pass in the Central Cascades. The general topography is one of mountainous peaks and valleys. For the first six miles of the project area, I-90 runs along a narrow corridor between the shores of Keechelus Lake, a deep-water agricultural reservoir, and steep mountain slopes. These steep mountain slopes contain volcanic bedrock at varying depths that are subject to deep fissures and stress cracks with weakened slip planes, which when combined with high annual precipitation and freeze-thaw conditions, makes them susceptible to landslides, debris flow, and avalanches.

Figure 2. The I-90 Hyak to Keechelus Dam project corridor.
In this area, I-90 is located between Keechelus Lake and steep rock cliffs

I-90 is built primarily within an easement on National Forest land. The large areas of protected state, federal, and conservation lands north and south of I-90 support a broad range of habitats and a diverse array of plants and wildlife. Since the late 1990s, the area has been managed according to the Snoqualmie Pass Adaptive Management Area Plan. This plan requires protection of old-growth habitat, removal of portions of existing Forest Service roads, and management of recreation to facilitate species movement. In recent years, there have been substantial private and public land conservation efforts to protect old-growth forest, provide larger contiguous blocks of forested habitat, and facilitate habitat connectivity across the I-90 corridor through the acquisition of private land. The Cascades Conservation Partnership, the Mountains-to-Sound Greenway Trust, the U.S. Fish and Wildlife Service (USFWS), and the U.S. Forest Service (USFS) have invested over $100 million in these efforts during the last five years. These land purchases, along with the I-90 Land Exchange, have added 75,000 acres (approximately 117 square miles) of land to the National Forest system adjacent to and within the I-90 Snoqualmie Pass East project area (Mitigation Development Team 2006, 1-4).

Even with conservation efforts, I-90's presence limits wildlife movement and forms a physical barrier between upstream and downstream aquatic environments. Existing culverts and narrow bridges limit aquatic species movement, and in many cases, the highway embankment has filled in habitat that once made up channels, floodplains, and associated wetlands (WSDOT Final EIS 2008, 1-8). Adequate connections between habitats and hydrologic features on either side of I-90 are necessary for the continued health of the project area's diverse ecosystems.

The last major road construction on I-90 Snoqualmie Pass began in the 1950s when President Dwight D. Eisenhower signed the Federal-Aid Highway Act of 1956, which started the construction of Interstate Highways; construction was completed in the 1970s. Since the 1970s, the state's transportation needs for I-90 over Snoqualmie Pass have changed, and the existing roadway has deteriorated.

Today, daily traffic on Snoqualmie Pass averages about 27,000 vehicles, typically 22,400 passenger vehicles and 4,600 freight vehicles. Traffic volumes can rise to more than 59,000 vehicles on weekends and holidays. According to

WSDOT traffic studies, travel across Snoqualmie Pass is growing at an annual rate of 2.1 percent, with 51,000 vehicles projected to use I-90 daily by 2028.

Identifying a Project Purpose and Need

Seeing a need for additional highway capacity and safety improvements, WSDOT began the public scoping process for the I-90 Project in 1999. By 2000, an interdisciplinary teams was formed consisting of representatives from WSDOT, the Federal Highways Administration (FHWA), the U.S. Forest Service (USFS), Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), and Washington Department of Fish and Wildlife (WDFW); advisory agencies included Washington State Parks, U.S. Army Corps of Engineers (USACE), and Washington Department of Ecology (Ecology). The IDT was formed to begin preliminary engineering and environmental analysis of the project area. Additional teams were formed, including a Mitigation Development Team (MDT) consisting of biologists and hydrologists from WSDOT, USFS, USFW, and WDFW, and a Wetlands Mitigation Technical Committee consisting of a GIS specialist, biologist, and environmental planner, to conduct further environmental analyses and provide design recommendations.

After five years of corridor analysis, WSDOT published the I-90 Snoqualmie Pass East Project Draft Environmental Impact Statement (Draft EIS) for public review and comment in 2005. The Draft EIS highlighted six build alternatives that could potentially meet the project's identified purpose and need for:

- Reducing the risks of avalanche to the traveling public and eliminating road closures required for avalanche control work,
- Reducing the risk of rock and debris falling onto the roadway from unstable slopes,
- Fixing roadway structural deficiencies by replacing damaged pavement,
- Providing for the growth-related increases in traffic volume, and
- Connecting habitat across I-90 for fish and wildlife (WSDOT Draft EIS 2005, ES-1).

Over the next two years, WSDOT continued using existing partnerships and formed new teams, including a Stormwater Technical Committee and Wildlife Monitoring Technical Committee to help advance technical investigations and identify a preferred design alternative for the I-90 Project. These collaborative efforts culminated with the release of the Final EIS in August 2008 that identified WSDOT's preferred design alternative for the I-90 Project. The Federal Highway Administration issued its Record of Decision concurring with WSDOT's preferred alternative in October 2008, which paved the way to complete final design and construction to begin.

Developing I-90 Project Design Concepts

After identifying the I-90 Project Preferred Alternative, project engineers began working with the IDT, MDT, and Wetlands Mitigation Technical Committee to develop conceptual design plans for ecological connectivity structures.
The MDT presented design engineers with scientific information and site-specific technical report data that determined the existing ecological conditions within the project area. This data identified 14 north-south ecological linkage areas, or Connectivity Emphasis Areas (CEAs), within the project area that provided the highest benefit-to-cost ratio and long-term solutions to the issue of ecological connectivity. Each CEA provided an opportunity to improve connectivity for a unique assemblage of species. CEAs ranged in complexity from single stream crossings to multiple stream crossings with associated wetlands and areas of diffused surface flow, to upland areas that were important travel corridors for wildlife (MDT 2006, ES-7). The MDT found that crossing structures would be more effective for some species if they contained habitat, rather than simply being physical connections between habitats on opposite sides of the highway. For instance, lower mobility animals would feel more secure crossing a structure if it contained hiding cover. Different animals show different preferences for crossing structures, whether the structures are small, medium, or large (MDT 2006, ES-8).

After analyzing all of the MDT's recommendations, WSDOT engineers and the MDT collaborated to develop conceptual designs for the highway alignment, drainage plans, staging and construction requirements, traffic control strategies, and initial bridge plans at each CEA. The design team also continued to develop designs independently.

While working with the MDT and technical committee, WSDOT and consultant engineers were also gathering geotechnical data from extensive drilling operations on the mountain slopes, in the lakebed of Keechelus Lake, and along the existing roadway to determine geological conditions. This data was essential to progressing conceptual CEA designs.

Geotechnical findings indicated that certain portions of the project area contained stable rock and favorable sediment, while other areas contained soft frangible rock and liquefiable soil conditions. Since liquefiable soil conditions result in global instability of structure foundations, WSDOT engineers had to rethink how to construct certain CEA concepts (bridges and culverts). Engineers worked to improve conditions and meet seismic regulations while still aligning with

MDT and Wetlands Mitigation Technical Committee recommendations. In addition to seismic issues, WSDOT engineers had to reformat other CEA designs to address other unforeseen issues pertaining to erosion, stormwater treatment, clearance, and constructability. These design changes had to be made in a way that minimized footprint impacts, prevented wetland impacts, considered endangered species in the area, and preserved archeological, cultural, and recreational resources.

In the following sections, we will discuss how WSDOT I-90 Project engineers modified original design concepts to resolve conflicts between ecological connectivity recommendations and objectives and the unforeseen seismic, erosion, stormwater treatment, clearance, constructability, and other resource issues.

Improving Ground Conditions at Gold Creek CEA without Impacts to Wetlands, Endangered Species, and Footprint

An important CEA identified by the MDT is located near the Gold Creek Valley. The Gold Creek CEA is located between milepost 55.2 and milepost 55.8, near the starting point of the I-90 Project. Gold Creek crosses I-90 under 138- and 126-foot bridges and empties into Keechelus Lake at the northwest tip of the lake. This CEA connects old growth stands in mountain hemlock-subalpine fir forests and provides important hydrologic functions for Gold Creek. Gold Creek represents a critical area for linking the Alpine Lakes Wilderness to the Norse Peak Wilderness, which, in turn, links to other wilderness areas and national parks throughout the Washington Cascade Mountains (MDT 2006, ES-15).

Figure 3. The existing Gold Creek Bridge

To be successful at meeting objectives, WSDOT and the MDT determined a high level of connectivity for the high- and low-mobility species associated with the mountain hemlock-subalpine fir forests, riparian habitats, wetlands, and floodplains must be provided year-round. Other objectives for this CEA include:

- Providing a high level of connectivity across the reservoir bed for approximately nine to 10 months of the year.
- Significantly reducing wildlife / vehicle accidents in this high roadkill zone for deer and elk. This will require wildlife fencing around the crossing structures.
- Restoring natural channel migration processes and reducing floodplain confinement, particularly upstream of I-90 where floodplains and associated wetlands are not inundated by Keechelus Lake; restoring capacity to convey flood flows, sediment, and debris through the Gold Creek crossing structure.
- Providing fish passage and habitat improvements for threatened bull trout for the full range of lake elevations.
- Improving water quality by properly treating stormwater and highway runoff, and minimizing de-icer chemical use.

The initial Gold Creek CEA concept recommended by the interdisciplinary team and accepted by WSDOT was to replace the existing 138- and 126-foot bridges with a 1,200-foot eastbound bridge and a 1,000-foot westbound bridge (MDT 2006, ES-15). This would provide a connection through the highway for approximately nine to 10 months a year (the Keechelus Lake reservoir inundates the lakebed at high pool during late spring). Additional clearance for winter snowpack was also recommended.

Figure 4. A design visualization of the new Gold Creek Bridges

After identifying objectives and conceptual Gold Creek CEA bridge designs, WSDOT conducted geotechnical drilling at the Gold Creek area. Geotechnical findings indicated areas of liquefiable soil conditions at the Gold Creek CEA site. Liquefiable soils (typically saturated sand) are a concern because during an earthquake, the soil looses shear strength and can flow like a liquid. This results in global foundation stability issues with bridge designs. To construct the bridges and meet seismic code requirements, WSDOT engineers would need to stabilize ground conditions.

Engineers originally proposed to improve liquefiable soils with a technique known as bottom-fed vibro-replacement stone columns. The stone columns were to range in diameter from 2.5 feet to 3.5 feet and would be constructed on a grid pattern designed to suit the load, soil, and performance types. Column holes were to be bored at varying design depths of approximately 50 feet deep in places, then dense, angular crushed or shot rock backfill would be introduced in discrete lifts from the ground surface. Re-penetration of each lift would compact the stone in the surrounding soil. Once complete, the replacement stone columns would have effectively reduced foundation settlement, mitigated liquefaction potential, improved shear resistance, and increased bearing capacity.

The ecological impacts of the vibro-replacement ground stabilization technique, however, raised red flags among partnering resource agencies. Partners were concerned that construction of the stone columns would temporarily and permanently impact wetlands and expand the footprint of the roadway prism. This technique would require a pattern of stone columns roughly 50 feet beyond the toe of the highway embankment, necessitating construction within adjacent wetlands.

Understanding the importance of addressing resource agency concerns, WSDOT design engineers developed a list of plausible alternatives for improving the soil conditions at Gold Creek. WSDOT presented these alternatives to its partners, and together, determined an acceptable method of improving ground conditions that met both transportation and ecological connectivity objectives.

The new, agreed-upon method of improving the liquefiable soils is compaction grouting. A very viscous (low-mobility), aggregate grout will be pumped in stages, starting up to 50 feet deep in places and working toward the ground surface. The grout will form a column of bulbs, which densifies and displaces the surrounding soils. WSDOT will construct the grout columns on a grid pattern designed to suit load, soil, and seismic performance. Once complete, the grout columns will reduce foundation settlement, mitigate liquefaction potential, improve shear resistance, and increase bearing capacity. This technique uses a much smaller pattern, which allows the highway footprint to be minimized.

Eliminating Scour Issues at Gold Creek Bridges While Maximizing the Restoration Area

The Gold Creek CEA serves as a wildlife crossing structure, restores natural channel migration processes, and reduces floodplain confinement. Because of high spring flows within the creek, WSDOT engineers had to plan for scour in their bridge designs. Original bridge designs called for optimizing costs by keeping the foundations shallow - above ground water level - and using “launching toe” revetments consisting of large rip-rap to protect the foundation embankments.

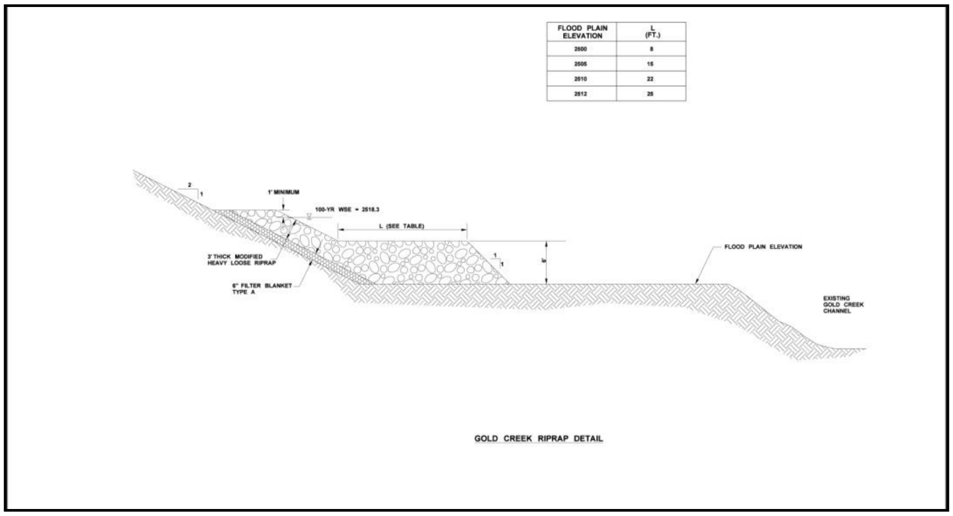

Figure 5. The original design plans using launching toe revetments of large rip-rap details

The height and width of the planned revetments, however, resulted in a conflict with CEA objectives. Partnering resource agencies were concerned revetments would reduce clearance and openness, limit the amount of re-vegetation that could occur, and reduce the amount of available wetland credit for the restoration area under the bridges.

WSDOT design engineers and the resource agencies collaborated on finding a new design that would satisfy CEA objectives and scour mitigation costs. The resulting compromise in design called for lowering the armament to just below ground level, thereby enabling re-vegetation and openness of the area. Bridge foundations will be accompanied by large rocks inserted underground, near the scour level at the toe of the bridge.

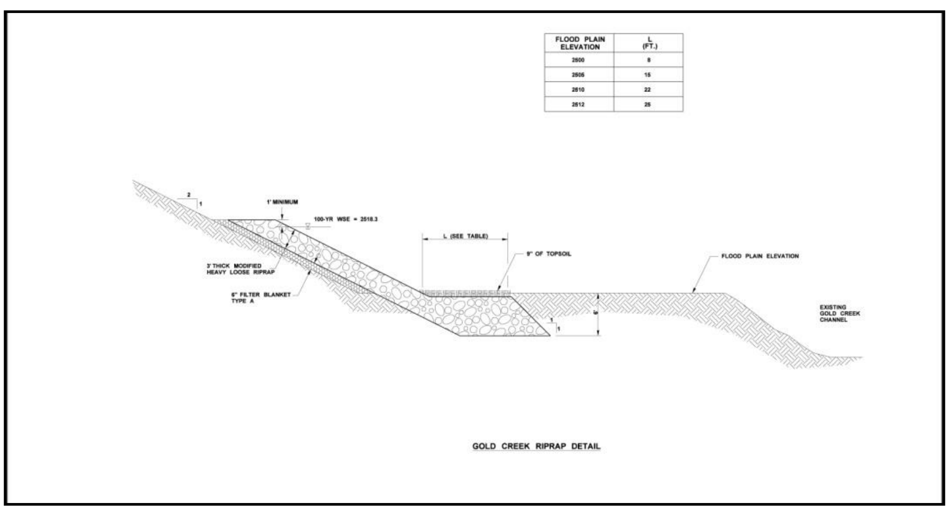

Figure 6. The modified design allowing for re-vegetation and openness

<u>Creating a Habitat Connection at Gold Creek CEA/Upper Keechelus Lake, While Treating Stormwater and Reducing Wetland Impacts</u>

The I-90 Project corridor passes through the Wenatchee National Forest and runs adjacent to the north eastern shore of Keechelus Lake for the first six miles, then parallels the Yakima River for the remaining nine miles. The project crosses five tributaries to Keechelus Lake and nine significant tributaries to the Yakima River, including the Kachess River. The project also crosses or is adjacent to numerous wetlands (WDOT / Otak 2007, 1-2). Therefore, incorporating stormwater management systems into I-90 Project is essential for minimizing contamination of terrestrial and aquatic habitats. Stormwater treatment facilities also present WSDOT with the opportunity to repair water quality problems caused by the existing highway. For example, in certain creeks located within the project area, water quality has been effected due in part, to sediment (traction sand from both I-90 and the adjacent WSDOT Maintenance facility sandpile), and the presence of metals (lead and arsenic) in stormwater runoff.

The selection, design, and mitigation process for this stormwater system is complex. Portions of the project are located on steep slopes (rock cliffs) where construction of Stormwater BMPs would be very difficult and require extensive structural support. Other typical freeway BMPs such as infiltration swales and ditches are infeasible because portions of the project are located in narrow corridors where cliffs are on one side of the freeway, and a lake or river is on the other side, with no room for a median. And while not exactly a physical constraint, snow management and snow hydrology plays a large role in how space is utilized and what BMPs are most suitable, with open areas in the median or adjacent to the freeway likely doubling as both snow storage areas as well as stormwater BMP locations (WSDOT / Otak 2007, 1-2).

To help identify issues and find the best solutions to solve stormwater treatment challenges, WSDOT created a multi-agency Stormwater Technical Committee to review stormwater technical and permitting issues; evaluate mitigation approaches developed by WSDOT; and recommend appropriate, effective, and efficient mitigation methods to the design team. Committee members included WSDOT and consultants, USFS, and EPA staff that have permitting approval roles or are partner agencies with a strong interest in helping solve stormwater problems.

WSDOT and the Stormwater Technical Committee conducted several in-depth studies and determined that a stormwater treatment and snow storage facility was needed near the Gold Creek CEA. The identified preferred location for the facility was at the WSDOT Maintenance facility, just west of the Gold Creek CEA, where additional upland habitat was being created to enhance the effectiveness of a planned undercrossing. WSDOT engineers believed they could further enhance the Gold Creek CEA's effectiveness by reducing visibility and noise of the stormwater treatment facility and reducing noise from the maintenance facility by building a separation between the two areas. (See Figure 7).

Plans originally called for using a wide grassy swale to treat stormwater from the maintenance facility and building of a tall berm at the upland below the undercrossing to reduce light and noise. Engineers also planned for snow storage within the grassy swale.

As designs progressed, however, resource agencies expressed concerns over the footprint of the Keechelus Lake bench design and its impact to the wetland. But because so many transportation facility design objectives and ecological objectives needed to be met at this one location, all parties had to compromise on design. To reach compromises, several organized meetings were held among engineers, technical committees, and resource agencies. In the end, WSDOT compromised for less snow storage space and a more compact stormwater BMP with higher maintenance requirements. The resource agencies compromised by allowing minor wetland and footprint impacts through a shorter, vegetated berm and reduced upland area, versus the previous taller bench design. WSDOT will add vegetation - tall trees - to the shorter and smaller berm design to make up the reduced structure height.

Figure 7. I-90 (lower left), Keechelus Lake (center), and the WSDOT Maintenance Facility (lower right). The facility provided a suitable stormwater treatment / snow storage area

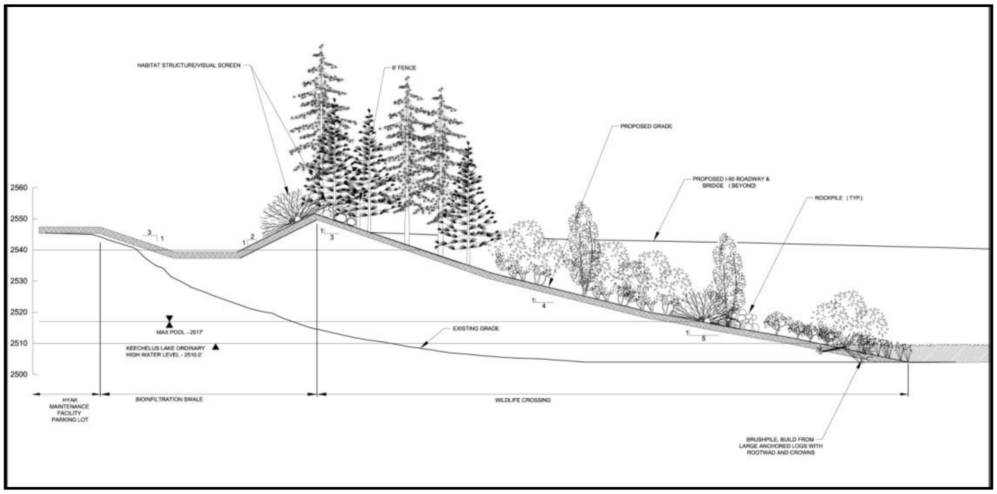

Figure 8. The conceptual plans for lowering the berm and vegetating it with tall trees to reduce noise and visibility of the stormwater treatment facility

Other Stormwater Treatment Design Challenges

Further challenges arose when designing other stormwater treatment facilities for the I-90 Project. Since the project corridor is constrained for most treatment options, Media Filter Drains (MFDs) were selected and approved by the Washington State Department of Ecology (Ecology) as the most viable treatment option for use along the corridor. However, use of MFDs as approved by Ecology is not inline with USFS invasive species guidelines since they do not allow for vegetated plantings.

While WSDOT has engaged in a pilot program to test composting and vegetating MFDs elsewhere in the state, the pilot program is still underway and vegetated MFDs are still considered experimental. WSDOT is currently seeking approval for use of a vegetated MFD on Snoqualmie Pass in order to meet USFS objectives.

Eliminating Scour Issues at Wolfe Creek CEA While Enhancing Wildlife and Aquatic Mobility

The Wolfe Creek CEA is located between milepost 57.1 and milepost 57.3. The forest habitat adjacent to this CEA is the Western Hemlock Series, grading into the Pacific Silver Fir Series at higher elevations. The creek has a very steep gradient and provides limited fish habitat, although Pacific giant salamanders and tailed frogs are relatively common (MDT 2006, ES-16).

Currently, Wolfe Creek passes under I-90 in a 6-foot box culvert and empties into the east side of Keechelus Lake. The MDT recommended that WSDOT construct a 25-foot by 8-foot bottomless culvert westbound and a 20-foot by 10-foot bottomless culvert eastbound to meet the connectivity needs of wildlife and aquatic organisms, while passing flood flows and debris. This conceptual bridge would need to meet WDFW stream requirement for fish bearing streams.

As engineering designs progressed at this CEA, hydrologic analysis identified scour issues from the high-velocity, steep gradient stream that could undermine the culvert foundations and walls. WSDOT engineers considered using larger foundations for the bottomless culvert design, but the larger, deeper foundations were costlier and generated additional construction impacts to the creek banks and / or wetlands. Engineers also explored bridge options, versus a culvert, but again, foundation and cost issues proved formidable challenges.

Design engineers, working with WDFW, developed an alternative that included a four-sided box culvert with a stream-simulated bottom. The stream-simulated bottom was designed deep enough to hold four feet of stream-simulation material and maintain the eight feet of clearance needed to meet MDT recommendations. WSDOT presented this design option to resource agencies, and after thorough review, the agencies agreed that the four-sided box culvert design would still meet the connectivity objectives of restoring capacity for flood and debris flow, providing fish passage for the full range of lake elevations, and providing aquatic organism connectivity.

Figure 9. The existing Wolfe Creek 6-foot box culvert

Figure 10. A conceptual four-sided box culvert design for Wolfe Creek

Designing Rocky Run Bridges for Clearance and Connecting Habitat

The Rocky Run Creek CEA is located between milepost 56.7 and milepost 56.9, with the creek originating above 4,800 feet elevation at Lake Lillian. The forest habitat adjacent to this CEA is the Western Hemlock Series, grading into the Pacific Silver Fir Series at higher elevations. The creek flows into the east side of Keechelus Lake and has a fairly steep gradient, although several fish species use this system.

The existing I-90 crossing over Rocky Run Creek is a 40-foot-long bridge eastbound and two 6-foot pipe culverts westbound. The MDT recommended that WSDOT improve connectivity in this area by building twin 120-foot bridges to meet the needs of wildlife and aquatic organisms, while passing flood flows and debris (MDT 2006, ES-16).

The challenge for WSDOT engineers was to design the MDT-recommended bridges to optimize clearance beneath the bridges for openness of habitat while keeping the footprint of the highway small to avoid impacts to Keechelus Lake. WSDOT engineers wanted to achieve clearance of at least 16-feet for each Rocky Run bridge to account for snow pack. Varying topography and road profiles between the separated eastbound and westbound lanes at Rocky Run Creek however, would not allow engineers to achieve the clearance needed without further elevating the road profile and increasing the highway footprint. Elevating the profile, however, would not meet design standards for design speeds and also presented safety considerations. To elevate the road profile, engineers would have to create a large crest in the road, creating visibility issues and impacting other resources by enlarging the footprint.

WSDOT engineers decided to go back to the drawing board for the Rocky Run Creek bridge designs. Engineers first determined that the new I-90 road profile at Rocky Run Creek needed to be built at the same elevation for both eastbound and westbound lanes across the separated highway to minimize footprint. Engineers also determined that the only way to keep the consistent elevation levels across the bridges, while adding habitat benches under the bridges for connectivity purposes, was to compromise bridge clearance on the westbound structure. The resulting design called for a westbound bridge with reduced clearance and an eastbound bridge with greater clearance. The eastbound bridge was also lengthened to accommodate longer fill slopes and keep some habitat along the creek.

Figure 11. A design visualization for the Rocky Run CEA

WSDOT engineers successfully overcame design challenges at Rocky Run Creek with new designs that achieved the connectivity objectives of providing moderate level connectivity for high- and low-mobility species associated with the mountain hemlock / subalpine fir species assemblage zone, restoring capacity for flood and debris flow at the crossing structure, and providing fish passage for the full range of lake elevations.

Subsequent Rocky Run Issue Regarding Profile Adjustment

After determining the best profile for the highway to meet clearance and footprint objectives at Rocky Run Creek, archeological and cultural conflicts arose with a USFS Service Road. By elevating the highway profile to create clearance at the creek bridges, the USFS Service Road adjacent to I-90 would become lower than the adjacent interstate, resulting in possible embankment encroachment. WSDOT proposed to raise the profile of the USFS Service Road to remedy the problem, but this would require WSDOT to disturb an adjacent property containing old growth trees and a structure eligible for the National Historic Register and State Historic Preservation Office resources.

Since not many compromises were available to reduce the primary and secondary impacts of the situation, WSDOT engineers accepted that designing around this issue would require additional cost. WSDOT moved forward with plans to raise the profile of the USFS Service Road and reduce impacts to the historic property by adding a small system of precast concrete barrier to retain the existing slope. WSDOT also re-routed planned drainage systems in the area to lessen the impact near the historic site.

Constructability and Floodplain Issues of Resort Creek CEA

The Resort Creek CEA is located between milepost 59.3 and milepost 59.7. The forest habitat adjacent to this CEA is the Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations. Currently, Resort Creek flows under I-90 in a 6-foot pipe culvert that is a barrier to fish passage, and drains into Keechelus Lake (MDT 2006, ES-17).

Figure 12. The existing 6-foot pipe culvert at Resort Creek

The MDT recommended that WSDOT install a series of bottomless culverts throughout the active channel-migration zone of Resort Creek. At least one of these culverts would have a minimum width of 30 feet and a minimum vertical clearance of 12 feet; the combined widths would span about 100 feet. These culverts would extend under both eastbound and westbound lanes, resulting in culvert lengths of about 150 feet. The series of culverts would allow the creek channel to shift location across the alluvial fan in response to sediment deposition and debris blockage. Culverts would be sized to meet WSFW stream simulation requirements for fish passage.

As WSDOT engineers advanced this design, uncertainty emerged about Resort Creek actually meandering across the alluvial fan. Additionally, the costs to install a temporary shoring system in order to construct the bottomless culverts and maintain traffic through the construction zone were exorbitant. WSDOT engineers reformulated designs by replacing the culverts with a 180-foot-long bridge that not only provided a large opening across the floodplain for natural creek function, but also created a better wildlife crossing structure for aquatic and terrestrial species.

WSDOT engineers presented this modified design to the IDT and MDT. The agencies agreed that this option achieved connectivity objectives – reducing wildlife / vehicle collisions, restoring capacity for flood and debris flow, providing fish passage, and restoring habitat / aquatic connectivity and channel migration – while meeting the additional objective of providing connectivity for large and small species.

Non-Engineering Challenges to Consider When Integrating Ecological Connectivity Objectives in Highway Improvement Projects

In the above case studies, several challenges WSDOT design engineers encountered while integrating transportation and ecological objectives on the I-90 Project were outlined. There are several other issues for engineering and environmental planners to consider when developing ecological connectivity objectives for highway projects, such as seasonal recreational uses of facilities adjacent to crossing structures, long-term management of crossing structures, and general maintenance and operation of the highway.

Recreation

Winter activities such as skiing and snowshoeing are predominate recreation activities adjacent to the I-90 Project corridor. Thousands of people are drawn to I-90 Snoqualmie Pass on winter weekends to take advantage of vast ski slopes and fresh snowfall. Many of the small businesses residing within the I-90 Project corridor rely on a busy winter season for their livelihood. Recreational activity along the slopes and neighboring Sno Parks has the potential to impact the effectiveness of several I-90 Project CEAs. Studies have shown that human activity in the proximity of crossing structures reduces their effectiveness.

WSDOT, as a transportation agency, decided against prioritizing between recreation and wildlife connectivity. We handed decision-making responsibility over to the land managers – USFS and the Washington State Parks and Recreation Commission. The two resource agencies later determined that winter recreation is important to the corridor and should be allowed to continue. They also believe that the crossing structures will be used less frequently by wildlife during the winter due to migration patterns.

Managing Crossing Structures

A tremendous amount of effort goes into planning for and building ecological connectivity structures, but oftentimes, long-term management of these structures is omitted from environmental documents. Since USFS manages the land adjacent to the I-90 Project crossing structures, WSDOT and USFS have been working to develop land-use management plans and strategies for prohibiting direct human use of the crossing structures. Land-use plans will be difficult to enforce, so WSDOT and USFS have committed to be diligent in resolving all conflicts with the planned crossing structures.

General Highway Maintenance and Operations.

General maintenance and operations of a highway can also affect ecological connectivity designs and objectives. For the I-90 Project, engineers and environmental planners had to design around heavy annual snowfall and extensive winter maintenance operations that are required to keep I-90 Snoqualmie Pass open from November to April. During winter operations, WSDOT snowplows are used to shovel snow from the roadway. There is an inherent risk that the large volume of snow plowed from the roadway could pile into the openings of crossing structures, thereby reducing the openness of the crossings. WSDOT engineers and environmental planners identified the potential risk early, and planned for the impact by requiring additional clearance equal to the average snowpack for bridge and culvert designs.

Designs for highway medians were also compromised by competing objectives for snow storage, highway footprint, and wetland impacts restrictions. Engineers had originally hoped to increase the median size to increase snow storage capacity. The larger median designs, however, adversely increased the highway footprint. To compromise, engineers maintained the current highway median size, even though it could create an added burden to winter maintenance operations.

<u>Moving Design Plans Forward and Preparing for Construction</u>

After years of working with project partners and resource agencies to find viable solutions to competing objectives between transportation facility design and ecological connectivity, WSDOT engineers are finalizing design plans and preparing for construction.

The funded five-mile portion of the I-90 Project from Hyak to Keechelus Dam has been broken into three construction contracts. Designs for the first construction contract – Phase 1A - are complete and construction began in July 2009. WSDOT is in the process of building a long-term detour bridge at Gold Creek for use in the second construction contract of the project. WSDOT is also mitigating for future lake storage impacts to Keechelus Lake – an irrigation reservoir – by excavating approximately 250,000 cubic yards of material from the lakebed. WSDOT has committed to a no-net-loss agreement with USBR to not affect lake storage capacity during construction of the I-90 Project.

WSDOT will complete designs and permits for the second construction contract – Phase 1B – in fall 2009, with an expected advertisement date to qualified contractors in October 2009. This contract calls for replacing the deteriorated concrete pavement of the existing four lanes, adding a new lane in each direction, rebuilding bridges and culverts, and extending chain up / off areas along the first three miles of the project. WSDOT expects to begin construction of Phase 1B in spring 2010.

Engineering designs and permitting actions are still underway for the third construction contract – Phase 1C – that will cover the remaining two project miles. Phase 1C calls for replacing deteriorated concrete pavement, adding a new lane in each direction, replacing the existing snowshed, addressing unstable slopes, building new bridges, and constructing new chain up / off areas. Phase 1C is expected to advertise to contractors in fall 2010, with construction scheduled to begin in spring 2011. All I-90 Hyak to Keechelus Dam Project improvements are scheduled for completion in 2015.

To move Phase 1 design plans forward, engineers are finishing geotechnical drilling on the rock cliffs and lakebed along the I-90 Project corridor. Drilling core samples will help identify structural needs for the snowshed and the potentially unstable slopes along the corridor that will require stabilization measures as the rock cuts are excavated. WSDOT will stabilize slopes with grouted steel bars that are designed in accordance with the structural geology and height of each rock cut. WSDOT and a consultant team of geologists are also conducting geophysical studies using downhole surveys for bedrock mapping to identify terrain conditions and design the highway realignment.

Other work includes completing the structural designs for the remaining three CEAs, roadway drainage, and the new snowshed, which also includes mechanical system designs for illumination, ventilation, back-up electrical generation, and Intelligent Transportation Systems (ITS). (See Figure 13). Engineers are also finalizing construction schedules and other logistics for traffic control and staging.

Figure 13. A design visualization of the new snowshed bridge

Pre-construction wildlife monitoring activities continue to move forward as well. As part of the I-90 Project Wildlife Monitoring Plan, WSDOT and its partners are evaluating the locations and rate of wildlife / vehicle collisions; assessing the use and effectiveness of wildlife crossing structures – both existing and planned; characterizing the locations and rate of at-grade highway crossings by wildlife; estimating species occurrence and distribution in the project area; assessing the effectiveness of fencing; and appraising the effectiveness of jump-outs (WSDOT / WTI 2008, ix). Methods being used to meet pre-construction objectives include assessing wildlife use of existing culverts and underpasses via remote cameras; documenting crossing rates via snow tracking; evaluating the distribution of various target species via both noninvasive survey methods and live-capture; and documenting wildlife-vehicle collisions. In addition, specific projects to monitor low-mobility species such as fish, amphibians, and pikas have been initiated.

Wildlife monitoring efforts will continue during and after construction of the I-90 Project. The engineering team is working to ensure successful post-construction monitoring efforts by integrating communication systems into the infrastructure of the highway. Engineers plan to install fiber-optic communication cables at each CEA that will instantly transmit wildlife usage data, including images, to WSDOT for more efficient collection of information. Engineers would also like to make the live feeds available for public viewing on the WSDOT Web site.

The engineering team continues to test various prototypes of wildlife exclusionary fencing to find a design that will withstand winter weather conditions, maintenance operations, and redirect wildlife away from the interstate and to crossing structures. Several prototypes have been tested over the last two winter seasons; engineers are hopeful to finalize fencing plans this year.

Continuing Collaboration to Resolve Future Issues

Open and honest communication, and the desire to establish and engage in partnerships early on, is what inevitably allowed WSDOT to develop consensus for a long-term vision for the I-90 corridor. By sharing ideas, being adaptive in designs, and receptive to compromises, WSDOT and our partners have designed a project that will not only improve the safety and reliability of a vital cross-state corridor, but will also ensure the continued health of the delicate ecosystems of the Central Cascades for generations to come.

WSDOT will continue to collaborate with project partners, stakeholders, and resource agencies to overcome challenges as they arise during construction and in future designs. While the remaining 10 project miles from Keechelus Dam to Easton remain unfunded at this time, WSDOT, along with our project partners, stand ready to deliver.

Biographical Sketches

Randy Giles is Project Director of the Washington State Department of Transportation’s I-90 Snoqualmie Pass East Project, a position he’s held since 2008. Prior to then, he was a project engineer for the I-90 Project, managing a co-located staff of WSDOT and consultant engineers involved in geotechnical field exploration, geometric design, hydraulic and stormwater engineering. Randy has over 17 years of experience in highway design and construction. He holds a bachelor’s degree in civil engineering from the University of Utah.

Scott Golbek is Project Engineer for the Washington State Department of Transportation's I-90 Snoqualmie Pass East Project, a position he's held since 2008. Prior to then, he was an assistant project engineer for the I-90 Project, managing a co-located staff of WSDOT and consultant engineers involved in geotechnical field exploration, geometric design, hydraulic and stormwater engineering. Scott has over 17 years of experience in highway planning, design and construction. He holds a bachelor's degree in civil engineering from the Oregon Institute of Technology.

Amanda Sullivan is a communications consultant for the Washington State Department of Transportation's I-90 Snoqualmie Pass East Project. While she is employed by the full-service communications firm, PRR, Inc., she is co-located with the I-90 Project team to help manage the extensive communications program. She joined PRR in 2008. Prior to then, Amanda was a senior staff writer at Executive Media Corp., a media relations director for a county museum, and an account executive for an advertising specialty corporation. Amanda holds a bachelor's degree in public relations from Central Washington University and associate's degree from Yakima Valley Community College.

Jerry Wood is the Acting Assistant Project Engineering for the Washington State Department of Transportation's I-90 Snoqualmie Pass East Project, a position he's held since 2008. Prior to then, he was a project field engineer for the South Central Region Field Office. Jerry has over 10 years experience in highway design and construction. He holds an associate in applied arts and sciences degree from Walla Walla Community College.

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Appendix A: List of Acronyms

BMPs - Best Management Practices
CEA—Connectivity Emphasis Area
EIS – Environmental Impact Statement
Ecology – Washington State Department of Ecology
FHWA—Federal Highways Administration
HCZ – Hydrologic connectivity zone
HRM – Highway Runoff Manual
I-90—US Interstate 90
I-90 Project – I-90 Snoqualmie Pass East Project
IDT – Interdisciplinary Team
MDT—Mitigation Development Team
MFDs – Media Filter Drains
Otak – Otak, Inc., hydraulic design consultant
ROW—Right-of-way
STC – Stormwater Technical Committee
USACE – US Army Corps of Engineers
USBR – US Bureau of Reclamation
USDA—US Department of Agriculture
USDI—US Department of the Interior
USFS—US Forest Service
USFWS—US Fish and Wildlife Service
WDFW—Washington Department of Fish and Wildlife
WSDOT—Washington Department of Transportation
WMTC – Wildlife Monitoring Technical Committee
WTI—Western Transportation Institute

A SUMMARY OF THE WILDLIFE LINKAGE AND HIGHWAY SAFETY ASSESSMENT: A PRIORITIZATION AND PLANNING TOOL FOR WESTERN MONTANA

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Abstract

Protecting habitat connectivity for wildlife is a management imperative facing agencies and wildlife organizations across the United States. To maintain connectivity and improve highway safety across transportation routes in western Montana, American Wildlands conducted a rapid wildlife linkage and highway safety assessment. This analysis had two primary objectives: 1) to provide a planning tool to direct American Wildlands' conservation efforts for protection of habitat connectivity across transportation routes; and 2) to provide data and information useful to agencies and other conservation partners. This assessment used four criteria to identify priority areas: i) road kill concentration areas, ii) important wildlife linkage areas, iii) planned transportation projects, and iv) land ownership as an indicator of the likelihood of conservation success. To complete the analysis, kernel density estimation and percent volume contours were used to identify high concentration areas where there is a dual concern for wildlife and human safety based on elevated numbers of road kill. Additional GIS data sets were used to further prioritize the potential priority areas. This process resulted in improved understanding of the road kill concentration areas in western Montana as well as a planning document which can be used by both public and private sector entities to improve local and regional planning and coordination. Critical to the success of this project was an engaged advisory group and a focus on delivery of the analysis results and products to the agencies and other partners. To ensure that advisory group members, representing their respective organizations, endorse and utilize the analysis results in their planning processes we actively encouraged and incorporated member input into the analysis process and data products. Delivery mechanisms (hard copy reports, GIS data, and web access) were agreed upon by the advisory group and are available with the final report. Continued collaborative efforts between public and private entities will be essential to ensure the appropriate level of conservation dollars and effort to meet protection needs in the identified priority areas. Since the western Montana study can be considered a pilot for a possible statewide initiative, the lessons learned may be used to create an improved product at the statewide level. Additionally, we propose this model be considered for application to other western states in need of a wildlife linkage and highway safety planning tool.

Introduction

Protecting habitat connectivity for wildlife is a management imperative facing agencies and wildlife organizations across the United States. An important component to ensuring habitat connections is maintaining successful wildlife movement across transportation routes (Forman et al. 2003). Research has shown wildlife-vehicle collisions are on the rise in the United States *(*Huisjer et al. 2007), and efforts are needed to reduce the number of these accidents.

The goal of this assessment was to use a systematic, transparent process to improve wildlife movement and human safety through the prioritization of wildlife movement areas suitable for mitigation along transportation routes in western Montana. Due to the high quality wildlife habitat present in the study area, there are numerous areas where wildlife mitigation is both needed and warranted along roadways. Personnel in wildlife and transportation agencies are aware of important locations through their work experience but have no coordinated mechanism by which to set and apply priorities. This rapid assessment was initially designed as a planning tool to prioritize American Wildlands' (AWL) wildlife and highway conservation work and to identify the intersection between human safety concerns due to wildlife-vehicle collisions and important wildlife linkages in western Montana. It was designed to incorporate best available data and utilize a collaborative process to find common ground and prioritize where wildlife linkage and wildlife vehicle collision issues should be addressed in the next five to ten years. Based on the high level of agency interest in the process and results, we expanded the project in June 2008 to act as a pilot to develop a multi-agency endorsed wildlife and highway planning document.

To guide the assessment process, American Wildlands relied heavily on a multi-agency and organization advisory group as a guiding force for goal setting and methodology. Through this 14 member advisory group, AWL developed a prioritization framework to rank wildlife movement areas along transportation routes that are in need of mitigation. The advisory group's role was to: 1) guide the assessment methodology and report, 2) help American Wildlands understand the obstacles and opportunities for collaborative wildlife conservation efforts along transportation routes, 3) find areas where improvement in collaboration strategy is needed, and 4) devise actions to improve the ability to collaborate.

This project and the resulting report function both as an analysis document and a planning tool. Our work is relevant to any individual, agency or organization who wishes to better understand methods for identifying important wildlife-transportation project areas, as well as those wishing to plan and prioritize wildlife and highway mitigation efforts in western Montana. Potential users of this report therefore include state wildlife and transportation agencies, federal, state and county planners, wildlife conservation organizations, and rural development organizations.

This paper summarizes the draft report provided to the working group (Williamson et al. 2009). The full report provides detailed methods, results, recommendations of the assessment as well as an extensive appendix. For those interested in applying this type of process to your work, the final report will be available in September 2009 and can be found at http://wildlands.org/programs/safepassages/assessment/.

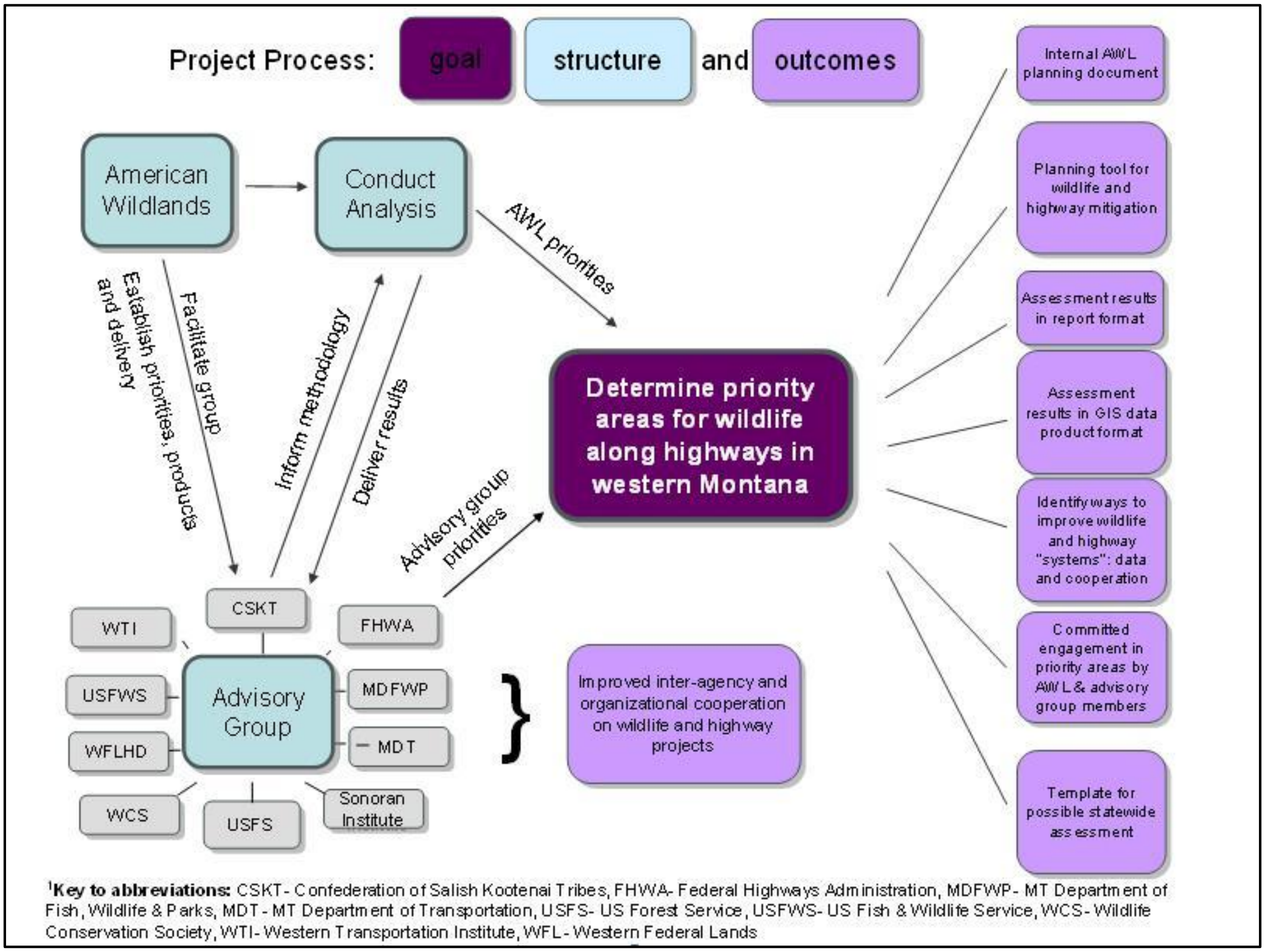


Figure 1. Diagram illustrating the goals, structure and potential outcomes of the project, as well as the roles of American Wildlands and the project advisory group.

Methods

Study Area

The boundaries of the study area are the Canadian border (north), Idaho border (west and southwest), Wyoming border and Yellowstone National Park (southeast) and Rocky Mountain Front and eastern slope of the Crazy, Castle, Beartooth and Little Belt mountain ranges (east).

The landscape of western Montana is characterized by rugged mountain ranges divided by river valleys. Elevations range from 555 meters (1820 ft) at the Kootenai River to over 3810 meters (12,500 ft) in the Beartooth range. Lower elevation habitats, below 1829 meters (6000 ft), vary greatly in composition and include mountain foothills, short-grass/sagebrush prairie, intensively cultivated areas, natural wetlands/lakes, riparian plant communities, man-made reservoirs, small communities, large towns, and cities. Mountainous habitats are dominated by coniferous forest and rocky sub-alpine/alpine communities.

We considered road kill events which occurred in this study area on 7947 kilometers (4914 mi) of Montana Department of Transportation managed roads. This route network is comprised of 282 interstate, state primary, state secondary, state urban, and "state highway" routes.

With guidance from the advisory group, a methodology was developed to identify and prioritize potential areas for wildlife mitigation in western Montana. We incorporated wildlife-vehicle collision highway data, wildlife linkage information, as well as land ownership and state transportation improvement program plans to determine priorities for wildlife mitigation on transportation routes in western Montana using a three step process. The diagram below provides a general illustration of the steps taken and the overall structure of the analysis.

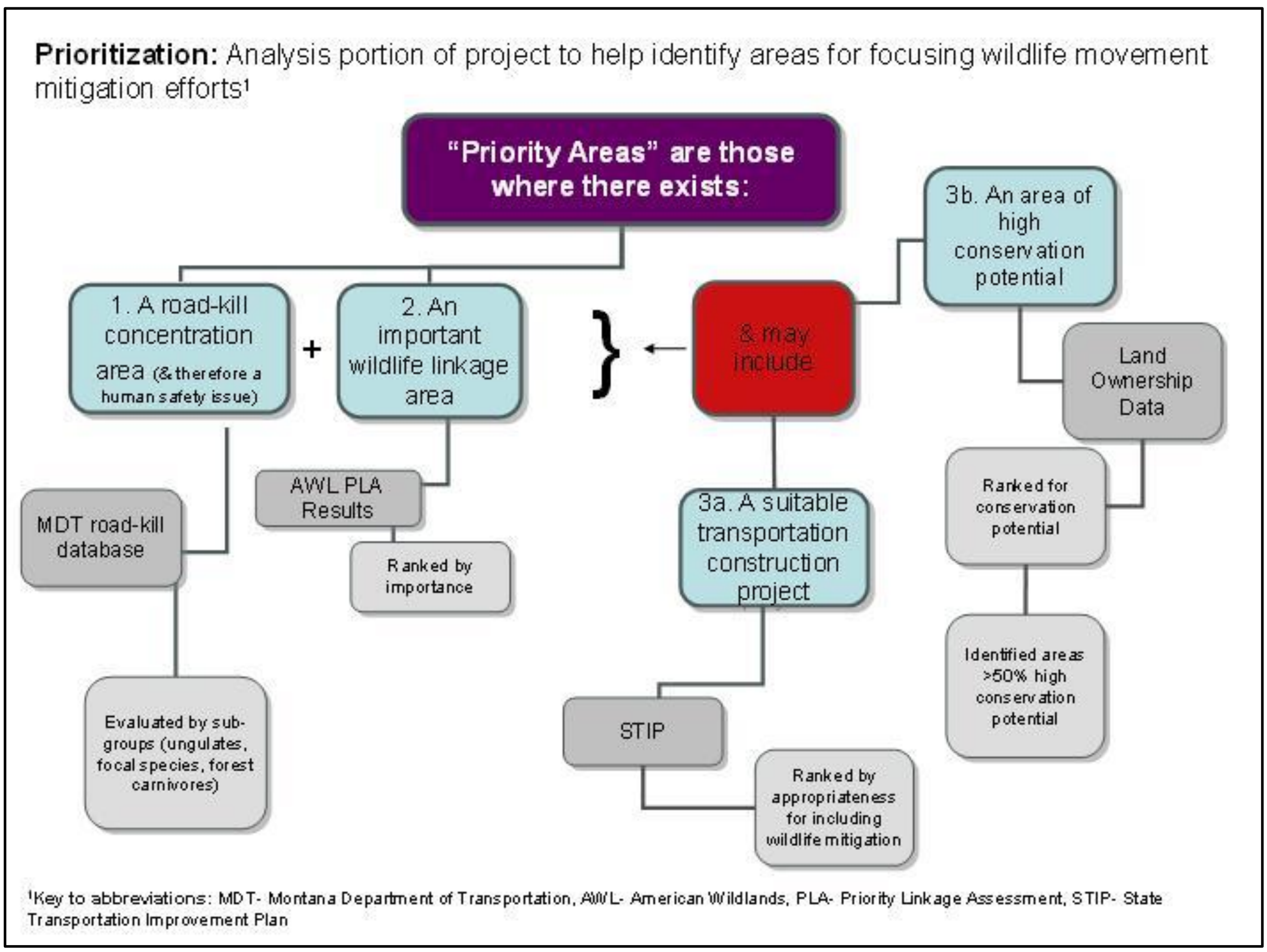


Figure 2. Diagram illustrating steps 1-3 of the analysis.

Step 1. Define high road kill concentration areas (HCA) based on ungulate, focal species and forest carnivore species groups.

A Geographic Information Systems (GIS) analysis point dataset was derived from MDT 2003-2007 tabular animal carcass data. The data was spatially referenced in Environmental Systems Research Institute (ESRI) ArcGIS 9.3 using MDT system mileposts. The dataset was refined to points within the western Montana study area and species of interest for the analysis (elk, fox, bison, bobcat, moose, gray wolf, mule deer, black bear, grizzly bear, bighorn sheep, mountain lion, mountain goat, whitetail deer, pronghorn antelope). Based on species, these data were grouped into three subgroups for separate analyses: ungulate species, focal species and focal carnivores (Williamson et al. 2009). Species groups are not mutually exclusive. Certain road kill events therefore, were included in more than one species group analysis.

A density surface was created for the ungulate, focal species and focal carnivore subgroups using standard kernel density estimation (KDE) methods (Clevenger et al. 2006). The analysis was conducted using ESRI's Spatial Analyst© extension. The grid layer generated by the KDE illustrates where road kill point locations are concentrated by calculating a density value for each 800 m^2 cell.
Percent volume contours (PVC) were calculated to isolate the highest road kill concentration areas for the continuous density surface for the ungulate species, focal species, and focal carnivore subgroups (Beyer 2004). Contour lines were drawn around the areas containing fifteen percent of the volume of the density distribution from the KDE output grid.

Step 2. Overlay of road kill high concentration areas with priority wildlife linkage information to determine and rank potential project areas.

In the next step of the analysis, the road kill high concentration areas were overlaid with wildlife linkage information for western Montana. This linkage data came from the 2007-2008, American Wildlands expert opinion-based model used to prioritize the most important wildlife linkage areas in the U.S. Northern Rockies (American Wildlands 2009).

To determine areas where the road kill high concentration areas intersected the wildlife linkages, three input datasets (ungulate and focal species high road kill concentration areas and wildlife linkage data) were converted to grid layers with a resolution cell size of 800 meters, consistent with the spatial accuracy assumed for road kill point events. The forest carnivore subgroup high concentration area data was removed from the analysis process due to small sample size; only the ungulate and focal species HCA, therefore, are used in the following steps of the analysis. A grid overlay function was used to combine the attributes from the three layers. Ungulate and/or focal species HCA located within or intersecting "very high" or "high" wildlife linkages were identified as potential project areas. These potential project areas were ranked into three categories (Tier I, Tier II, and Tier III) based on the HCA and wildlife linkage rank (Fig. 3).

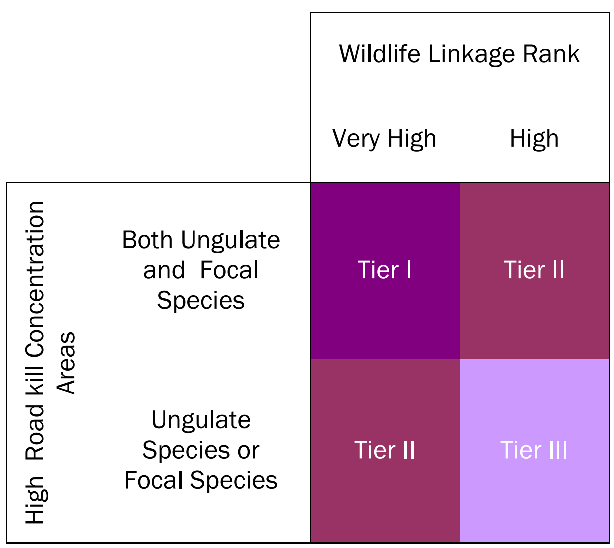


Figure 3. Schematic illustrating criteria contribution to identification of an initial ranking of potential project areas (in purple).

Step 3. Rank potential project areas based on state transportation improvement program plans and a land ownership conservation potential index.

To provide planners with an increased ability to prioritize important mitigation areas, two decision matrices were used to further rank the potential project areas identified in Step 2. Potential project areas were considered “added opportunity areas” if they were coincident with Statewide Transportation Improvement Program projects (STIP) and/or surrounding land ownership that could facilitate highway mitigations for wildlife. The factors were evaluated independently to isolate the possible contribution of each to mitigation opportunities in the potential project areas.

Potential Project Area Ranking based on Statewide Transportation Improvement Program Projects

For evaluation in the decision matrix, STIP projects were first weighted based on the relative opportunity for including wildlife mitigation efforts in each scope (type) of project (Williamson et al. 2009). The decision matrix was defined with the ranked potential project areas on one axis and weighted STIP projects on the opposing axis. The resulting values were ranked into three categories (Tier I, Tier II and Tier III) that reflected both the opportunity for incorporating wildlife mitigation into highway projects and the need for mitigation based on road kill high concentration areas and highest priority wildlife linkage areas (Fig. 4).

<table>
<tr><td colspan="2" rowspan="3"></td><td colspan="3">Ease of incorporating wildlife mitigation into highway project ranking</td></tr>
<tr><td>High</td><td>Moderate</td><td>Low</td></tr>
<tr><td>8-10</td><td>3-7</td><td>0-2*</td></tr>
<tr><td rowspan="3">Initial Potential Project Area Rank (based on Step 2)</td><td>I</td><td rowspan="3">Tier I</td><td></td><td>Tier II</td></tr>
<tr><td>II</td><td rowspan="2">Tier II</td><td rowspan="2">Tier III</td></tr>
<tr><td>III</td></tr>
</table>

* A zero indicates that there was no intersection between potential project areas and STIP project.

Figure 4. Ranking of potential project areas based on State Transportation Improvement Program projects.

Potential Project Area Ranking based on Land Ownership Conservation Potential (LOCP)

A simplified decision matrix was also used to evaluate and rank potential project areas based on the land ownership composition of the region within one mile of potential project areas. Rankings of land ownership types were provided by advisory group members (Williamson et al. 2009). This decision matrix was designed to evaluate land ownership influence on potential project areas. The matrix takes into consideration potential project area rank and land ownership conservation potential value to determine the added opportunity tier value presented by favorable land ownership. Tier I project areas have a high need for mitigation based on road kill density and a high potential for mitigation based on land ownership conservation potential. Tier II and Tier III project areas have relatively decreasing need and potential for mitigation based on the same criteria (Fig. 5).

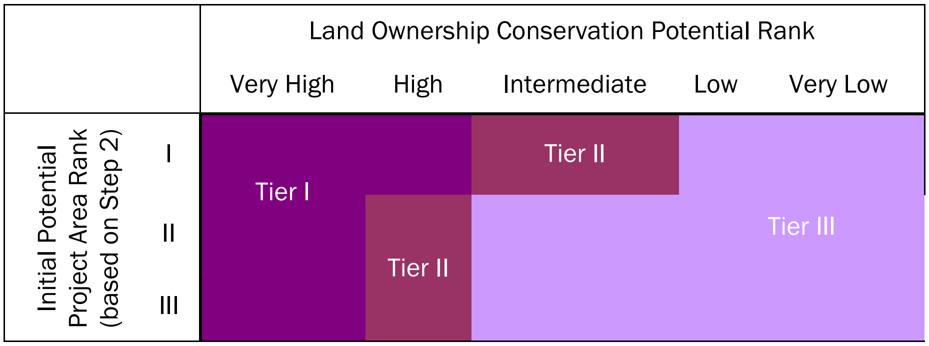


Figure 5. Ranking of potential project areas based on Land Ownership Conservation Potential.

Results

The major findings of the assessment include:

- One hundred and ten high road kill concentration areas were identified in western Montana based on a Montana Department of Transportation animal carcass database, broken into ungulate, focal species, and focal carnivore subgroups.
- Twenty-nine potential project areas were identified for prioritization; these include ungulate or focal species high concentration areas located in a very high or high wildlife linkage area.
- Nine potential project areas were identified in close proximity to a State Transportation Improvement Program project with high potential for wildlife mitigation.
- Ten potential project areas were identified as having high land ownership conservation potential.
- Three potential project areas had both high value State Transportation and Improvement Program projects and high land ownership conservation potential

As outlined in the methods, the analysis provided three sets of results: 1) an analysis of high road kill concentration areas, 2) the intersection of these areas with priority wildlife linkages, and 3) a ranking of potential project areas based on highway projects and land ownership. The results of each of these steps are detailed below. The results, as they pertain specifically to prioritization needs for western Montana highway mitigation, are provided in detail in the full report.

Step 1: Defining road kill high concentration areas.

There are 27,979 records of species-of-interest road kill that were located in the western Montana study area (Table 1). Roughly 99.4% of the records were included in the ungulate analysis, 4.4% in the focal species analysis, and 0.6% in the focal carnivore analysis.

Ungulates

The total number of ungulate road kill recorded in the study area was 27,813. Of these records, 26,730 were mule or whitetail deer (>96% of the ungulate subset, 93% of all road kill reported in western Montana). There were 66 areas identified as having a high concentration of ungulate road kill events. The number of observed road kill records contained in these areas ranged from 17 to 808. These areas of high concentration cover 303 km of roads, 3.8% of the total length of transportation routes in western Montana.

Focal Species

There were 1249 focal species road kills reported. An annual average of 250 collisions occurred with focal species with a range of 203 to 302 records per year. We identified 25 areas where a high concentration of focal species road kill occurred. Within these areas, records ranged from a minimum of 3 to a maximum of 75. The total length of the road within areas is 95.5 km, 1.2% of the total length of the transportation routes in western Montana.

Focal carnivores

The subset of focal carnivore species had 166 road kill events in five years. The analysis identified 19 areas where a high concentration of road kill involving focal carnivores occurred. These areas ranged from 2 to 5 observed records each. The total length of the road contained in these areas equaled 75 km, representing less than 1% of the road network.

Common Name	# of Records in Database	Species Groups		
		Ungulate	Focal	Focal Carnivore
Bighorn sheep	50	X	X	
Bison	4	X	X	
Black bear	97		X	X
Bobcat	7		X	X
Deer, unknown sp.	114	X		
Elk	738	X	X	
Gray wolf	5		X	X
Grizzly bear	2		X	X
Moose	172	X	X	
Mountain goat	4	X	X	
Mountain lion	22		X	X
Mule deer	6271	X		
Pronghorn antelope	115	X	X	
Red fox	33		X	X
White-tail deer	20,345	X		
Total Records by Group		27,813	1249	166

Table 1. Road kill analysis species subgroups.

Step 2: Potential project areas as defined by high road kill concentration areas with "very high" and "high" wildlife linkage values.

Spatial Relationships

Ungulates: Of 66 ungulate high concentration areas, 48 intersect with a wildlife linkage area. Almost half of these (23 HCA) occurred in a very high or high linkage.

Focal Species: Of 25 focal species high concentration areas, 21 intersect with a wildlife linkage area. A third of these (7 HCA) occurred in a very high or high linkage.

Potential Project Areas

A total of 29 potential project areas were identified and ranked in tiers: 0 Tier I, 13 Tier II and 16 Tier III. The potential project areas are illustrated in Figure 6.

Step 3: Added Opportunity Areas based on STIP and LOCP*.*

Added Opportunity Areas: Statewide Transportation Improvement Program Projects

Of the 29 potential project areas, nine intersected STIP project areas. A Tier I added opportunity ranking was attributed to six of the 29 potential project areas. All six Tier I added opportunity areas intersected a STIP project with a "high" STIP scope value. Three potential project areas received a Tier II added opportunity ranking. All three Tier I added opportunity areas intersected a STIP project with a “moderate” STIP scope value. The remaining 20 potential project areas were given a Tier III added opportunity ranking since they did not intersect any STIP projects.

Added Opportunity Areas: Land Ownership Conservation Potential.

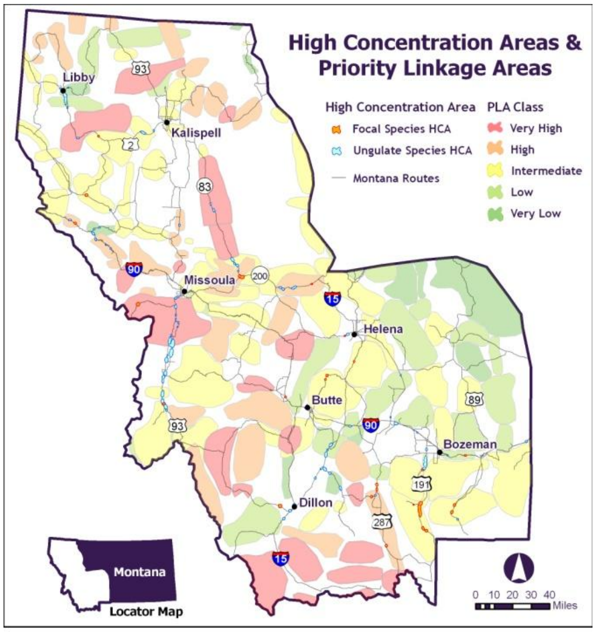
We identified six potential project areas in western Montana that had a Tier I added opportunity ranking based on a “very high” percentage of favorable land ownership within a one mile buffer of the defined area. Four potential project areas were attributed a Tier II added opportunity ranking based on a “high” percentage of favorable surrounding land ownership. The remaining 19 potential project areas received a Tier III added opportunity value based on surrounding land ownership composition with an “intermediate”, “low” or “very low” conservation potential.

Discussion

Analysis considerations

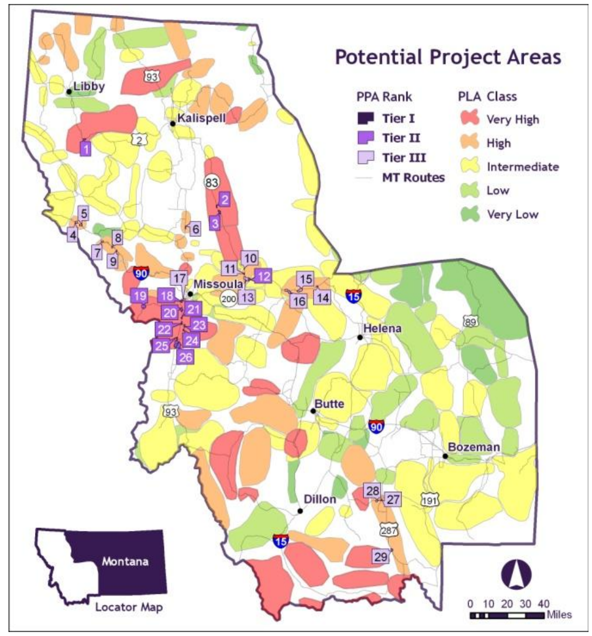
There are several issues that should be recognized when considering the methods used in this project. As with any analysis, it is vitally important to understand the limitations of the datasets being used. The road kill high concentration areas identified in Step 1 were based solely on the existing MT Department of Transportation (MDT) carcass database. The MDT carcass data, while collected over a relatively long period of five years, was not systematically collected. Due to variation in procedures and collection intensity within the study area, the database is opportunistic in design and has inherent limitations. Data gaps were identified in various locations in the study area. Overall, a species collection bias is assumed because MDT personnel are mandated to only remove road kill that pose a threat to the traveling public. Additionally, sensitive species are at times collected by the state wildlife agency, not MDT. Ideally, we would have combined datasets from the multiple agencies that play a role in animal carcass documentation in western Montana. However, due to time constraints and the lack of a central database of carcass information by the other agencies, creating an optimized data set was not possible in the project’s timeframe. To account for these constraints, we relied on the large sample size in the database, over 27,000 records, to help relieve the inconsistencies in data collection. Because of the limitations of the road kill data set, the high concentration areas were also not relied on as a sole indicator of wildlife movement. To strengthen the analysis, we used the priority wildlife linkage data rather than to rely on road kill concentration patterns for this need.

The twenty-nine potential project areas identified in Step 2 are locations where the road kill high concentration area results overlap with either “very high” or “high” ranked wildlife linkage areas. These potential project areas were categorized into three tiers to prioritize where conservation action may be most effective and essential. However, because the underlying data includes high road kill concentration areas and the highest priority wildlife linkages, all of the potential project areas identified should be considered important for potential mitigation measures. Sites with an ungulate species concern are, however, likely to have higher levels of road kill incidence and therefore may be of greater interest to agencies and organizations where human safety is a primary concern. Other data, especially empirical data, may be available for select sensitive species for overlay with the road kill high concentration areas. If future analyses were to be conducted, we suggest that these data be included in the GIS analysis. Embedding or combining disparate data sets, however, is time consuming and may greatly extend the time period needed to provide prioritization products.



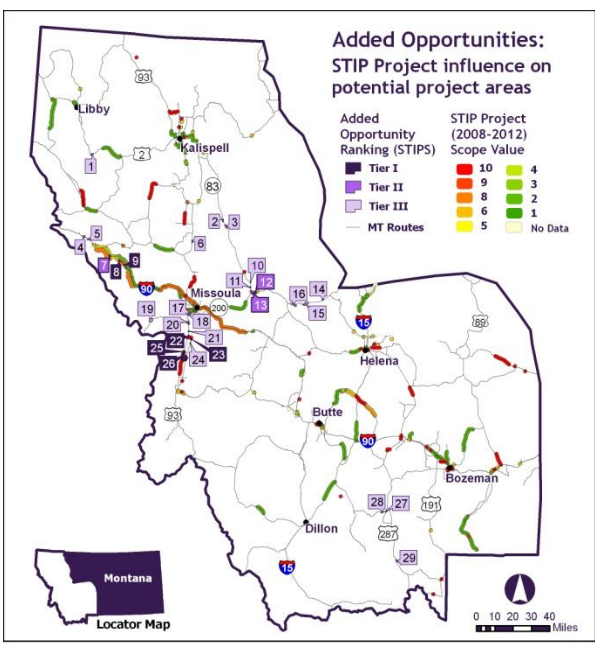
Step 1 Results:
Ungulate Species and Focal Species Road Kill High Concentration Areas.

Note: Linkages are displayed underneath but were not considered in the analysis until Step 2.

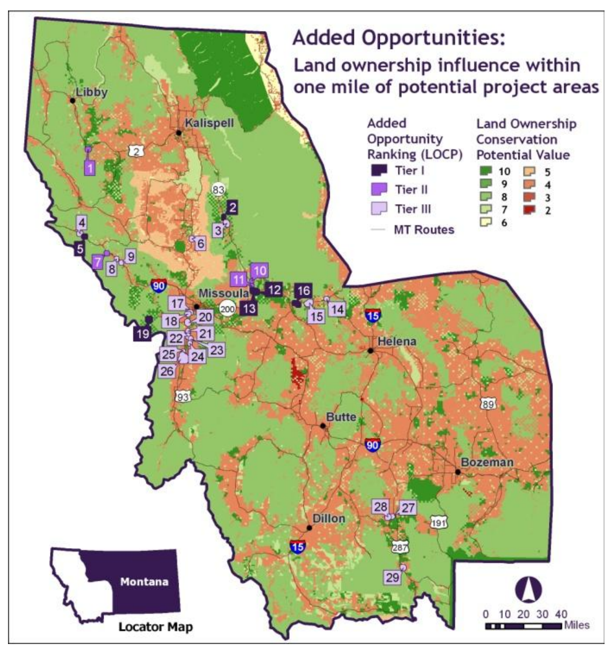


Step 2 Results:
Tier I, II, & III Potential Project Areas based on intersection of Ungulate Species and Focal Species Road Kill High Concentration Areas with highest priority linkage areas.

Note: All wildlife linkages are displayed on map but only "very high" and "high" linkages were considered in determining the potential project areas and consequent tiers.



Step 3a Results:
Potential Project Areas in Tier I, II, & III rankings based on State Transportation Program projects.



Step 3b Results:
Potential Project Areas in Tier I, II, & III rankings based on Land Ownership conservation Potential.

Figure 6. Four map series illustrating prioritization results from analysis steps 1 – 3.

It is important to recognize that the added opportunity areas (Step 3), that are based on the State Transportation and Improvement Program and the Land Ownership Conservation Potential index, are designed to provide additional information for the prioritization process, but not to act as dictating criteria. It should not be inferred that the existence of a STIP project or high value LOCP is required for prioritizing a wildlife mitigation area. The presence of a highly valued STIP project may make highway-based mitigation easier to achieve, but we recognize that other areas without a planned STIP project may be more important for protecting wildlife movement or improving human safety. In these cases, projects can be nominated for mitigation work through the STIP process. The same is true for the Land Ownership Conservation Potential index. While the LOCP was designed to highlight areas where the costs of conservation (in terms of dollars and political capital) may be less, there may be areas with low LOCP values that, due to importance for wildlife, are prioritized.

We found the STIP to be a useful tool for prioritizing areas, especially in the short term, due to the fact that a MDT transportation-related project already exists. Upon discussing the STIP with MDT however, we learned that the projects included in the program are not guaranteed. In MT and most likely in many other states, these projects are provisional and, due to a variety of factors, some projects may not make it to completion.

GIS Techniques

The use of kernel density estimate (KDE) was appropriate in the western MT analysis because it was applied across a large geographic region. KDE spreads density values over a newly created surface, enabling the user to visualize where a high concentration of underlying points occurs, but may not be exactly spatially coincident with the underlying points. For example, where there are many road kill events along a curve in the road, the highest density illustrated will be inside the area defined by the curve. This could result in the appearance of a high concentration of road kill events slightly away from rather than directly on the road. A similar issue arises when road kill events occur near intersecting roads or on roads that are adjacent to one another. Finally, the KDE outputs a relative density value for each cell. Therefore, the user cannot read the density surface such that one color represents an absolute number of underlying road kill events, only that a color represents a density category ("high" to "low"). Of the areas that are displayed as belonging to the same category, it is not possible to determine which has a higher value. For single road networks or across a smaller area (fine scale), we recommend a set of potentially more sophisticated cluster analysis tools, such as those imbedded in CrimeStats (Levine 2007). We used percent volume contour to calculate the desired percent of overall density volume using the center of the grid cells rather than the grid cell as a whole. As a result, the polygon products can be smaller than the input grid cells, suggesting a finer resolution than is attainable given the underlying grid. A 500 meter buffer was added around each area defined by the PVC to address this issue. Buffering the PVC results, to some extent generalizes the resulting high concentration areas. This reduces the potential for product users to misinterpret areas identified in this section as point locations necessitating mitigation. An additional benefit to buffering polygons is that it encourages the user of the results to consider more of the surrounding landscape when investigating the need for mitigation.

The Assessment as a Planning Tool

A guiding principle of this project was to utilize a rapid and collaborative process to create a planning tool that could be used by American Wildlands and by other organizations and agencies. This type of assessment is a useful prioritizing method for determining areas which warrant activity and protection. As such, this assessment fulfils a variety of planning needs. American Wildlands will use the report for internal planning by using the results, along with other information, to determine the most important and appropriate areas for focusing our program efforts. Through this prioritization process, we strengthened AWL's internal programmatic planning and improved coordination and communication with our partners. The assessment is also useful as an external planning and coordinating tool for our partners and regional agencies. This effort will help foster better cooperation and coordination between wildlife and highways entities throughout the region.

This assessment was not designed to identify exact areas deserving wildlife mitigation, but rather as an overarching planning tool to target areas warranting increased focus. In those areas, further information regarding specifics of wildlife movement and linkage opportunities is required. This is especially true due to the opportunistic nature of the road kill database, limited road kill data for threatened, endangered and sensitive species, and the regional scale of the wildlife Priority Linkage Assessment data. In areas where enough collective information is already known regarding wildlife movement and the transportation routes, action could be taken quickly. However, due diligence about wildlife and habitat conditions in each of the potential project areas and/or the other high concentration areas is essential. Additionally, the working group discussed alternative ways of viewing the information, especially in terms of MDT's State Transportation Improvement Program projects. Although locations with added opportunities due to an existing

STIP project were identified, there are many sites in western Montana currently not identified in the STIP which may be well suited for future projects.

While this assessment provided a focused list of potential project areas it also set the stage for capacity and policy improvements within the participating agencies. Through the identification of data gaps and planning hurdles between the agencies the group members were better able to propose new ways to improve interagency coordination. Following the preliminary results of the analysis, the advisory group agreed to work towards a series of process-based next steps. These steps are designed to: 1) improve road kill data collection, and 2) increase cooperation between agencies and organizations on wildlife- transportation issues. They include: setting up an interagency "Montana Wildlife Linkage and Highway Safety Committee;" conducting an advisory group-based prioritization based on individual member organization capacity analysis in conjunction with report findings; and designing an inter-agency centralized road kill database (building off other state database models, such as Idaho's). This level of agreement and the development of next steps highlight the value of this process as a consensus building tool.

Conclusion

This rapid assessment process can be adapted by others to prioritize transportation and wildlife mitigation efforts as well as improve coordination between parties with varied interests and management directives. The ability to complete a draft document in just one year is one of the most valuable aspects of this project. Since this process was centrally driven by dedicated staff at an organization separate from the partner agencies and organizations, the speed of the assessment was greatly increased. This efficiency results in data products that are relevant and timely which, in turn, translate into improvements in policy, data management, and on the ground results. To be successful it is critical that there be sufficient representation from the main parties involved in the issue. Allowing these partners to help direct the analysis process increases the likelihood that the results and products will be internalized into agency policy and actions.

To support improved planning processes, and help ensure that this analysis is fully utilized by the partner agencies, American Wildlands worked closely with working group members to define and then create products that best fit the varied needs of the members. These products include data layers used in the analysis that can be incorporated into internal planning efforts by individual agencies. To effectively convey the results of each analysis step we produced a series of maps that summarize the results. These maps serve as a quick reference for managers and planners as they plan and design projects. We also created short summaries and maps for the 29 potential project areas that were identified for prioritization. We are encouraging broad use of this analysis by packaging the entire process in a comprehensive report and by providing these products in digital form on the internet. Through an inclusive, responsive and data driven process we have created a planning resource and process that is not only useful in western Montana but can serve as a model for others looking to conduct a similar analysis.

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Biographical Sketches

Julie Betsch has 8 years of field experience in wildlife and conservation biology with an emphasis on employing non-invasive methods to study large carnivores. Most recently she was employed as a GIS analyst at American Wildlands, where her efforts focused on wildlife connectivity issues in the northern Rockies. She earned a B.S. in Biology from the University of Cincinnati and is currently an NSF IGERT trainee and PhD student at the University of Montana.

Sarah K.F. Olimb coordinated the geospatial and statistical analyses at American Wildlands from 2006-2009. Since 2003, she has used Geographic Information Systems to guide and strengthen conservation research in the Northern Rocky Mountains, Northern Great Plains, and Southern Appalachia. She has a Masters of Biology from the University of North Dakota (2006) and a B.S. in Population and Conservation Ecology from the University of Georgia (2003).

Dylan W. Taylor works on wildlife habitat connectivity and transportation issues at American Wildlands. He has 10 years experience in conservation policy and wildlife biology in the Rocky Mountains. In addition to his current efforts in Montana, he has worked on transportation and wildlife movement research and advocacy in Banff National Park in Canada, on the Bridger-Teton National Forest in Wyoming, and in the Vail Pass section of Interstate 70 in Colorado. Dylan received a B.A. in Environmental Studies at the University of North Carolina, Wilmington (1994), and a Masters of Forestry at the Yale School of Forestry and Environmental Studies (2002).

Elizabeth Williamson is currently responsible for coordinating the science, policy and partnership aspects of American Wildlands' *Safe Passages* program. Since 2001, she has been working on habitat connectivity and corridors issues as they pertain to the U.S. Northern Rockies. Much of her work has focused on regional and landscape identification of wildlife corridors using Geographic Information Systems. She has a MSc. in Land Resources and Environmental Sciences from Montana State University and a B.A. in Geography from the University of Vermont.

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USING NONINVASIVE GENETIC SAMPLING METHODS TO ASSESS THE VALUE OF WILDLIFE CROSSINGS FOR BLACK AND GRIZZLY BEAR POPULATIONS IN BANFF NATIONAL PARK, ALBERTA, CANADA

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Abstract

The section of the Trans-Canada Highway (TCH) that bisects Banff National Park, Alberta supports the highest volume of traffic of any road in the North American national park system and is also the location of one of the most extensively-studied systems of wildlife crossing structures in the world. Wide-ranging carnivores, such as grizzly (*Ursus arctos*) and black bears (*U. americanus*), are vulnerable to road mortality and habitat fragmentation caused by roads such as the TCH. In order to mitigate these negative impacts on wildlife, 23 crossing structures have been constructed across the TCH. Over twelve years of intensive study of these wildlife crossings has shown they reduce mortality and maintain wildlife movements. Track pads have recorded both bear species crossing the TCH on 1764 occasions, but the number of different individuals using the crossings, their genders and the demographic and genetic benefits of the crossings for populations remain unknown.

In 2004 and 2005, a pilot study was conducted at two of the crossing structures to evaluate the feasibility of using a barbed wire hair-sampling system to determine the number of individual male and female grizzly and black bears using the wildlife crossings. Based on the results of that pilot study, a three-year research project was initiated in 2006 to assess the conservation value of wildlife crossing structures for grizzly and black bear populations in the Bow Valley of Banff National Park. The hair sampling system was installed at 21 of 23 of the crossing structures to determine the total number of male and female bears using the crossings and the populations of grizzly and black bears in the Bow Valley surrounding the TCH were also sampled using a combination of hair snares and rub tree surveys. The genetic information derived from the hair samples will be used to: assess the effectiveness of different types of crossing structures, estimate the population sizes for both bear species in the Bow Valley, calculate the proportion of the population using the crossings and quantify the level of movement and gene flow across the TCH.

This paper highlights some results from our 3-year evaluation of the demographic and genetic benefits of wildlife crossings for bear populations in Banff National Park. All 3 of the noninvasive genetic sampling methods that we used proved successful at obtaining individual ID's and genders. In 2006, 11 grizzly bears (4 females, 7 males) and 11 black bears (5 females, 6 females) were identified from the samples collected at the crossing structures and 40 black bears (16 males, 24 females) and 63 grizzly bears (37 males, 26 females) were identified from the samples collected from the hair snares and rub trees. A total of 17% (n=11) of all grizzly bears and 25% (n=11) of all black bears were identified using the crossings. The conservation value of wildlife crossings must be assessed at the population level so that biologists and engineers can make informed decisions regarding the incorporation of wildlife overpasses and underpasses in transportation systems.

Introduction

Engineered wildlife crossings are increasingly used by transportation agencies to meet the needs of animals to cross roads with reduced hazard to motorists and wildlife (Clevenger and Waltho 2000; Gagnon et al. 2007). Studies have demonstrated that a broad range of species will use wildlife crossing structures (Foster and Humphrey 1995; Mata et al. 2005) and thus can lead to reduced road mortality for some species (Clevenger et al. 2001; Dodd et al. 2007; Huijser et al. 2007). One would intuitively expect these measures to enhance the viability of wildlife populations due to an increase in survival.

Until now, research has largely focused on the level of use that crossings receive from a range of wildlife species, with the assumption that the greater the use, the more successful the crossing structure. Questions remain, however, as to whether these measures actually improve population viability and which species might benefit from them. Previous studies have yet to go beyond showing that various species will use crossing structures. But use does not necessarily translate into the flow of genes, viable populations and maintenance of ecological processes that characterize functional connectivity (Crooks and Sanjayan 2006; Hilty et al. 2006; Kindlmann and Burel 2008). Investigation of these factors can provide evidence-based data on whether populations benefit from wildlife crossing mitigation, and thus whether support for the continued and growing implementation of wildlife crossings by transportation and resource management agencies is warranted. Research that addresses these unanswered questions will require new methods that allow assessment of connectivity for populations, communities and ecological processes.

Obtaining empirical data to evaluate population benefits for some species can be problematic. Population-level data can be difficult to obtain because wide-ranging, fragmentation-sensitive species such as bears (*Ursus sp.*), cougars (*Puma concolor*) and wolverine (*Gulo gulo)* typically are elusive and occur in relatively low densities (Weaver et al. 1996). At present, the most reliable method involves live-trapping, marking and closely monitoring the movements of individuals within a population, but for logistical reasons this is impractical. Evaluate whether crossings provide population-level benefits (adult male and female movement across roads; juvenile dispersal, survival and reproduction of offspring) using telemetry studies would require a decade or more of intensively tracking animal movements. This is an inordinately long time for management to wait for answers from research.

Molecular techniques now make it possible to identify species, individuals, their genders, and genetic relatedness from hair samples collected through non-invasive genetic sampling (NGS) methods (Foran et al. 1997; Woods et al. 1999; Long et al. 2008). NGS techniques potentially enable the measurement and analysis of parameters related to the dispersal of individuals, viability of populations and ultimately the maintenance of local and regional biodiversity (Epps et al. 2005; Cushman et al. 2006; Schwartz et al. 2007). Compared to telemetry methods, this technique could provide an efficient, relatively inexpensive, and non-invasive way to acquire critical information regarding genetic interchange facilitated by crossings, in a relatively short period of time, without ever having to capture or see the animal (Kendall and McKelvey 2008). The development of a NGS method that more clearly defines the demographics and genetics of animal movement through wildlife crossings will significantly advance our knowledge of the conservation value of these measures and provide evidence-based support for their future implementation.

We describe a NGS method of obtaining information on potential population-level benefits of wildlife crossings in Banff. Our technique was focused on black bear and grizzly bear populations that were impacted by the TCH in the Banff-Bow Valley. Specifically we describe the study design and preliminary field data from the implementation of the NGS technique on black and grizzly bear populations using data collected at multiple wildlife crossings along the TCH and their populations in the surrounding landscape. Finally, we discuss the added value of non-invasively collected genetic data for conservation and management applications.

Methods

In 2006, the prototype hair-sampling system developed at the wildlife crossings (Clevenger and Sawaya, submitted) was incorporated into a three-year landscape-scale study in Banff. NGS methods were used to obtain information about the bear population that uses the wildlife crossings and occupies the study area. The goal of using these methods was to extract DNA from the hair samples for use in genetic analyses. These analyses would provide an estimate of the number of individual male and female grizzly and black bears that use the crossing structures and that occupy the Bow Valley. The genetic data would also be used to determine relatedness and relationships between individual bears of each species. We used hair traps as described by Woods et al. (1999) and rub tree surveys following Boulanger et al. (2008) to collect DNA from the population of bears in the Bow Valley.

We used the hair-sampling system that was described above to collect DNA from bears passing through the wildlife crossing structures (see Figure 1). A study area boundary was established by creating a 14-km buffer in all directions around the mitigated section of the TCH extending 45 km from the park's east entrance to Castle Junction. Since hair traps for grizzly bear population estimates typically employ a 7 km x 7 km grid (Boulanger et al. 2008) to distribute effort across the region of interest, we chose a 14-km buffer so that we could have a grid that spanned the TCH and allowed for sampling up to two full grid cells away from the highway (Figure 1). The orientation of our grid location was chosen to make our grid continuous with a larger sampling effort to inventory grizzly bears in Alberta conducted by the Foothills Research Institute (G. Stenhouse, in preparation). By following these criteria, we created a sampling grid that straddled the TCH and contained equal numbers of 7 km x 7 km grid cells to the north and south of the highway. We surveyed all trails within the 14-km buffer for the presence of rub trees (Figure 2). We recorded the geographic coordinate of any rub trees located using a global positioning system unit (Garmin® 12XL, Garmin Ltd., Olathe, Kansas) and placed three 30-cm strands of barbed wire on them for future sampling (see Kendall et al. 2008).

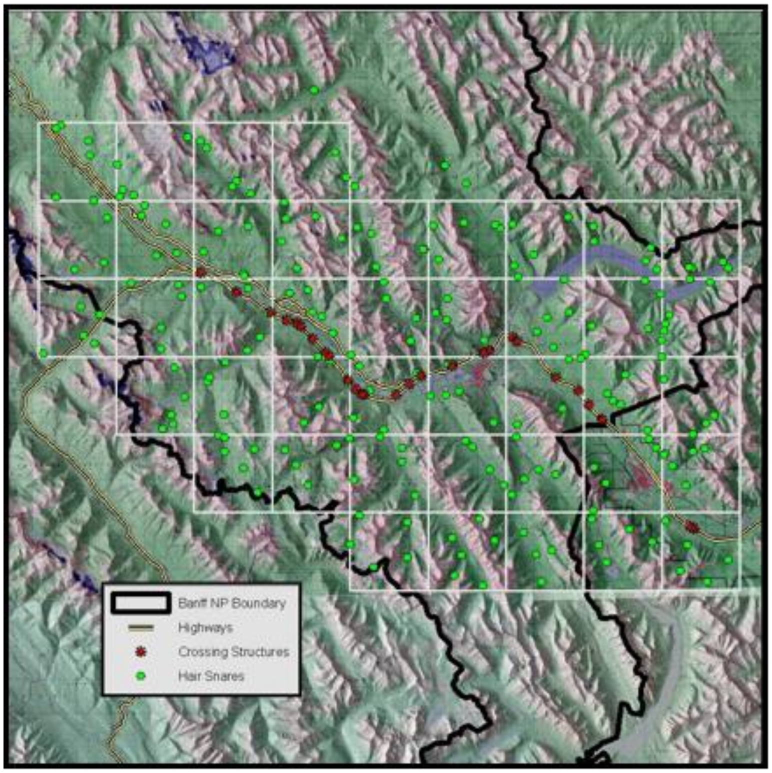

Figure1: Location of hair traps ("hair snares") monitored for non-invasive genetic sampling of black and grizzly bear populations in Banff National Park during 2006 and 2008. Grid cells are 7 km x 7 km.

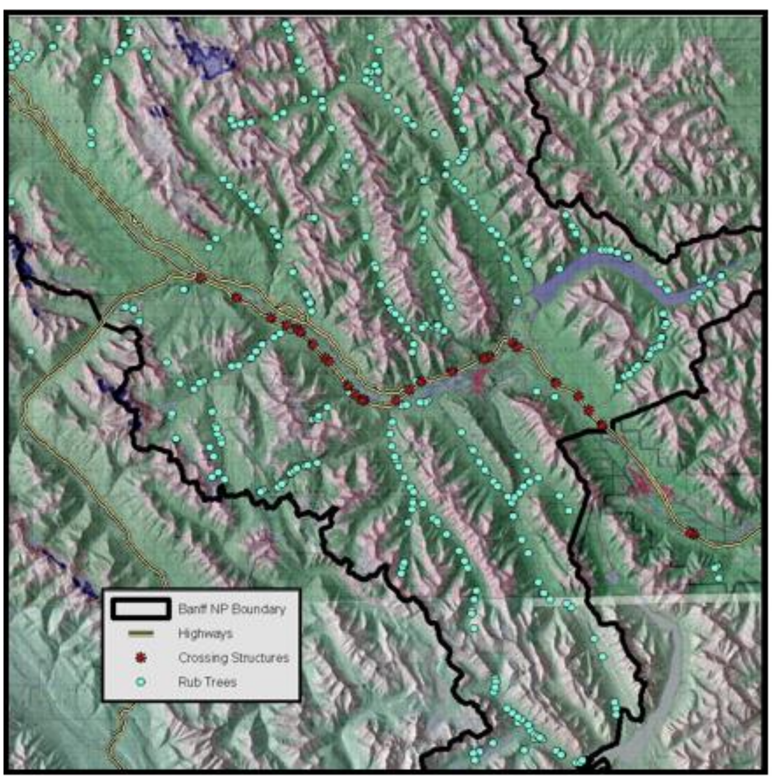

Figure 2: Location of rub trees monitored for non-invasive genetic sampling of black and grizzly bear populations in Banff National Park between 2006 and 2008.

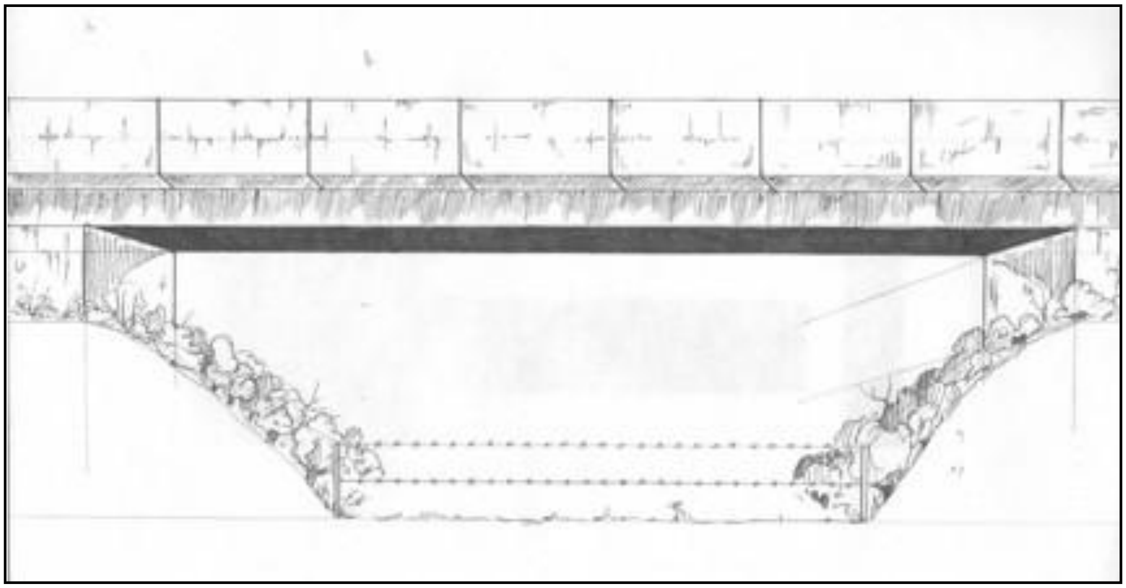

Figure 3: Illustration of hair-sampling system at wildlife underpass in Banff National Park (Illustration by S. Harrison).

In 2006, we monitored 20 of the 23 wildlife crossings using our hair-sampling system. Of the three underpasses not monitored, two were excluded due to high levels of human use (Edith, Buffalo), and the third was excluded because it floods during the summer months (Cascade). Buffalo and Cascade underpasses are rarely used by bears because of their close proximity to the town of Banff (Clevenger and Waltho 2000; Clevenger et al. 2002). Between May 24 and August 11, we deployed hair traps in 37 grid cells during five, 14-day sampling periods. A total of 188 hair-trap sites were set and maintained. Between August 15 and October 15, we monitored 330 rub trees and conducted a minimum of three rub tree surveys per trail segment. Surveys were run on average once every three weeks.

In 2007, we monitored 20 of the 23 wildlife crossings using our hair-sampling system. We chose not to set and maintain any hair trap sites during our second field season due to the high cost and effort associated with running a hair trap grid and the greater potential for bears to avoid hair traps when sampling consecutive years. Between May and August of 2007, we expanded our rub tree monitoring and added an additional 167 rub trees. We monitored a total of 497 rub trees and surveyed every trail segment at least twice between May 25 and October 15.

In 2008, we continued to monitor the 20 wildlife crossings using our hair-sampling system and we also sampled the population using both hair traps and rub tree surveys, as in 2006. We set and maintained 210 hair trap sites between May 24 and August 19. We deployed 42 hair traps in a 7 km x 7 km grid for five, 14-day sampling periods. We monitored 497 rub trees between May 15 and October 15 and we conducted a minimum of three rub tree surveys per trail segment.

Results and Discussion

Sampling Success

In 2006, we collected 352 hair samples from the hair-sampling system at the wildlife crossings, 831 samples from 188 hair traps and 886 samples from 331 rub trees. In 2007, we collected 413 hair samples from the wildlife crossings and 2,795 samples from 497 rub trees (no samples were collected from hair traps since no hair traps were deployed). In 2008, we collected 553 samples from the wildlife crossings, 1,125 samples from 210 hair traps and 2,859 samples from 497 rub trees. The number of samples collected at the wildlife crossings included incidental hair collection from some non-target species such as deer and coyotes.

The percentage of bear crossing events for which we obtained hair samples (hair-sampling success rate) ranged from 47 percent for black bears to 63 percent for grizzly bears between 2006 and 2008 (Table 1). The rate of hair sampling for black bears remained relatively constant, while the rate for grizzly bears declined slightly during the three-year period. Although our hair-sampling system was not designed for cougars or wolves, hair-sampling rates for the two carnivores ranged from 17 percent to 56 percent.

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2006	Crossing events	Number of events with >1 sample collected	Percent hair-sampling success
Grizzly bear	85	54	63%
Black bear	126	60	47%
Cougar	48	16	33%
Wolf	138	77	56%
2007			
Grizzly bear	78	39	50%
Black bear	60	29	48%
Cougar	54	9	17%
Wolf	185	73	39%
2008			
Grizzly bear	148	83	56%
Black bear	74	37	50%
Cougar	98	21	21%
Wolf	332	96	29%

Table 1: Hair-sampling success rate for large carnivores at Banff wildlife crossings.

Rub trees were more likely to provide hair samples than hair traps (Table 2). During the three-year period an average of 72 percent of the rub trees yielded at least one hair sample, while 48 percent and 49 percent of the hair traps produced samples during 2006 and 2008, respectively. The percentages were calculated as number of sampling units yielding at least one hair sample divided by total number of sampling units.

	Percent hair trap success (N)	Percent rub tree success (N)
2006	48% (188)	67% (331)
2007	N/A	76% (497)
2008	49% (210)	70% (497)
Total	49% (398)	72% (1,325)

Table 2: Hair-sampling success rate at hair traps and rub trees in Banff, 2006–2008.

Summary of Genetic Analysis and Methodology

The DNA amplification success rate varied between 55 percent and 82 percent for black and grizzly bear samples obtained at the wildlife crossings (

Table 3). In 2006, 11 black bears (five females, six males) and 11 grizzly bears (four females, seven males) were identified using the wildlife crossings. In 2007, eight black bears (four females, four males) and 12 grizzly bears (six females, six males) were sampled using the wildlife crossings. These are considered minimum estimates of individuals and genders using the crossings as we were unable to sample hair from all individuals and not all samples were adequate for genetic analysis. Samples collected in 2008 are awaiting analysis. Amplification success rates of hair samples from cougars and wolves ranged from 39 percent to 81 percent. In 2006, three wolves (one female, two males) and one cougar (male) were identified, whereas in 2007 a total of five wolves (four females, one male) and three cougars (males) were identified using the crossings.

2006	Number of samples collected	Number of samples to individual[1]	DNA amplification success rate	Total number of individuals	Number of females	Number of males
Black bear	94	64	68%	11	5	6
Grizzly bear	110	69	63%	11	4	7
Cougar	23	9	39%	1	0	1
Wolf	92	40	43%	3	1	2
2007						
Black bear	55	45	82%	8	4	4
Grizzly bear	198	109	55%	12	6	6
Cougar	16	13	81%	3	1	2
Wolf	107	65	61%	6	4	1

[1] Total number of samples that could be identified to an individual.

Table 3: Results of non-invasive genetic sampling of large carnivores using wildlife crossing structures in 2006 and 2007. These numbers are minimum counts as not all individuals left adequate samples for genetic analysis. Samples from 2008 are pending analysis.

In 2006, 29 grizzlies and 40 black bears were identified from the hair trap samples and 53 grizzlies and four black bears were identified from the rub tree samples. The total number of individuals identified at the crossings, hair traps and rub trees combined (there was substantial overlap among sampling methods) was 66 grizzlies and 43 black bears. A total of 17 percent (n=11) of all grizzly bears and 25 percent (n=11) of all black bears were identified using the crossings with our hair-sampling system. The 2007 data are not readily comparable to 2006 data and not summarized since no hair traps were deployed in 2007 and the size of the sampling area changed slightly between years.

Our hair-sampling system using two strands of barbed wire was effective at obtaining hair samples from not only our target bear species, but also cougars and wolves. The preliminary results of our population-level study showed that we were able to extensively sample black and grizzly bears at the wildlife crossings (Figure 4) and the greater population (hair traps and rub trees) using NGS methods. Nearly 10,000 hair samples were collected during the three-year study (not all samples were sent to the genetics lab for analysis), demonstrating the efficacy of the methods at sampling the target populations. We did not analyze all the rub tree samples in 2007 and 2008 because the 2006 rub tree data showed that a high proportion of samples collected from a given tree were identified as the same individual. Kendall et al. (2008) found similar results at rub trees in Glacier National Park, Montana.

We derived individual identifications and determined genders from samples collected from all three sampling methods. Although our hair-sampling success rate for grizzly and black bears was approximately 50 percent, our sampling success rates were also respectable for non-target cougars (33 percent) and wolves (56 percent). Hair-sampling success of grizzly bears at the wildlife crossings declined from 2006 to 2008, despite our efforts to maximize hair collection at each of the crossings. Our camera data showed that each successive season, grizzly bears, in particular, made increasing attempts to avoid the barbed wire. Such avoidance tactics included jumping over the wire and stepping on and pushing down the upper wire. Black bear hair capture success at the wildlife crossings was constant during the three-year period. The lower hair- sampling success rate for black bears is likely due to their smaller size and ability to avoid rubbing the wire. Among hair traps and rub trees, our results indicated that hair-sampling success was greater at rub trees compared to hair traps. In the only other study where hair traps and rub trees were sampled simultaneously, Kendall et al. (2008) found the opposite, that hair traps consistently yielded more samples than rub trees.

Figure 4: Grizzly bear passing through hair-sampling system on one of the wildlife overpasses in Banff.

Spatial and Temporal Patterns of Hair Collection at Wildlife Crossing Structures

Twelve years of monitoring at Banff's wildlife crossings has revealed a number of spatial and temporal patterns of use by a variety of large mammal species. An examination of spatial patterns is important to the understanding of the relationship between crossing structure types and crossing structure preferences, while an examination of temporal patterns of use is important to the understanding of when and why animals cross the road. Since our track pad monitoring has revealed some interesting spatial and temporal patterns of use, we compared the detections from track pads to the detections from DNA analysis of hair samples to see whether those patterns are reflected in our hair sampling collection. A direct comparison of track pad data to hair sample data provides cross-validation between the methods and allows us to determine if the sample is representative in space and time for bears using the crossings.

Spatial Pattern of Hair Sampling and Track Detections

Data from black bears were collected at the wildlife crossing structures using track pads and hair collection methods. During the 2006 and 2007 field seasons, we detected 178 black bear crossing events using track pads, and collected at least one hair sample from 71 (40 percent) of those crossings (Figure 5). For the two years of data that we have been able to analyze, black bear hair collection was highly correlated with the black bear track detections ($r2=0.87$). The distribution of black bear hair sample collection was strikingly similar to distribution of black bear track detections. Black bear track detections occurred at 15 wildlife crossing structures, while hair samples were obtained from 14 crossing structures. The majority of track detections and hair samples were obtained at the Duthil (DH) wildlife underpass. Track detections were highest at Duthil and Powerhouse (PH) underpass. Like track detections, hair samples were obtained from a wide geographic range of wildlife crossings, from the east gate almost to Castle Junction

(Copper) and covering nearly 45 km.

Similar to black bears, grizzly bear hair collection was highly correlated with grizzly bear track detections (r2=0.99). During 2006 and 2007, we detected 211 grizzly bear crossings and collected at least one hair sample from 86 (41 percent) of those crossings (Figure 6). The distribution of grizzly bear hair samples was strongly correlated to the distribution of grizzly bear track detections (Figure 6). Grizzly bear track detections occurred at 13 wildlife crossing structures, while hair samples were obtained from only four crossing structures. The majority of track detections and hair samples came from three crossing structures: Redearth overpass (REOP), Wolverine overpass (WOP) and the Healy wildlife underpass. Track detections were highest at these three crossing structures, as were grizzly bear hair sampling events. Unlike track detections that were obtained from a wide geographic range of wildlife crossings, hair samples were obtained from a limited number of wildlife crossings.

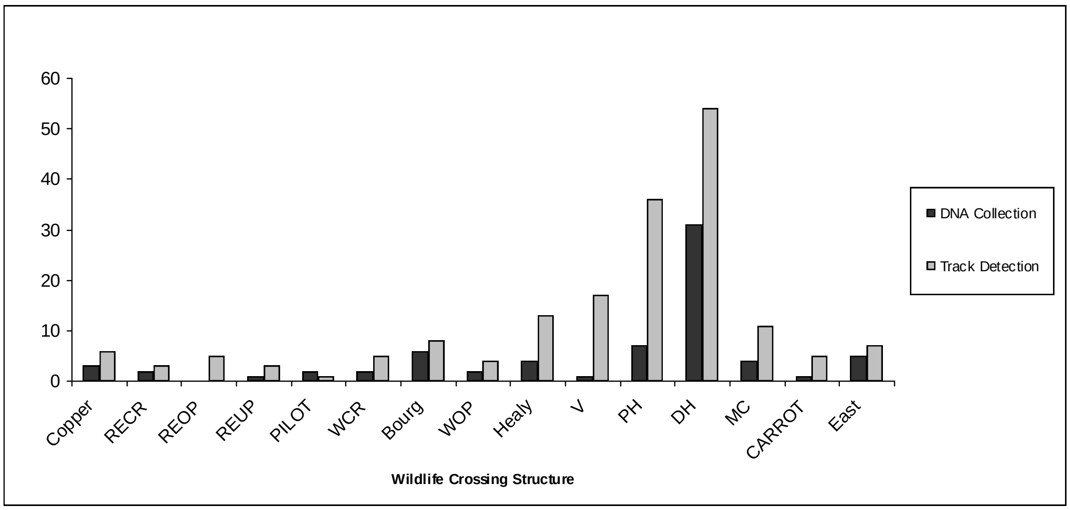

Figure 5: Correlation of black bear detections from tracks and collection of hair samples with black bear DNA at wildlife crossing structures, 2006–2007. Only crossing events that produced species identification and individual identification from hair samples were included in results. Many crossing events resulted in the collection of multiple samples from the same individual and some individuals were detected at the same wildlife crossing on multiple occasions. Crossing structures are ordered from West (left) to East (right).

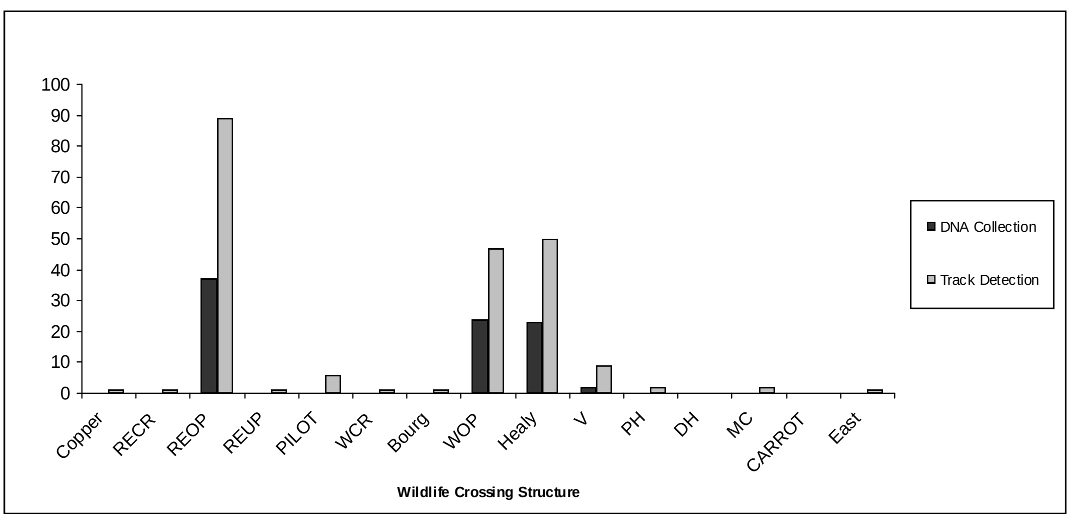

Figure 6: Correlation of grizzly bear detections from tracks and collection of hair samples with grizzly bear DNA in 2006–2007. Only crossing events where hair samples produced species identification and individual identification were included in results. Many crossing events produced more than one

sample that assigned to the same individual and some individuals were detected at the same wildlife crossing on different dates. Crossing structures are ordered from West (left) to East (right).

Temporal Pattern of Hair Sample Collections

The collection of hair samples from bears using the wildlife crossings was strongly associated with the month of the year (Figure 7). Hair sampling occurred from May to October. We analyzed hair collection data from 2006 and 2007. The temporal pattern of black bear and grizzly bear hair collection was strikingly similar. The peak of black bear and grizzly bear hair collection occurred in June and July. The similarity between species and timing of the peak could be explained by the fact that bears are searching widely for both food and mates during these months of the year. The mating season for grizzly and black bears occurs between June and July and high-quality forage and spring foods are most abundant in the valley bottom montane habitat during these months. As summer progresses bears tend to leave the valley bottom habitats and move higher up in the mountains to forage on newly emergent vegetation. We suspect that as bears spend more time in the valley bottom habitat there is greater likelihood that they will also need to cross the TCH via wildlife crossing structures.

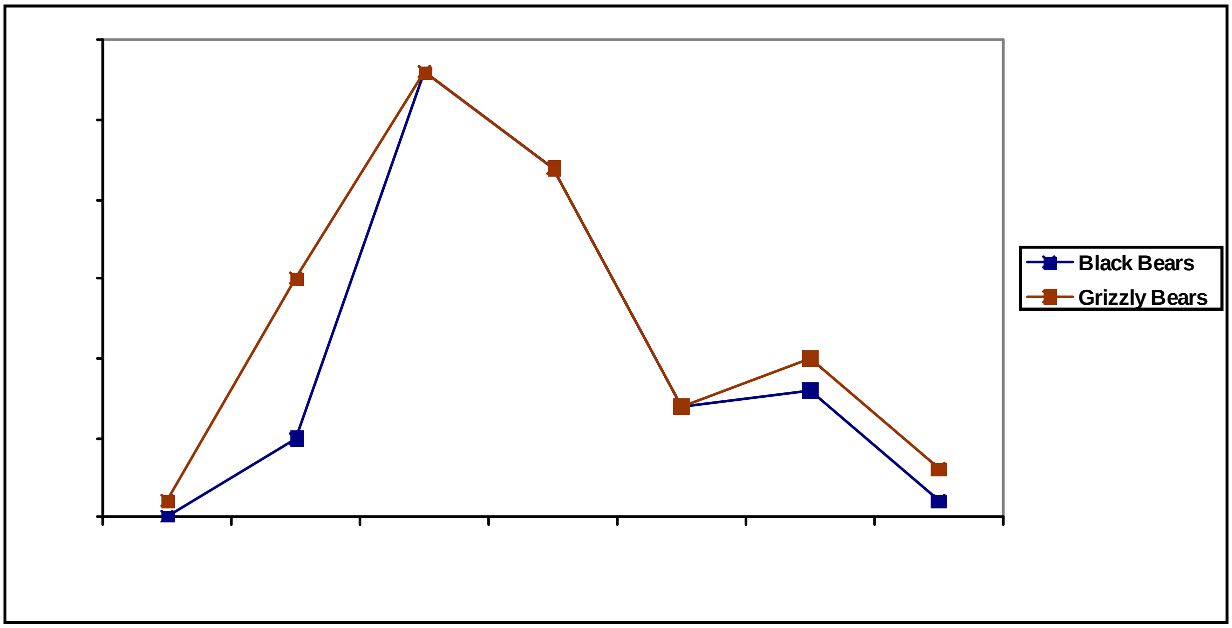

Figure 7: Number of crossing events per month with collection of bear DNA at hair sampling system at wildlife crossings in Banff during 2006–2007. Only crossing events where hair samples produced species identification and individual identification were included in results. Many crossing events produced more than one sample that assigned to the same individual and some individuals were detected at the same wildlife crossing on different dates.

Individual Use of Wildlife Crossing Structures

Twelve years of monitoring at Banff's wildlife crossings has revealed a number of spatial and temporal patterns of use by a variety of large mammal species, but a deeper understanding of individual use is necessary to interpret what these patterns really mean for individuals and populations. We must quantify the variability and distribution of use between individuals in order to fully assess the merits of different crossing structure types.

The mean number of bear crossings per individual identified through DNA analysis was 5.46 for black bears and 6.14 for grizzly bears (
Table 4). There was more variability in the number of crossing events per grizzly bear individual than per black bear individual (range=1–17 vs. range=1–25, SE=1.73 vs. SE=1.53).

	Black bears	Grizzly bears
Mean	5.46	6.14
Standard Error	1.53	1.73
Median	4.00	3.50
Minimum	1	1
Maximum	17	25
Total crossings	71	86
Number of bears	13	14

[1] Hair samples produced individual ID and gender information.

Table 4: Descriptive statistics for number of crossings per individual bear detected through DNA analysis of hair samples collected at wildlife crossings during 2006–2007.

The frequency of bear crossings by individual males and females detected from hair samples helps explain how many individuals contributed to the total number of crossing events. It is of interest to know how that frequency is distributed between gender classes. Among black bears, two individuals were detected in a high proportion of crossing events (**Figure** 8). Since DNA collection was highly correlated with track detection, we can speculate that one male and one female black bear were responsible for the majority of wildlife crossings detected by DNA analysis. Since it is impossible to obtain age information from DNA, we cannot infer too much about the distribution of individual bear use at crossings until we correlate the DNA data with the remote camera data to determine age classes of individuals. Bear use of crossings may be a function of age, or social and reproductive status, and without knowing the age of an animal, we are unable to know about the other conditions. Cubs of the year are small, which should make them more difficult to detect with our hair sampling system, thus resulting in underestimating their use of crossing structures.

Among black bears, two individuals were detected in a high proportion of crossing events (Figure 8). Since hair collection was highly correlated with track detection, we can speculate that one male and one female black bear were responsible for the majority of wildlife crossings detected by DNA analysis.

One male individual was detected in a high proportion of grizzly crossing events (Figure 4.9). Because hair collection was highly correlated with track detections, we can speculate that one male grizzly bear was responsible for the majority of wildlife crossings detected by DNA analysis. As was the case with black bears, at this point we cannot infer too much about the distribution of individual grizzly bear use at crossings until we correlate the DNA data with the remote camera data to determine age classes of individuals. Similar to black bears, grizzly bear cubs of the year are small, making them more difficult to detect with our hair sampling system, which could result in underestimating their use of crossing structures.

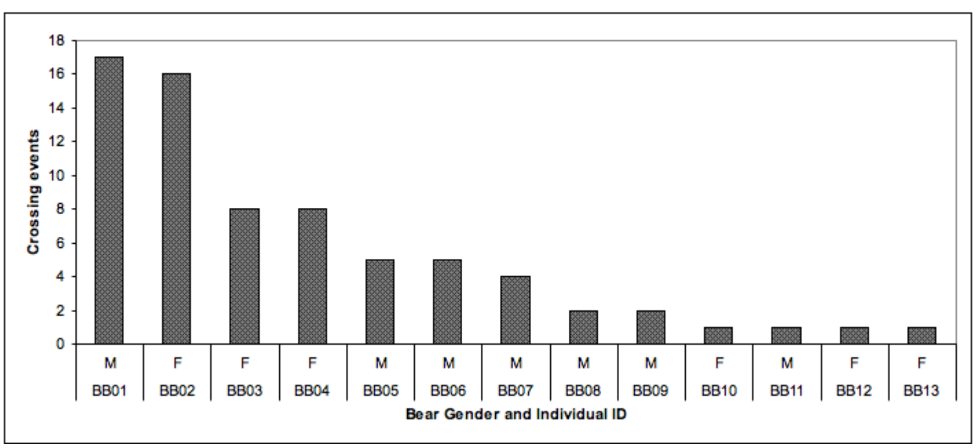

Figure 8: Frequency of black bear passages by each male (M) and female (F) individual detected from hair samples collected at wildlife crossings in Banff during 2006–2007.

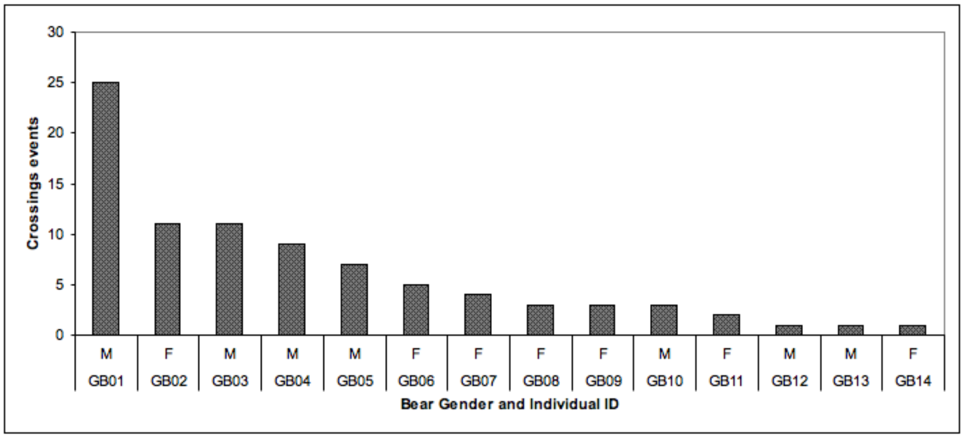

Figure 9: Frequency of grizzly bear passages by each male (M) and female (F) individual detected from hair samples collected at the wildlife crossings in Banff during 2006–2007.

Applications

The genetic data gathered from our hair-sampling system has added greatly to our knowledge of the number and gender of individual bears, cougars and wolves that use the Banff wildlife crossings to move across the TCH. However, the potential applications for management have yet to be realized. The genetic data collected from the three hair-sampling methods we employed could have other applications for the conservation and management of wildlife populations. The data could be used to monitor and estimate population size (Banks et al. 2003; Piggot and Taylor 2003; Pearse and Crandall 2004), develop species occupancy models (MacKenzie et al. 2006; Pearce and Boyce 2006; Long et al. 2008), calculate migration rates (Manel et al. 2005; Dixon et al. 2006) and quantify the degree of genetic population structure (Pearse and Crandall 2004; Proctor et al. 2005; Millions and Swanson 2007). This information could then be used to parameterize population viability and genetics models (Beissinger and McCullough 2002; Hanski and Gaggiotti 2004). Because each hair sample is associated with a geographic coordinate, then crude home range maps can be constructed in cases where the same individual is sampled repeatedly (Taberlet et al. 2003).

Our study examines a non-invasive approach to assess the efficacy of a suite of wildlife crossing structures in restoring demographic and genetic connectivity of black and grizzly bear populations. Similar research questions for management can be addressed at different spatial scales and for different taxonomic classes. Amphibian tunnels and small culverts are often used by transportation agencies to mitigate road effects on herpetiles and small- and medium-sized mammals (Langton 1989; Dodd et al. 2004). These tunnels and culverts are assumed to benefit target populations by reducing mortality and enhancing population connectivity. Many of these species have special habitat requirements, localized populations, and are strongly impacted by road-related mortality (Fahrig et al. 1995, Gibbs and Shriver 2002, Rondini and Doncaster 2002). Obtaining empirical data demonstrating population-level benefits of crossing structures for these species can be less problematic and challenging than for the large, wide-ranging species in our study. We encourage others to test the protocols that we have developed in Banff for similar large-sized mammals or with other taxa that should benefit from the investment of crossing structures.

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Biographical Sketches

Michael Sawaya received a Bachelor of Science in Wildlife Biology at the University of Montana in 1997. For the past eleven years, Mike has been studying bears, cougars and wolves using methods ranging from radio-telemetry to noninvasive genetic sampling. After receiving his BS degree at the University of Montana, he spent three years working on the Greater Glacier Bear DNA Project in Glacier National Park and then spent five years working for the Hornocker Wildlife Institute and the Wildlife Conservation Society on the Yellowstone Cougar Project in Yellowstone National Park. Mike is currently working on his PhD in Fish and Wildlife Biology at Montana State University.

Anthony Clevenger is a senior wildlife biologist at the Western Transportation Institute at Montana State University. In 1996, he was contracted by Parks Canada to carry out longterm research assessing the performance of mitigation measures designed to reduce habitat fragmentation on the Trans-Canada Highway in Banff National Park, Alberta, Canada. Tony is currently a member of the U.S. National Academy of Sciences Committee on Effects of Highways on Natural Communities and Ecosystems. Since 1986, he has published over 40 articles in peer-reviewed scientific journals and has co-authored three books including, Road Ecology: Science and Solutions (Island Press, 2003). Tony has worked as a research wildlife biologist for the World Wide Fund for Nature–International (Gland, Switzerland), Ministry of Environment–France (Toulouse), U.S. Forest Service, and U.S. National Park Service. Tony is a graduate of the University of California, Berkeley, has a master's degree in Wildlife Ecology from the University of Tennessee, Knoxville and a doctoral degree in Zoology from the University of León, Spain.

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THE ECOLOGICAL IMPLICATIONS OF CURED-IN-PLACE PIPE REHABILITATION TECHNOLOGY

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Abstract

Cured-in-place pipe (CIPP) technology is commonly used for pipe rehabilitation, and transportation agencies are increasingly using it to repair damaged pipe culverts. In typical CIPP applications, a lining tube saturated with a styrene-based thermosetting resin is installed into the damaged pipe. Subsequent curing with a heat source results in a pipe-within-a-pipe.

In this study, seven styrene-based, steam-cured CIPP installations in surface water and stormwater conveyances in Virginia were identified and observed over the course of 1 year. Although the sites were not directly linked to sources of drinking water, styrene levels at five sites were higher than the U.S. Environmental Protection Agency's maximum contaminant level for drinking water of 0.1 mg/L. These concentrations were detected at these sites for a minimum of 5 days to at least 71 days after installation. Certain measurements were also found to exceed the LC_{50} values (i.e., the concentration required to kill 50 percent of a study population) for several freshwater aquatic indicator species.

The findings suggest that the elevated styrene levels could have resulted from one or a combination of the following: (1) installation practices that did not capture condensate containing styrene, (2) uncured resin that escaped from the liner during installation, (3) insufficient curing of the resin, and (4) some degree of permeability in the lining material.

A summary of the actions taken by the Virginia Department of Transportation (VDOT) in response to the preliminary findings of this study is also provided in this report. VDOT suspended the use of styrene-CIPP for pipes that convey surface or stormwater while further evaluating CIPP repair and subsequently developing new requirements for these installations.

Introduction

Because many pipes and culverts were placed more than 20 years ago, repair or replacement of damaged or worn pipes is becoming a large maintenance concern in the United States. Cured-in-place pipe (CIPP) rehabilitation is one of several "trenchless" pipe repair technologies that allow users to repair existing underground pipes in place rather than using the conventional method of unearthing and replacing sections of damaged pipe. Trenchless technologies were first developed about 25 years ago and were used primarily in western Europe until about 15 years ago, when departments of transportation and construction outfits in North America began to use them (Lueke and Ariaratnam 2001). In the mid-1990s when the city of Houston, Texas, undertook a major overhaul of its sewer system, contractors used trenchless methods for 87 percent of the repairs, involving millions of feet of pipe line. Of the many trenchless methods available, contractors used CIPP technology significantly more than any other in situ pipe rehabilitation method (Wright 1995). CIPP repair dominates the underground pipe rehabilitation industry (Hoffstadt 2000), and both under- and above-ground CIPP rehabilitation is common worldwide. The CIPP business was pioneered by Insituform Technologies, Inc., which now performs projects for industries and municipalities in 40 countries and for transportation agencies in 36 U.S. states (Insituform 2007).

Despite its widespread and frequent use, little has been investigated regarding the environmental impact of CIPP technology on surface water or aquatic habitat. Although literature on the mechanisms involved in CIPP rehabilitation is readily available, studies have not been published regarding the potential environmental impacts if effluent is leaked or discharged downstream or if chemicals leach from the cured pipe after the installation is completed. Of particular concern are the potential effects of styrene, which is commonly used as a main component of the resin that saturates the lining tube. Styrene is classified by the U.S. Environmental Protection Agency (EPA) as a mutagen and is thus potentially carcinogenic (U.S. EPA 2007a). In certain concentrations, styrene is toxic to aquatic species (Cushman et al. 1997, Baer et al. 2002, Machado 1995, and Qureshi 1982).

The Virginia Department of Transportation (VDOT) uses CIPP repair technology for many of its pipes that convey streams or stormwater beneath or along roads. VDOT uses CIPP rehabilitation more than any other pipe repair method and issues contracts to several companies to perform this work (Stanley L. Hite, unpublished data).

Procedures and Materials for CIPP Installations

Typical CIPP operations begin with the project setup, which includes measures to prevent water flow through the damaged host pipe. ASTM standards for CIPP procedures specify that bypassing or diverting the flow should be done by pumping the flow to a downstream point (ASTM 2003 and 2007). Rocks and debris are then removed from the pipe. The next phase of the operation is liner insertion. The resin-saturated liner, which has been transported from the factory via a refrigerated truck, is inserted into the host pipe. Depending on the company, the liner is either pulled or inverted through the host pipe. Inversion is accomplished by forcing air into one end of the liner, causing the liner to turn inside-out as it travels the length of the host pipe. The liner is expanded to conform to the inner dimensions of the host pipe and is subsequently cured to form a pipe-within-a-pipe. Typical curing is achieved by circulating heated water or steam through the pipe to polymerize the resin material. The curing process takes up to several hours, depending on the size of the pipe. The curing process and subsequent cool-down period generate spent process water or steam condensate. ASTM standards (ASTM 2003 and 2007) specify that during the cool-down period, hot water or steam effluent should be drained through a small hole in the downstream end of the pipe and replaced with the introduction of cool water. Following the cool-down period, the closed ends of the cured liner are cut open, and generally a video camera is inserted into the pipe for a final inspection. A more detailed explanation of CIPP procedures is provided in ASTM F1743-96 (2003), ASTM F1216-07b (2007), and ASTM D5813-04 (2004). These standards contain a caveat that “it is the responsibility of the user to establish appropriate safety and health practices and determine applicability of regulatory limitations prior to use” (ASTM 2003, 2004, and 2007).

The pipe lining material used in CIPP operations is composed of absorbent non-woven felt fabric that is pre-saturated (at the manufacturing facility) with a thermosetting resin. Typically, the liner tube has a membrane coating to protect and contain the resin; the membrane is generally a flexible thermoplastic, such as polyethylene or polyurethane (Hoffstadt 2000). This coating is normally only on the inner surface of the finished product. This allows the resin to migrate into any voids in the host pipe such as joints or cracks prior to curing. Three types of resins are typically used in CIPP applications: unsaturated polyester resins, vinyl ester resins, and epoxies (Hoffstadt 2000). Unsaturated polyester resin and vinyl ester resins are the most common and contain styrene; epoxies do not.

The styrene content of polyester and vinyl ester resins is generally on the order of 30 to 50 percent (by weight). A Material Safety Data Sheet (MSDS) obtained from one vendor shows the styrene content of the resin to be 44 percent (by weight), with the remaining components composed of unspecified polymers (50% to 54%) and colloidal silica (1% to 5%) (Ashland 2005).

Standards and Toxicity Studies on Styrene Concentrations in Water

The EPA drinking water standard lists the maximum contaminant level (MCL) for styrene as 0.1 mg/L (0.1 parts per million [ppm]) (U.S. EPA 2007a). The EPA does not have established regulatory standards for ecological toxicity specifically for styrene concentrations in water. In Canada, however, a section of the British Columbia Environmental Management Act sets limits for toxins in discharged effluent (Environmental Management Act 1999). Under the act’s Municipal Sewerage Regulation (which includes regulations for surface water), effluent must not be discharged unless any toxins in the effluent are below the lethal limit for rainbow trout (*Oncorhynchus mykiss*) as determined by Environment Canada’s 96-hr LC_{50} bioassay test method (i.e., the concentration required to kill 50% of the test population after 96 hours of exposure to that concentration) for this species (Environment Canada 1990).

Numerous acute toxicity studies have documented the impacts of styrene on aquatic organisms (Cushman et al. 1997, Baer et al. 2002, Machado 1995, and Qureshi 1982). Table 1 provides a summary of published values for acute styrene toxicity studies for several aquatic indicator species that are found in freshwater habitats throughout the United States. Indicator species are sensitive to pollutants, and their disappearance from a body of water can be indicative of contamination.

The literature reveals that spills of uncured resin from CIPP installations can cause large fish kills. Three to four gallons of uncured resin were released during a CIPP installation (the location of which was not disclosed in the report) on a stormwater drain. The residual uncured resins were carried to a creek, resulting in the death of more than 5,500 fish of various species. Water samples indicated a 100 ppm (100 mg/L) concentration of styrene in the downstream manhole at the project site (Lockheed Martin 2007).

Except in the immediate vicinity of a spill, typical environmental exposures of styrene are not deemed to cause deleterious effects on natural communities of organisms (Alexander 1997). Styrene volatilizes rapidly and has not been shown to bioaccumulate in organisms to any measurable extent (Alexander 1997). Rates of volatilization are dependent on many factors, including styrene concentration, water temperature, and oxygen availability. Styrene compounds degrade more rapidly once microorganisms adapt to their presence (Alexander 1997, Bogacka et al. 1997). Bogacka et al. found that the styrene (and other aromatic hydrocarbons) introduced to river water in concentrations up to 37 mg/L was reduced by 99 percent after 20 days (1997). Fu and Alexander found that 50 percent of 2 to 10 mg/L was lost by volatilization in 1 to 3 hours in lake water samples (1992).

Aquatic Species	LC_{50} or EC_{50}[a] (mg/L)	NOEC[b] (mg/L)	Reference
Water flea (*Daphnia magna*)	48-hr EC_{50}: 4.7 48-hr EC_{50}: 1.3	1.9 0.81	Cushman et al. 1997 Baer et al. 2002
Amphipod (*Hyalella azteca*)	96-hr LC_{50}: 9.5	4.1	Cushman et al. 1997
Fathead minnow (*Pimephales promelas*)	96-hr LC_{50}: 5.2 96-hr LC_{50}: 10	2.6 4	Baer et al. 2002 Machado 1995
Rainbow trout (*Oncorhynchus mykiss*)	96-hr LC_{50}: 2.5	NA	Qureshi et al. 1982
Freshwater green algae (*Selenastrum capricornutum*)	96-hr EC_{50}: 0.72 72-hr EC_{50}: 2.3	0.063 0.53	Cushman et al. 1997 Baer et al. 2002

[a]Lethal concentration (LC_{50}) and effective concentration (EC_{50}), or the concentration required to kill (LC_{50}) or have a defined effect on (EC_{50}) 50% of the test population after a given number of hours of exposure in that concentration.
[b]No Observable Effect Concentration or the highest limit at which no mortalities or abnormalities were observed.

Table 1. Styrene Toxicities for Various Freshwater Indicator Species

Styrene has a high degree of adsorption onto soils, and although styrene will mineralize to carbon dioxide under aerobic conditions (Fu and Alexander 1992), some is readily desorbed from soil and can enter groundwater. It is not expected to be transported considerable distances through soil, however, because of its high biodegradability (Fu and Alexander 1992).

Purpose and Scope

The purpose of this study was to evaluate the potential for impacts on water quality from use of the steam-cured CIPP process. Of the thermosetting resins used in CIPP applications, styrene-based resins are the most common. Thus, this research focused on styrene-based CIPP products.

To gather information on the methods used in VDOT's CIPP installations and to analyze the impacts that the process might have on water quality, seven steam-cured CIPP installations in Virginia were identified and observed over the course of a 1-year study. Water samples were collected from each project site and analyzed for styrene. The results were then evaluated for compliance with established regulatory standards and published aquatic toxicity criteria.

Methods

Seven CIPP installations were identified within the Piedmont and Blue Ridge Physiographic Provinces of Virginia, and water samples were collected over the course of this 1-year study (see Table 2). The installations were conducted by three primary companies that perform CIPP rehabilitation in Virginia. All project sites were surface water conveyances where the pipe inlet and outlet were exposed with the exception of Site 4, which was an entirely subsurface stormwater conveyance. None of these sites directly links to a source of drinking water.

Field Observations

Project sites were observed during CIPP installations and at various periods after the installations were complete. Because the CIPP installations observed continued up to 30 consecutive hours and because of the distance between the project sites, the authors could not be present to collect samples at consistent intervals during and after all installations. Observations of incidents that could potentially result in adverse impacts to water quality were documented.

Site	County	Route No.	Pipe Size		*Conveyance Description*
			Diameter (in)	Length (ft)	
1	*Spotsylvania*	*1316*	*36*	*71*	*Conveys an unnamed tributary drainage to Massaponax Creek. Drains into concrete-lined ditch. Continual flow.*
2	*Prince Edward*	*15*	*18*	*60*	*Conveys an unnamed tributary drainage to Briery Creek. Drains into earthen ditch. Intermittent flow.*
3	*Prince Edward*	*628*	*30*	*100*	*Conveys an unnamed tributary drainage to Dickenson branch of Briery Creek. Drains into stream bed. Continual flow.*
4	*Albemarle*	*1722*	*24*	*121*	*Conveys stormwater entirely below ground. Drains into stormwater pond. Intermittent flow.*
5	*Nottoway*	*460*	*15*	*112*	*Conveys an unnamed tributary drainage to Lazaretto Creek. Drains into stream bed. Continual flow.*
6	*Nottoway*	*460 (Business)*	*18*	*64*	*Conveys an unnamed tributary drainage to Jacks Branch. Drains into stream bed. Intermittent flow.*
7	*Nottoway*	*613*	*30*	*60*	*Conveys an unnamed tributary drainage to Deep Creek. Drains into stream bed. Continual flow.*

Table 2. Project Descriptions for Seven CIPP Installations in Virginia

Water Samples

A control sample was collected from the water within 1 m of the pipe outlet at Sites 1, 3, and 4 immediately prior to CIPP installations. At sites that were not monitored until the installation was underway (Site 2) or until 15 to 16 days after installation (Sites 5-7), a control sample was collected after installation at least 10 m upstream from the pipe inlet. Water samples were collected at various intervals during installation at Sites 1, 2, and 3 and at various intervals after installation at all seven sites. During each sampling period, a sample was taken from the water within 1 m of the pipe outlet. During some sampling periods at five of the six surface water sites (Sites 1, 2, 3, 5, and 7), samples were also taken from the water 5 to 40 m downstream. At Sites 2 and 3, a sample was taken from the stream water within 1 m of the outlet during steam condensate release. Water samples were collected at all sites for a maximum of 30 to 116 days, depending on the site, after CIPP installation until the styrene concentration at the site was below the reporting limit (0.005 mg/L) of the primary laboratory (Microbac) used in this study.

The subsurface stormwater pipe at Site 4 conveyed water only during rain events. Because it was difficult to time sample collections with rain events, a rain event was simulated for each sampling period by pouring 1 gal of distilled water into the inlet of the repaired section of pipe and capturing the water as it flowed out of the outlet of the pipe section.

All samples were collected into 40-ml volatile organic analysis (VOA) vials with HCl preservative. The samples were packed on ice and sent to the laboratory via an overnight courier service. All samples were analyzed for styrene in accordance with the EPA's SW-846 Method 8260B (U.S. EPA 1996) by Microbac Laboratories in Baltimore, Maryland. Samples collected at the last one to two sampling periods from Sites 1, 4, 5, 6, and 7 were also sent to Air, Water, and Soil Laboratories, Inc., in Richmond, Virginia. These samples were also packed on ice and sent to the laboratory via an overnight courier service. Sample analyses were "blind" in that locations and project descriptions were not disclosed to either laboratory.

Results

Field Observations

Table 3 lists observations during and following CIPP operations at Sites 1 through 4.

The authors observed effluent from the steam condensate being discharged downstream by workers at Sites 2 and 3. At Sites 1, 3, and 4, the authors observed uncured resin residue waste immediately outside the pipe outlet or inlet (Fig. 1). A sample of the uncured resin left in the stream bed at Site 1 (collected 1 day after installation) had a styrene concentration of 580 mg/L.

At Sites 1, 2, and 3, algal blooms were apparent within 6 to 8 days after installation (Aaron L. Mills, unpublished data); algae were not visible at any of these sites when visited before the CIPP installation and were not present upstream of the installation. (The other three surface water sites in this study were not monitored until 15 and 16 days after installation; algal blooms were not visible at these sites.) Algae appeared most dense at the pipe outlet (occurring up to 8 in below the water surface), and the density decreased further downstream; the algae were present in clusters up to 50 m downstream from the repaired pipe section. Although the density of algal blooms appeared to decrease over time, blooms were observed 50 to 55 days after installation. Blooms were no longer visible 78 to 88 days after installation.

Site	Stream Flow Management	Curing Method	Effluent (Steam Condensate) Disposal Method	Post-project Conditions
1	Temporary dam	Steam	Not observed (authors not present at this stage of installation)	Extruded resin in stream (Figure 1A); algal blooms present at pipe outlet (0 to 10 m downstream, Figure 1A); residue present at pipe outlet (present at each sampling period up to study's end)
2	None necessary (dry pipe at time of installation)	Steam	Discharged by workers in stream (see associated water sample results in Figure 2)	Algal blooms present at pipe outlet (0 to 5 m downstream); residue present at pipe outlet (present at each sampling period up to study's end)
3	Temporary dam	Steam	Discharged by workers in stream (see associated water sample results in Figure 2)	Extruded resin in stream (Figure 1B); algal blooms present at pipe outlet (0 to 50 m downstream); residue present at pipe outlet (present at each sampling period up to study's end)
4	None necessary (dry pipe at time of installation)	Steam	Not observed (authors not present at this stage of installation)	Extruded resin just outside of pipe inlet (present at each sampling period up to study's end)

Table 3. Environmental Observations for Four CIPP Installations for Surface Water Conveyances

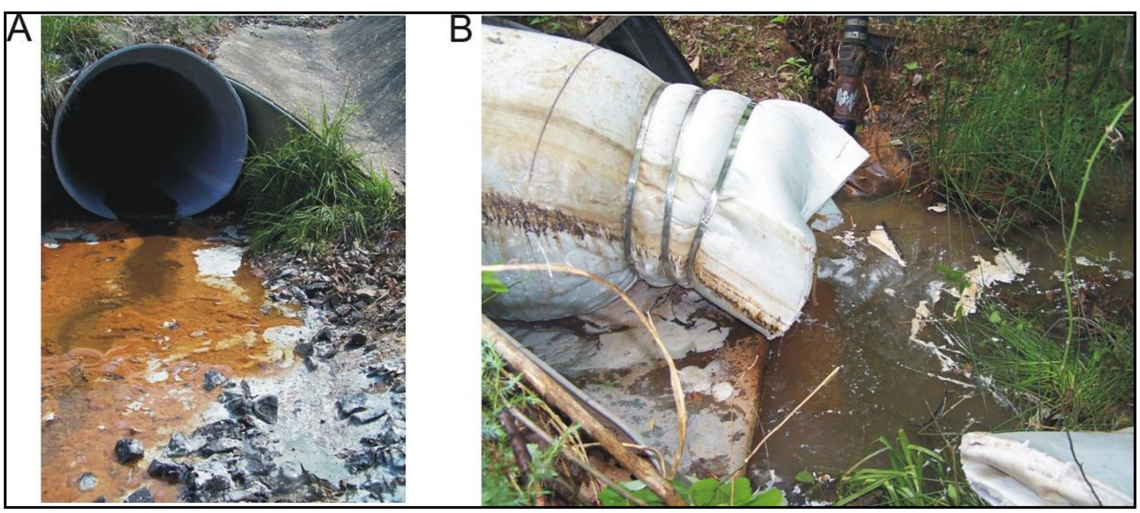

Figure 1. ***A:*** **Uncured resin waste (gray substance adjacent to outlet and along rocks on right side of image) at Site 1, 1 week after installation; algal blooms (brown cloudy substance in water) also visible.** ***B:*** **Uncured resin waste (white substance adjacent to pipe liner and in water) extruded during installation, just before pipe end was cut.**

Water Sampling Results

Styrene concentrations in all control samples were below the reporting limit (0.005 mg/L) of the primary laboratory used in this study. Samples were collected until styrene concentrations were below the reporting limit at all sites. Samples collected at the pipe outlet often contained residue that was visible on the water surface after installation.

Figure 2 provides styrene concentrations at all sites as compared with the MCL and with the EC_{50} or LC_{50} values for two species (as detailed in Table 1). Samples for three sites were taken during installation, and samples for all sites were taken at various intervals after installation. No compounds other than styrene were detected in the laboratory analyses.

The results indicate that styrene concentrations were generally highest in water samples collected during installation, although comparable levels were detected at some sites several days after installation. The highest concentration (77 mg/L) was recorded at Site 3 at the outlet while steam condensate was discharged during the installation process.

Styrene concentrations and the duration of its detectable presence were highly variable among sites. Samples from some sites did not show a consistent decrease in concentration, particularly at sites with low or intermittent water flow. Although none of the sites was directly linked to a source of drinking water, styrene concentrations exceeding the MCL for drinking water were measured at five of the seven study sites. The concentrations at Sites 1, 2, 3, and 6 exceeded the MCL for drinking water (0.1 mg/L) at sampling periods of 5 to 50 days after installation, and at Site 4, the concentration exceeded the MCL 71 days after installation during a period of very low flow. The maximum styrene concentrations at four sites (Sites 1, 2, 3, and 6) exceeded published EC_{50} or LC_{50} values (Table 1) for various aquatic species. At Site 2, the concentration exceeded these values for the water flea and the rainbow trout at the sampling period of 24 days.

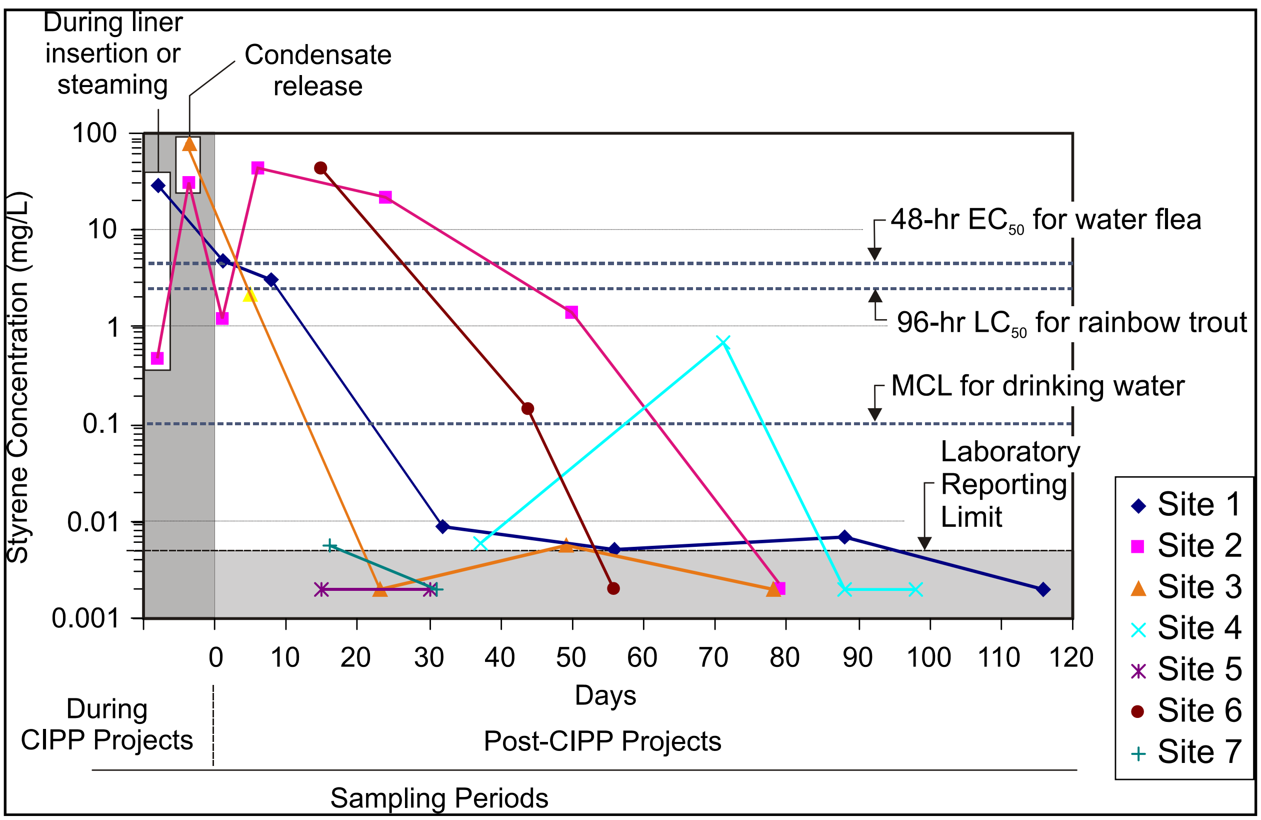

Figure 2. Styrene concentrations in water samples collected at pipe outlet during installation and at sampling periods up to 116 days after installation. Horizontal lines indicate the maximum contaminant level (MCL) of drinking water (0.1 mg/L), the EC_{50} or LC_{50} styrene concentrations for two aquatic species (as detailed in Table 2), and the laboratory reporting limit (0.005 mg/L). For styrene concentrations below the laboratory reporting limit, the data points shown merely indicate that sampling occurred and that the results were below the limit of 0.005 mg/L; they do not indicate the true concentration value.

Discussion

At certain times after CIPP installation, styrene concentrations exceeded the MCL for drinking water at five of the seven study sites and exceeded the EC_{50} or LC_{50} values of the water flea (Cushman et al. 1997) and the rainbow trout (Qureshi et al. 1982) (common indicator species) at four of the monitored project sites. As compared with samples collected from sites with continual water flow, samples from sites with intermittent flow contained relatively higher styrene concentrations for a greater length of time after CIPP installation. This suggests that flow volume and regularity are important factors in diluting styrene concentrations.

At the two sites where styrene was not detected, the initial sample was not collected until 15 and 16 days, respectively, after installation; therefore, it cannot be known whether these installations had any effect on water quality or whether styrene, if indeed present, had decreased to concentrations below detection. At sites where styrene was detected, styrene was above the laboratory reporting limit (0.005 mg/L) at sampling periods 44 to 88 days after installation.

Styrene concentrations reached as high as two orders of magnitude greater than the MCL for drinking water. Concentrations exceeded the MCL for drinking water for at least 5 days after installation at five sites and for at least 44 to 71 days at three of these sites. Concentrations above the MCL were detected up to 40 m downstream. Although the sites in this study do not directly link to a drinking water supply, roadway conveyances often convey water upon which a variety of aquatic species depend. The sample results from five of seven sites exceeded one or more aquatic toxicity criterion (EC_{50} or LC_{50} values, Table 2) for styrene, and concentrations exceeding these values were detected as far as 10 m downstream. Styrene concentrations at one site exceeded the EC_{50} value for the water flea and the LC_{50} value for the rainbow trout at the sampling period of 24 days following installation.

One apparent ecological change during this study was the emergence of algal blooms, which appeared at three surface water sites within 6 to 8 days after CIPP installation and remained at these sites for at least 50 to 55 days post-installation. Algal blooms are often indicative of poor water quality (commonly from nitrogen or phosphorus pollution) and can have adverse ecological impacts (U.S. EPA 2007b). The fact that algae blooms were not seen at project sites before CIPP installation could be seen to suggest that some aspect of the CIPP process could be a contributing factor for the blooms, but the specific cause (whether hot effluent discharge, styrene leaching, factors unrelated to the installations, etc.) is unknown.

As typical CIPP resins contain between 30 and 50 percent styrene, even a relatively small amount of uncured resin could potentially result in water samples with detectable styrene concentrations at the project site or downstream. Any resin that might be unintentionally released during installation would not have been subject to the same curing conditions as the resin contained within the liner. A sample of the uncured resin waste in the stream bed at Site 1 collected 1 day after installation had a styrene concentration of 580 mg/L. Styrene was detected at sites even where resin waste was either not released or had washed downstream; styrene was also detected at sites long after observed discharges of steam condensate had been flushed downstream. These observations, coupled with the length of time styrene was detected after installation, suggest that these installation practices (i.e., uncured extruded resin and discharge of the steam condensate effluent) were not solely accountable for the styrene concentrations in water. These findings suggest that the resin-saturated liner was not completely cured during the installation process and continued to leach styrene, perhaps through or around the inner membrane liner.

Although the scope of this study did not lend itself to definitive determination of the specific contribution of styrene from each aspect of the CIPP process, the styrene concentrations identified in the laboratory tests of water samples may have resulted from one or a combination of the following: (1) installation practices that did not capture condensate containing styrene, (2) uncured resin that escaped from the liner during installation, (3) insufficient curing of the resin, and (4) some degree of permeability of the lining material.

Standards and Regulations

Although CIPP technology dominates the underground pipe rehabilitation industry and is a common method for above-ground pipe rehabilitation, only 3 of 85 trenchless pipe rehabilitation standards pertain directly to CIPP methods and materials (Hoffstadt 2000). ASTM standards for CIPP rehabilitation (ASTM 2003, 2004, and 2007) do not separate surface water conveyance guidelines from those for sewer lines. They also do not address measures to ensure containment of the resin that saturates the lining material. Although ASTM standards (ASTM 2003 and 2007) contain a caveat that it is the user's responsibility to determine the applicability of regulatory limitations prior to use, the standards direct users to dispose of the curing water or condensed steam (effluent) by allowing it to drain from a hole made in the downstream end of the pipe. It is also important to note again that ASTM standards for CIPP procedures specify that the flow be bypassed or diverted before CIPP installation (ASTM 2003 and 2007).

A culvert pipe liner guide (Federal Highway Administration 2005) published by the Federal Highway Administration lists existing specifications for pipe repair technologies and provides a decision analysis tool designed to help users choose an appropriate pipe repair method based on various factors. The guide lists some specific environmental limitations of CIPP rehabilitation, including (1) possible thermal pollution from the discharge of the curing water, (2) potential toxicity of styrene-based resins prior to completion of the curing process, and (3) possible hazards to an environmentally sensitive area. The decision analysis tool addresses such concerns for CIPP technology by assigning it the highest ranking for environmental risk (on a scale of *1* to *5*). Neither the guide nor the decision analysis tool, however, provides guidelines or additional specifications (beyond the referenced ASTM standards) to mitigate environmental risks.

The EPA does not have published standards for allowable levels of styrene for receiving streams; however, the discharge of pollutants (which includes chemical wastes) to waters of the United States is regulated (U.S. EPA 2007c). The discharge of steam condensate or spent cure water into waters of the United States would require a permit under the National Pollution Discharge Elimination System (NPDES) or state equivalent (U.S. EPA 2007c and Virginia Department of Environmental Quality 2007a). The permit conditions may require pre-treatment and monitoring prior to any discharge. State environmental regulatory agencies also typically have additional statutory and/or regulatory authority to prevent or regulate the discharge of pollutants to state receiving waters, including groundwater (Virginia Department of Environmental Quality 2007b). Although the state and/or federal agencies could use published water quality standards such as the relevant MCL or published aquatic toxicity criteria to determine acceptable styrene levels, it is unclear what, if any, environmental regulation would govern the leaching of styrene from a finished CIPP product.

Actions Taken by the Virginia Department of Transportation in Response to Preliminary Research Findings

VDOT took several actions upon receiving the preliminary research findings of this study:

1. *VDOT's Chief Engineer immediately placed a stop work order on all styrene-based CIPP repair projects contracted by VDOT* (Winstead 2007a*).* VDOT subsequently elected to allow CIPP installations on sanitary sewer projects (under certain conditions) while continuing to review the use of styrene-based CIPP repair (Winstead 2007b).

2. *A VDOT task group led by VDOT's Environmental Division was formed to evaluate further the use of steam- and water-CIPP repair projects containing styrene.* Task group participants included members of VDOT's Scheduling & Contract, Administrative Services, Materials, and Asset Management Divisions, as well as scientists from the Virginia Transportation Research Council (VTRC). Information gained from this evaluation was to be used to provide VDOT with recommendations for further action regarding the use of styrene-based CIPP technology.

3. *The task group conducted the evaluation,* which included acquiring the services of an independent environmental consultant to provide third party verification of the preliminary study findings and to test additional CIPP sites, meeting with the Virginia Department of Environmental Quality for support and guidance, and holding two series of interviews with CIPP industry representatives.

4. *The task group issued their evaluation report to the Office of the Commonwealth Transportation Commissioner in November 2007.* The report (Virginia Department of Transportation Task Group 2007) provided recommendations regarding the modification of VDOT's CIPP contracting specifications, project management considerations, and conditions for reinstatement of styrene-based rehabilitation. The recommendations were primarily designed to prevent the unintentional release of styrene-based resin during installation and the leaching of styrene from the finished product.

5. *The Office of the Commonwealth Transportation Commissioner charged VDOT's Scheduling & Contract Division with developing an action plan to implement the recommendations outlined in the task group report.* In April 2008, these recommendations were implemented and are incorporated in a VDOT memorandum that includes revised CIPP specifications (Coburn 2008). These specifications include the following measures:
    - a requirement that a VDOT project inspector (who has undergone a CIPP training program) provide oversight of CIPP installations for the duration of each installation
    - the acquisition of discharge-related permits, including air, water, and wastewater treatment
    - ASTM and other applicable standard compliance requirements
    - a requirement that all CIPP installations be performed in the dry (i.e. no water is contained or conveyed in the pipe during installation)
    - a requirement that the contractor submit preconstruction installation and cure specifications

- additional lining materials and measures to ensure the containment of resin and styrene
- procedures for monitoring the curing of the CIPP lining material
- thorough rinsing of the finished product
- proper disposal of cure water, cure condensate, and rinseate
- requirements for water and soil testing prior to and after installation.

Statewide VDOT CIPP installations using the new procedures and specifications were reinstated in June 2008. These actions are part of VDOT's ongoing effort to prevent the risks associated with styrene-based CIPP technology and, in doing so, to ensure due diligence by VDOT for the protection of the public health and safety as well as the environment.

Conclusions

- *The use of styrene-based CIPP technologies may result in detectable levels of styrene at and near the work site of the CIPP installation.* In this study, styrene was detected in water samples collected from the pipe outlet during or after installation at five of the seven CIPP installations monitored in this study. Styrene concentrations in water samples ranged from <0.005 mg/L to 77 mg/L and were generally highest in samples collected during and shortly after installation. The maximum time styrene was detected at any site was 88 days following CIPP installation.

- *Although further research is needed to discern the contribution from each potential source of styrene, the findings suggest that the elevated styrene levels could have resulted from one or a combination of the following:* (1) installation practices that did not capture condensate containing styrene, (2) uncured resin that escaped from the liner during installation, (3) insufficient curing of the resin, and (4) some degree of permeability in the lining material. These factors appear to pose a risk of negative impacts from the use of styrene-based CIPP technologies.

- *Under the observed conditions, styrene concentrations could result in violations of state and/or federal environmental standards.* Although the EPA does not have published standards for allowable levels of styrene for receiving streams, the discharge of pollutants to waters of the United States is regulated under the NPDES permit program.

- *Research on the ecological and species effects of chronic styrene exposure in natural conditions would be useful in order to foster an understanding the potential impacts.* These studies should also look at the factors that would create conditions leading to algal blooms.

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Biographical Sketch

Bridget Donaldson completed her bachelor's degree in biology from University of Colorado, and received a master's of science degree in ecology and evolutionary biology from University of Tennessee in 2001. She has twelve years of experience in ecology and conservation. Her work has included research on terrestrial animals throughout the U.S., the Gulf of Mexico, Queensland Australia, and Grand Cayman Island. She has been a research scientist for the Virginia Transportation Research Council (a component of Virginia Department of Transportation) in Charlottesville, Virginia for six years. Her research projects involve various topics in ecology and transportation, including wildlife underpass monitoring, animal-vehicle collisions, and aquatic ecology.

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Managing an Unpredicted and Unexpected Large Scale Amphibian Migration: Applying Hungarian Experience and Knowledge to Protect Western Toads on a British Columbia Highway

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Abstract

The plight of amphibians globally is becoming increasingly serious as the adverse impacts to their natural habitats caused by human development are being recognized. Throughout Europe and North America, formerly widespread indigenous amphibian species are becoming increasingly less common. The spatial distributions of some species, once considered ubiquitous throughout large regions of these continents, are becoming limited to progressively smaller and more isolated geographic areas. Where once, large expanses of undisturbed natural environments enabled amphibian populations to remain stable, human activities have resulted in extensive habitat fragmentation and reduced genetic diversity. The elimination of migratory routes between remaining habitats critical for the lifecycle stages of amphibians has raised the significance of mitigating the impact of transportation corridors.

While large mammals, such as deer, moose and elk have both the physical size and speed to avoid motor vehicles and trains; small, slow moving amphibians are completely vulnerable when attempting to cross transportation corridors. Large mammals can be protected from transportation corridors by the installation of wildlife exclusion fencing and critical habitat connectivity can be maintained to some degree by the construction of engineered crossing structures. Protecting amphibians is a more complicated task due to the greater number of species and their significantly wider range of physical sizes, movement patterns and lifecycle characteristics. Consequently, species of amphibians co-existing in the same environments fragmented by transportation corridors may need a diverse range of mitigation strategies in order to survive. However, geographically distinct species from the same genus, with similar characteristics, such as physical size, migration radius, and migration patterns, may be protected with the same types of mitigation measures. In such cases, knowledge and experience collected while protecting a specific amphibian genus on one continent can effectively be used to protect the same genus on another continent.

In August, 2007, the British Columbia Ministry of Transportation (BCMoT) was notified of an unpredicted and unexpected, large scale migration of Western toads (*Bufo boreas*) occurring across a major highway on Vancouver Island in British Columbia, Canada. Although extensive wildlife assessments conducted prior to the design and construction of the highway did not identify the potential for Western toads, an estimated one million toadlets were discovered converging on the highway. The migration was successfully managed in part with expertise developed by researchers at the Hungarian Danube Research Station of the Institute of Ecology and Botany of the Hungarian Academy of Sciences working to protect the same genus in Hungary. Temporary amphibian fencing was immediately installed and a collection system was developed. Approximately 950,000 toadlets were successfully recovered and transported across the highway. As a result of the migration, BCMoT developed a wildlife migration response protocol and initiated Western toad monitoring in the area. Similar migration events, with the same and other amphibian species, have the potential to occur at other locations in Europe and North America. The collection and dissemination of best practices can promote and facilitate the expedient use of existing experience and knowledge developed to protect amphibians on either continent.

Introduction

The Vancouver Island Inland Highway (VIIH), Highway 19, starts in the City of Nanaimo and continues north, along the east coast of Vancouver Island, for 390 km. The Vancouver Island Highway Project (VIHP) planning for the high speed (110 km/hr), four lane, limited access highway began in 1987 (Jones, 2001). The new alignment was constructed away from developed areas, largely on provincially owned and forest company lands, to avoid impacts to residential, commercial and industrial properties.

Along its entire alignment, the highway traverses sensitive fish and wildlife habitats. Extensive pre-construction environmental impact assessments (EIAs) were an integral component of the VIHP's planning and construction process. Consequently, many new and innovative techniques to protect the environment were developed by the project's engineers, biologists and construction crews. Adverse impacts to sensitive habitats were minimized by a combination of avoidance, recovery, replacement and enhancement (Jones, 2001).

South of the Town of Courtenay, between Millar Creek and Pup Creek, the VIIH passes within 100 metres of the west side of Keddy Swamp. The large wetland was created for fish and wildlife by a collective effort by Fisheries and Oceans Canada, Ducks Unlimited and the local landowner (Barlow, 2001). The preconstruction EIA indicated the swamp provided habitat primarily for fish, elk, and deer. It appears no one anticipated Keddy Swamp would also provide habitat for amphibians. Consequently, in 1999, when tens of thousands of juvenile Western Toads (Bufo boreas) began migrating westward from the swamp and crossing the unfinished highway during grade construction, nothing had been planned to protect these amphibians. Fortunately, through a collaborative effort between the British Columbia Ministry of Environment and the VIHP environmental staff, the project was able to design and install an amphibian exclusion system incorporating over 50 amphibian crossing underpasses with fine mesh fencing along both sides of 1.8 kilometres of the highway near the swamp (Barlow, 2001). The amphibian exclusion system was incorporated into a fencing system designed to protect deer and Roosevelt Elk. From observations made in 2000 and 2001, it was concluded the system operated as designed, enabling the toads to migrate in both directions under the highway (Barlow, 2001).

There were no issues relating to the Western Toad along the VIIH corridor until 2007, many years after the highway had been completed and the VIHP environmental staff and team of environmental consultants disbanded. Environmental responsibilities for the highway were assumed by the British Columbia Ministry of Transportation (BCMoT) Headquarters, Regional and District staff.

Discussion

Unanticipated Large Scale Western Toad Migration

In August, 2007, after the Mud Bay to Courtenay section of the VIIH had been in operation for over 4 years, juvenile Western Toads were discovered migrating toward the highway near Pup Creek (Figure 1) (Sielecki 2007). Although toad migration routes south of this location had been identified during the 1990's by extensive pre-construction EIAs and mitigated with amphibian fencing and tunnels, there had been no indication toads were present where the migration was occurring. Consequently, there was no amphibian fencing or passage structures in place to protect the toadlets. The migration was unprecedented in BCMoT history. On the first day, hundreds of toadlets were found at a crossing site that stretched approximately two kilometres along the highway. The following day, the number found jumped to about 10,000. Each subsequent day, as the mass migration continued, the numbers grew rapidly. Never before, had BCMoT experienced an amphibian migration of such magnitude on a major highway.

Figure 1. Location of 2007 Highway 19 Western Toad Migration

Significance of Western Toad Migration

Historically Western Toads (*Bufo boreas*) have been widely distributed in the western regions of North America, but their numbers have been declining (Muths et al. 2006). Western toads are considered endangered in U.S. several states and their status is under review in other states. The U.S. Fish and Wildlife Service lists Rocky Mountain populations of Western toads, specifically in Colorado, New Mexico, and Wyoming as a candidate species (U.S. Department of the Interior 1991). The Colorado Division of Wildlife and the New Mexico Department of Game and Fish lists western toads as endangered and Western toads are a protected species in Wyoming. In British Columbia, Western Toads are on the provincial Yellow List (Wind and Dupuis 2002). They are considered a species of special concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Wind and Dupuis 2002). The Western toads on the east side of Vancouver Island are completely isolated from the mainland of British Columbia where the majority of Western toads in the province are found (Wind and Dupuis 2002). On Vancouver Island, Western toad habitat is further fragmented by urban and agricultural development. Given the barriers to movement, the potential recovery of threaten populations on Vancouver Island through migration is extremely limited. Background on the Western Toad is provided below.

Appearance

Adult Western Toads have stocky bodies with short legs (Green and Campbell 1984). They tend to walk rather than hop (Fisher et al. 2007). Their thick skin appears dry and bumpy and can range in colour from pale green to grey, dark brown, and red (Corkran and Thoms 1996). They typically have pale-coloured bellies mottled with black, and a pale coloured stripe down their backs (Matsuda et al. 2006). Their beautiful gold-flecked eyes have distinctive horizontal oval pupils.

Adults range from 5.5 to 12.5 centimetres in body length, excluding the hind legs (Russell and Bauer 1993). Males are generally smaller than females and have dark pads on their thumbs that help them cling to the female during mating. The skin of male toads is usually smoother and less blotched than the skin of female toads.

Western Toad eggs look like small black pearls laid single file in long strings in the water (Wind and Dupius 2002). Tadpoles are black or charcoal coloured, with a dark, rounded fin along the length of their tail (Green and Campbell 1984). Tadpoles metamorphose into toadlets as small as 6 millimetres long that resemble miniature adults (Figure 2).

Figure 2. Juvenile Western Toads

Life Cycle

Depending on latitude and elevation, Western Toads are active between January and October. Adult toads migrate to communal breeding sites in early spring. Breeding and egg deposition can occur between April and July, usually following rains after snow and ice have melted (Russell and Bauer 1993, Gregory 2000). Female Western Toads produce an average of 12,000 eggs, and as many as 16,500 eggs, in a single clutch (Samollow 1980; Blaustein 1988). It is estimated fewer than 1% of eggs survive to adulthood. Those that survive may live more than ten years. Individuals in captivity have lived up to 36 years (Russell and Bauer 1993).

Depending on water temperature, eggs typically hatch in 3 to 12 days, and develop into tadpoles within six to eight weeks (Gregory 2000). Tadpoles swarm in groups ranging from hundreds or hundreds of thousands through the warmest, shallowest water available. Tadpoles can form huge temporary aggregations, at times containing millions of individuals (Gregory 2000, Matsuda et al. 2006). By the end of the summer, tadpoles transform into toadlets and leave their water habitat. Dense aggregations of toadlets can often found hidden along the shore of breeding sites. When the weather turns cold, the toadlets cluster in piles. It takes toadlets between four and six years to reach maturity (Olson 1988; Olson 1992; Carey 1993). After spring breeding, adult Western Toads spend the summer and fall foraging in warm, low lying areas. Although they are primarily nocturnal, at higher elevations and latitudes, they are active during the day. With the onset of colder temperatures in fall and winter, Western Toads retreat into hibernation to await spring.

Diet

Western Toads are exceptionally adept at capturing a wide variety of insects and invertebrates (Russell and Bauer 1993). The adult diet consists primarily of flying insects, ants, beetles, sowbugs, spiders, centipedes, crayfish, slugs, and earthworms. If presented with the opportunity, Western Toads will also consume larger items (Green and Campbell 1984). Tadpoles are herbivores. They feed on aquatic plants, detritus and algae.

Predation

Western Toads are subject to predation by a host of other animals (Gregory 2000). In British Columbia, garter snakes are a major predator of metamorphosed toads (Green and Campbell 1984). Toads are also eaten by birds, mammals and even other amphibians. Adult Columbia Spotted Frogs have been observed eating newly metamorphosed toadlets. Western Toad tadpoles are vulnerable to birds, fishes and predaceous insect larvae.

Habitat

Western Toads utilize three different types of habitat over the course of the year: breeding habitats, terrestrial summer range, and winter hibernation sites. Permanent or temporary water bodies with shallow sandy bottoms are preferred breeding sites for Western Toads (Green and Campbell 1984; Russell and Bauer 1993; Matsuda et al. 2006). After breeding, the adult toads disperse into terrestrial habitats, such as forests and grasslands. They are more tolerant of dry conditions than most frogs and can roam relatively far from standing water (Matsuda et al. 2006). However, they cannot tolerate extreme dryness and prefer damp environments (Green and Campbell 1984). They spend much of their time underground. While they are capable of digging their own burrows in loose soils, they usually find shelter in small mammal burrows, beneath logs and in rock crevices (Russell and Bauer 1993). They hibernate in burrows below the frostline, up to 1.3 metres underground.

Geographical Distribution and Abundance

Western toads are found throughout much of western North America, on the west side of the Rocky Mountains (Matsuda et al. 2006). Their range extends from north-central Mexico to the south eastern corner of Alaska (Figure 3) (Stebbins 1985). The toads can be found at elevations from sea level to at least 2250 metres. In British Columbia, they are found in semi-arid and wet forested areas (Cook 1984). They are the only amphibian native to the Queen Charlotte Islands (Green and Campbell 1984).

Adult female Western toads travel further than adult males, typically moving between 400 and 600 metres upland to summer ranges (Wind and Dupuis 2002). Migratory movements upwards to 7.2 kilometres have been reported. On Vancouver Island, toads tend to have small, defined home ranges about 0.1 hectares in size (Gregory 2000).

Western Toads are relatively common in most of British Columbia. However, population declines are suspected in the south western part of the province (Wind and Dupuis 2002). In the United States, Western Toad populations have suffered significant losses and are becoming less common in many areas of the Pacific Northwest, the Rocky Mountains and other areas (Muths et al. 2006).

The cause for such declines is still uncertain, but a combination of threats is suspected. This phenomena is attributed to environmental changes caused by habitat loss, in particular wetlands, due to residential and agricultural development (Dodd and Smith 2003; Muths et al. 2006). Development in and around wetlands can destroy or isolate populations.

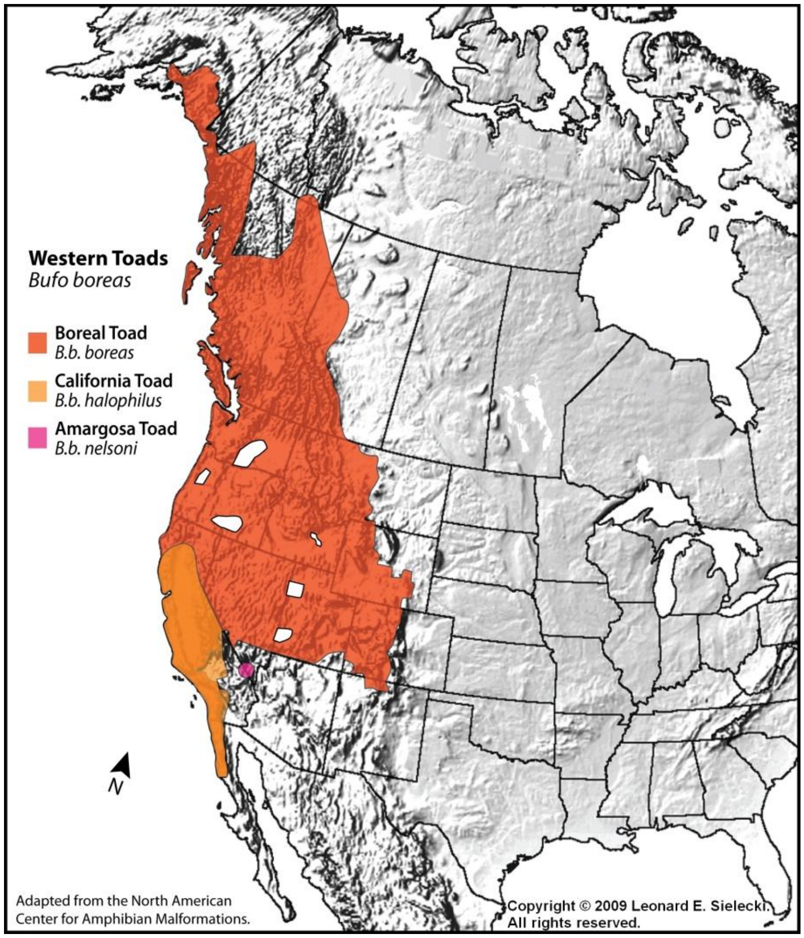

Figure 3. Distribution of Western Toad Species in North America

Pollution, the introduction of aquatic predators (e.g., stocking lakes with fish), and the spread of parasites and diseases are also harmful (Johnson et al. 2002). Large-scale concerns such as global warming and ozone depletion can affect Western Toads by changing temperatures, affecting water levels, and increasing ultraviolet radiation (Pounds et al. 2006).

Migrating toads are also killed by motor vehicles. Both juvenile and adult toads are relatively slow-moving and are frequently run over by traffic as they migrate across roads and highways. Due to population declines in the United States, the centre of the world's distribution of Western Toads has shifted from the United States to British Columbia.

Seeking External Expert Advice

The Western Toad migration on the VIIH came at a time when BCMoT's wildlife expertise was limited primarily to fish and large mammals. The VIHP team of environmental consultants responsible for developing the amphibian mitigation infrastructure near Millar Creek was no longer intact, with many of its former members working on non-BCMot projects throughout the Province. Given the urgency created by the Western Toad migration, it was imperative BCMoT obtain guidance for managing the toadlets.

Through the ongoing involvement of BCMoT's wildlife expert with Infra Eco Network Europe (IENE) and the International Conference on Ecology and Transportation (ICOET), BCMoT was to immediately access the expertise and knowledge of the world's leading researchers in amphibian habitat fragmentation caused by the construction and operation of linear transport infrastructure such as roads, railways and waterways.

Of particular help were the researchers of the Hungarian Academy of Sciences at the Hungarian Danube Research Station of the Institute of Ecology and Botany. In Europe, Hungarian researchers are recognized for their extensive experience with amphibians and road-related mortality (Puky, 2006; Hartel et al., 2009). In Hungary, studies have shown amphibians are the most frequently killed vertebrates on roads (Fenyves 1989, Onuczan 1992).

In Hungary, road-related amphibian mass mortality was recognized early and toad rescue teams created to construct temporary mitigation measures using buckets and plastic fences (Frank et al. 1991, Kárpáti 1988, Kelemen 2000, Puky 1989). Since the 1980's, permanent solutions to protect amphibians have been developed across the country. In 1986, the first amphibian-related culvert modification in central Europe occurred in Parassapuszta, Hungary (Puky 2003). Since then, several dozen amphibian-oriented mitigation infrastructure elements have been made under roads and highways. Much of this development occurred after 1995.

In 1998, a long-term conservation survey on existing roads near Hungarian national parks was conducted to identify locations where road-related amphibian mortality was greatest (Puky 2001, 2006; Simonyi et al. 1999). The survey was also responsible for suggesting technical solutions for those locations. Later, in 2000, as an integral part of the national survey, twenty-four road sections with wildlife mitigation measures were monitored. The survey included locations with game passages and game bridges, known to enable between one and five million amphibians to safely cross roads each year. The national survey found that mitigation measures helped at least thirteen amphibian species, representing almost 70% of Hungarian amphibian fauna, to cross roads (Puky and Vogel 2004).

Hungarian amphibian experts had the extensive knowledge and experience with road-related toad mortality necessary to immediately assist BCMoT develop a strategy for dealing with the Western toad in progress on the VIIH.

BCMoT Migration Response

Using advice provided by researchers of the Hungarian Academy of Sciences, BCMoT Headquarters environmental staff were able to direct the work of BCMoT District staff and wildlife consultants. The installation of temporary amphibian fencing to funnel the toadlets into collection buckets was done within days (Figures 4 and 5). Additional BCMoT staff were seconded to assist District Staff. Ministry contractors and numerous volunteers also provided assistance, building the temporary amphibian fence, capturing the toadlets and transporting them in buckets safely to the western side of the highway. The migration continued for over eight weeks. At its peak, it is estimated over 50,000, penny-sized toadlets were trying to cross the highway each day.

As the waves of toadlets quickly rose and increasing numbers of volunteers were involved in their recovery, BCMoT took further steps to ensure public safety. Existing solid highway median barriers were replaced with skuppered ones to enable any toadlets that managed to bypass the amphibian fencing a better chance of crossing the highway (Figures 6 and 7). In a virtually unprecedented move, BCMoT also closed the northbound curbside lane of the highway to traffic to protect the toads and those carrying them, as well as a rapidly growing number of news media personnel, complete with camera crews vying for good pictures.

The toadlet migration received extensive media attention across Canada. The event was recorded by national newspaper, radio and television services. In addition, many local people were driving out to the migration site and stopping on the highway to witness the event. The decision to close one northbound lane of the highway was not a simple one, as it had significant impacts to commercial traffic flow and increased the potential for motor vehicle collisions. Given the convergence of toadlets and humans, something had to be done right away. Warning signs and traffic cones were installed to direct traffic away from the toadlets and volunteers (Figures 8 and 9). As a result of BCMoT's initiatives for toad and human safety, the bucket brigade transported an estimated one million toadlets safely across the highway without incident. With the onset of lower temperatures in the fall, toadlet ceased and the VIIH returned to normal operations.

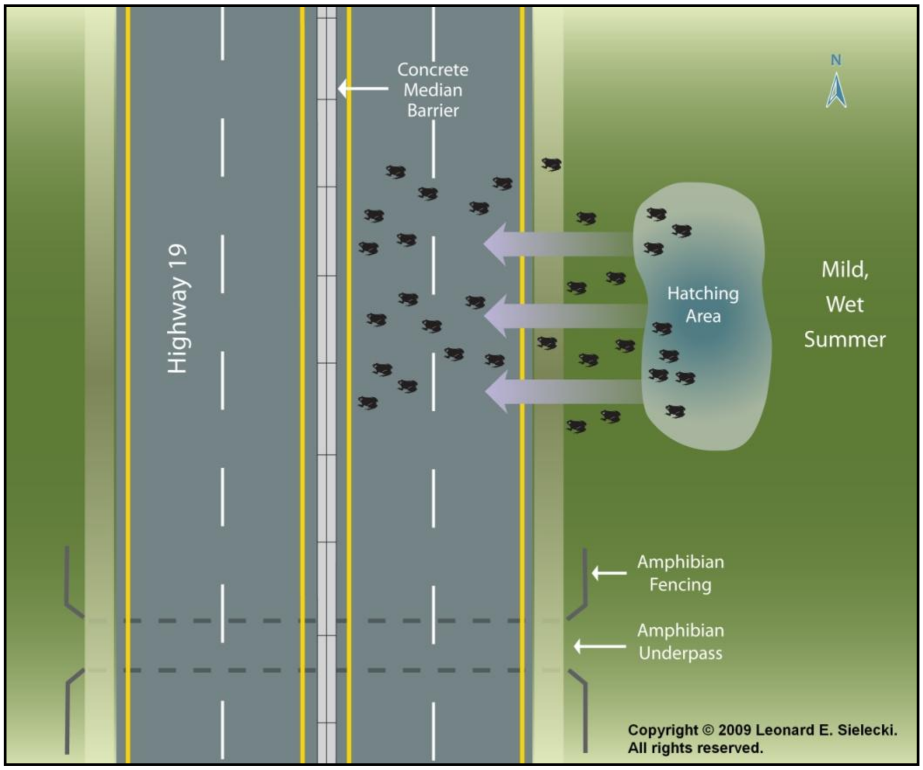

Figure 4. Pre-mitigation Migration Conditions

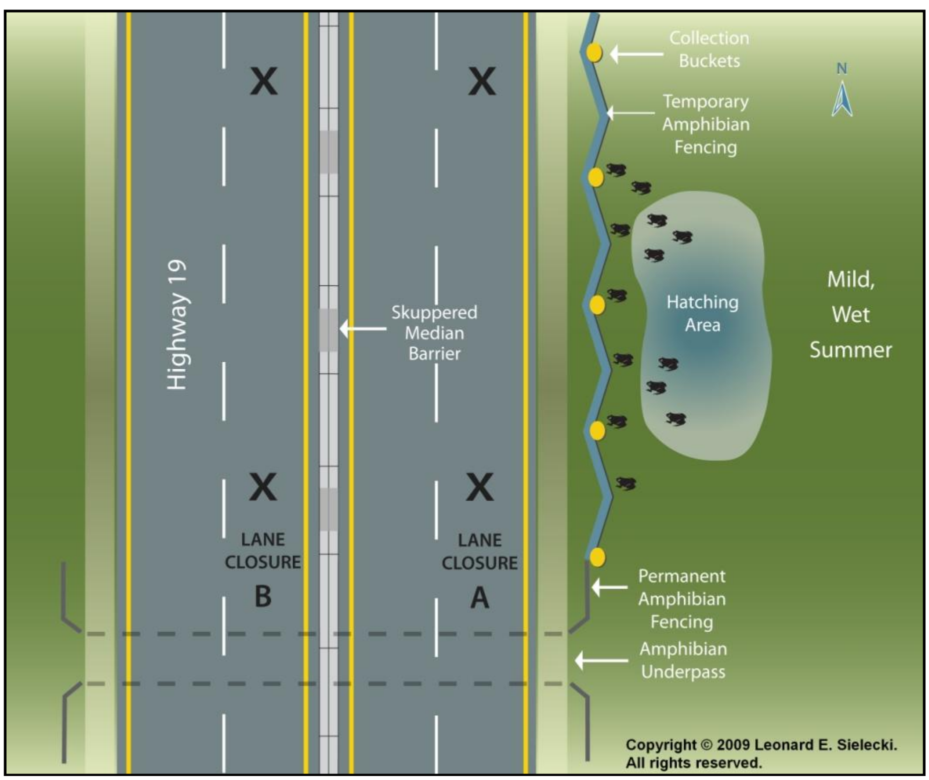

Figure 5. Post-mitigation Migration Conditions

Figure 6. Lane Closures and Installation of Scuppered Concrete Median Barriers

Figure 7. Installed Scuppered Concrete Median Barrier

Figure 8. Temporary Amphibian Fencing in Highway Right-of-Way

Figure 9. Collection of Juvenile Western Toads

Post Migration Debriefing and Lessons Learned

After the toadlet migration ended, debriefing sessions were held with all those involved in the event. BCMoT Headquarters, Regional and District staff were brought together with British Columbia Ministry of Environment staff, BCMoT maintenance contractors, and professional biologists. Representatives from the major landowners in the migration area were also invited. BC Hydro, British Columbia's largest electric utility, and TimberWest, the largest owner of private forest lands in western Canada, sent their environmental and land development staff to the debriefings (Sielecki 2008). Efforts were made to examine every aspect of the migration to better understand what had happened, why it had happened, and what could be expected for the future.

As a follow-up to the debriefing sessions, and a compilation of lessons learned, BCMoT's first wildlife migration response protocol was developed. The protocol was designed to help BCMoT staff to respond as promptly and effectively as possible, should another mass migration of toads, or other species of animals begin crossing a Provincial highway (Appendix 1). The protocol outlines immediate courses of action for designated BCMoT staff to protect the migrating wildlife, the motoring public, and migration response personnel. The protocol also establishes an official migration event command structure and a framework for managing news media communications, and identifies funding sources for hiring professional biologists needed to supervise the handling of specific species of wildlife.

The key aspects of managing an unpredicted and/or unexpected large scale amphibian migration are:

1. To ensure a clear chain of command, a single person should be appointed the Migration Event Commander (MEC) responsible for overseeing all aspects of the migration response and the activities of all agencies, organizations and personnel involved.
2. The MEC, or designate, should be the point of contact and liaison between state and local agencies (i.e. departments of transportation, natural resources, etc.)
3. To manage media inquiries, the MEC, or a designate, should be made the principal media contact and responsible for providing press releases, making statements, and coordinating media access to the migration site.
4. If volunteers are needed to assist in the migration response, the MEC, or a designate, should arrange volunteer recruitment through local fish and game clubs, scout troops, 4-H groups, and other formal associations so volunteers are organized and covered by the insurance carried by these organizations.
5. To reduce the potential for injuries and death for migration response personnel and the species involved, all persons must be advised of the chain of command, how to conduct themselves on a road or highway right-of-way, and how to safely handle the migrating species without harming themselves or the species being handled.
6. Volunteer recruitment, assembly and training should be done away from the migration site to minimize congestion at the migration site.
7. Arrangements should be made to provide all migration response personnel access to toilet facilities and water for maintaining personal hygiene, as well as emergency first-aid if required.
8. To keep activities at the migration site under control, only those personnel directly involved in the migration mitigation, or those authorized by the MEC, should be allowed to be present at the migration site.
9. When migration response activities occur near or on roads and highways, federal and state safety regulations must be observed and all migration response personnel must use approved safety equipment (i.e. reflective vests and footwear).
10. To avoid congestion and potential danger to the migration response personnel and migrating species, only authorized motor vehicles deemed absolutely necessary for the mitigation activities should be allowed to park or operate at the migration site.
11. Where migration activities occur near state or local roads and highways, state or local traffic safety engineers must be involved in any traffic control necessary to protect the migration response personnel and the motoring public.

Conclusions

Despite careful highway planning, comprehensive environmental assessments, and efforts to protect wildlife, unpredicted and unexpected large scale wildlife migrations across highways can occur, especially with amphibian species like the Western Toad.

Where local expertise and knowledge for a particular species of wildlife is not available, opportunities exist to access expertise on similar species, through networks established by IENE and ICOET, from experts in other parts of the world. It is possible to apply, or modify if necessary, proven wildlife management techniques developed in other jurisdictions to local situations.

Unexpected and/or unpredicted wildlife migrations across roads and highways can be successfully handled to protect both wildlife and the motoring public. For natural resource and transportation agencies, establishing a wildlife migration response protocol can provide an operational framework for timely and efficient wildlife migration management which minimize cost and maximize safety for motorists, wildlife and migration response personnel.

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Wildlife Migration Response Protocol for Highway Operations

1) Purpose

To enable British Columbia Ministry of Transportation and Infrastructure (BCMOT) District staff to respond to unexpected wildlife migrations that occur on existing Provincial highways in a timely, effective and safe manner.

2) Migration Event

A migration occurs when a large number of a single species of wildlife begins moving en masse across a highway for a sustained period of time. Migrations can involve any group of wildlife, including amphibians and reptiles. The causes of migration vary from normal seasonal factors to changes in adjacent land use.

3) Identification of a Migration Event

A migration may be identified by BCMOT District staff through their regular activities, or confirmed by BCMOT District Staff after contacts by BCMOT maintenance contractors, other agencies, law enforcement agencies, the motoring public or the media.

4) Course of Immediate Action

The two main objectives are maintaining the safety of the motoring public and protecting the migrating wildlife. Depending on the type and magnitude of the migration and the potential safety concern to motorists, steps should be taken to ensure motorists are aware of the migration.

If BCMOT District staff determine that a safety concern to motorists exists, they should exercise traffic control, using temporary warning signs as necessary. Where time permits, public announcements should be coordinated through the Public Affairs Bureau. However, when the migration represents a serious immediate hazard, and the Public Affair Bureau staff can not be readily contacted, BCMOT District staff should take steps to notify the local media directly.

Once a migration has been confirmed by BCMOT District staff or BCMOT contractors, and steps taken to protect the motoring public, Ministry Regional Environmental Manager (REM) and the Public Affairs Bureau must be contacted and advised of the migration event. The REM, or appointed designate, shall be the BCMOT person responsible for overseeing the BCMOT migration response. In the case of a large scale migration when the REM cannot be reached, the Environmental Management Section at Ministry Headquarters should be contacted as soon as possible.

5) Protecting the Motoring Public and BCMOT Migration Response Personnel

Where BCMOT managed mitigation activities regarding wildlife migration occur on or close to a provincial highway, steps must be taken to protect the personal safety of those involved in the migration response activities. The following steps must be adhered to:

1. The local BCMOT District Manager, or designate, must appoint a BCMOT staff person to be the Migration Event Commander (MEC) responsible for overseeing the activities of the personnel involved in the event.

2. Recruitment of volunteers should be overseen by the MEC, or designate, through local fish and game clubs, streamkeeper groups and other formal associations so volunteers are covered by the insurance carried by these organizations.
3. During recruitment of volunteers, all personnel must be advised of the chain of command, how to conduct themselves on the highway right-of-way including WCB regulations and requirements, and how to handle the migrating species. They must agree to the conduct requirements in writing.
4. Only those personnel directly involved in the migration mitigation are allowed to be present at the migration location as authorized by the MEC, or designate.
5. Worker Compensation Board (WCB) regulations must be observed and all personnel must use WCB-approved safety equipment, i.e. reflective vests and footwear.
6. Only authorized motor vehicles deemed absolutely necessary for the mitigation activities should be allowed to park or operate at the migration location.
7. All authorized motor vehicles must be equipped with emergency flashing lights.
8. Traffic control may be necessary to protect the migration response personnel and the motoring public.

6) Cost of Migration Response

If the services of a species-specific wildlife expert is necessary to assess a wildlife migration and/or provide the Ministry guidance for handling the wildlife species involved, the Environmental Management Section at Ministry Headquarters shall be responsible for contacting and contracting the wildlife expert.

The BCMOT District, in which the wildlife migration is occurring, shall be responsible for all other wildlife migration associated costs, including, but not limited to, signage, traffic control, vegetation management, species salvage, and temporary fence construction,

7) Media Contacts

The BCMOT MEC should direct all media contacts regarding a wildlife migration to the Communcations Manager for Transportation - Provincial Public Affairs Bureau.

8) BCMOT Regional Environmental Services Contacts

Region 1 – Greg Czernick, Manager, Environmental Services, Phone: (604) 660-8077
Region 2 – Brent Persello, Manager, Environmental Services, Phone: (250) 828-4197
Region 3 – Daryl Nolan, Manager, Environmental Services, Phone: (250) 565-6484

9) BCMOT Writing Services Branch

Sara Haskett, A/Manager, Writing Services Branch, Phone: (250) 387-5705

10) BCMOT Public Affairs Bureau Contact

Jeff Knight, Communications Manager, Public Affairs Bureau, Phone: (250) 356-7707

11) BCMOT Environmental Management Section – Headquarters Contact

Leonard Sielecki, Environmental Issues Analyst, Phone: (250) 356-2255

DOWN THE DRAIN: HOW TO AVOID TRAPPING AMPHIBIANS IN ROAD AND SEWER DRAINAGE SYSTEMS – DESIGNING FAUNA FRIENDLY DRAINAGE SYSTEMS AND OTHER PROTECTIVE MEASURES

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Abstract

The high mortality toll paid by migrating amphibians on roads has been one of the earliest fragmentation impacts recognized. In Switzerland first mitigation measures were implemented in the late 1960's. Actions consisted in collecting migrating individuals in buckets along roads and manually bringing them to the safety on the other side. In the 1970s first amphibian passages were built at sites of regular migration. To date more than 180 road stretches have been mitigated with permanent constructive measures in Switzerland. However the road pavement is not responsible for all of the high mortality. In the 1990's it became evident that many small animals, especially amphibians were also falling into sewage systems or road drainage systems, staying trapped to death. Up to 3500 amphibians have been rescued in one single sewer treatment plant in one year.

In the canton of Argovy in Switzerland the high mortality in certain sewage systems sparked a collaborative effort between maintenance personnel, road engineers and biologists to find solutions. Different escape ramps were developed and tested. The road design was also studied, to see how to keep amphibians out of drainage systems. First recommendations for local maintenance and road engineers were published in 1996 in a limited edition in German. More solutions were tested and proved their efficiency in saving animals. After 10 years of gathered experience, the Swiss Association of Road and Transportation Experts (VSS) decided to take up this work and publish it as an annex to their standards on roads and amphibians, developing a trilingual guideline. This paper presents the most innovative aspects of the guideline published in 2009. The measures tested go from escape ramps to adaptation of curb and drainage design. The presented solutions need to be adapted to each particular situation and are to be seen as design recommendations. By a broader application and thorough follow-ups, it is hoped that design can be further optimized and conflict points better mitigated.

Discussion

Drainage Systems as a Newly Recognized Danger for Amphibians

Transport infrastructure creates barriers for small animals, fragmenting their natural habitat and isolating populations. Roads are also an important source of mortality, especially for amphibians. Our dense network of infrastructure often cuts breeding grounds off from wintering grounds. Amphibians then suffer a high mortality when attempting to cross roads during migration. Already in the 1960's in Switzerland Heusser pointed out the high mortality on roads calling it a massacre. Local nature protection groups started actions to save the amphibians by collecting them in buckets on one roadside and releasing them on the other side. In 1969 the first permanent amphibian passage was built in the canton of Zürich (Grossenbacher 1981). Since then more than 180 road stretches have been mitigated with amphibian passages (Oggier et al. 2007).

More recently it has become evident that not only the pavement represents a mortality risk for amphibians when run over. The drainage system can also be deadly trap. (Elmiger & Trocmé 2007). Detention basins, pumping stations and waste water treatment plants represent the end of an odyssey that begins at the drainage inlet. Border stones, gutters and gullies direct surface water and small animals towards the drainage openings (Fig. 1), as they attempt to cross roads during migration. During dry periods the ambient humidity of the inlet and catch basin attract amphibians.

Once in the drainage system they can no longer escape and are flushed into detention basins, pumping stations or the sewage treatment plant. The walls of the basins are too high and smooth for the animals, so that they cannot crawl out. In sewer treatment plants they are killed by raked bar screens. When the basins are emptied the animals get either caught in the sludge or remain at the bottom.

Personnel of the treatment plants find regularly dead and live amphibians. Where the personnel are sensitive to the problem and motivated, actions have been taken to rescue the animals.

Figure 1. The gutter leads small animals to this curb inlet.

Methodology

Assessing Mortality

Sampling from waste water treatment plants, detentions basins, pumping stations, catch basins and oil separators have shown that amphibians can be found in almost all. In 3 different waste water treatment plants of the canton of Argovy (Wildegg, Zurzach and Baden) nature conservationists collected animals out of the pre-treatment facilities several times a week during a 12 year period. More than 3500 animals were found alive in the sewer treatment plant of Zurzach in 1999. In all more than 61'000 animals were collected over the years. The high number of animals found still alive is astonishing considering they were all collected after first screening. The mortality caused by the raked bar screen and compressor and number of dead animals evacuated in with the pre-treatment sludge is unknown. However the mortality numbers must be very high, when extrapolating the number of gutter openings attracting amphibians on their migration pathways. The total impact of certain roads can be enormous.

Developing Mitigation Measures

The canton of Argovy started in 1992 equipping storm water installations with escape structures for amphibians. The mitigating structures were developed by a group of storm water experts, zoologists, technicians and civil engineers and tried in different facilities. The first experiences were compiled in 1996 for a publication by the Department of civil engineering of the canton of Argovy (Baudepartement 1996). Since then experience has continued to be collected and further mitigation measures have been tested.

The results of this further mitigation have been compiled with the help of the Swiss Association of Road and Transportation Experts into an annex to the Swiss standard on Fauna and traffic – mitigation measures for amphibians (Schelbert 2009). It will be translated from German into French and Italian to allow for a large dissemination through the country.

This paper presents the main results of this work, with the most innovative mitigation measures permitting small animals to escape from storm water and sewage treatment plants.

Mitigation Measures for Detention Basins, Pumping Stations and Waste Water Treatment Plants

Protective Measures

The first priority is to keep animals out of the drainage system. This can be done by keeping animals off of roads altogether with appropriate passages and fencing at main migratory sites, such as described in the Norm SN 640 699 (VSS 2004). However this does not suffice for more diffuse migration where passages cannot be installed. In these situations the numerous curb inlets represent as many points of entry into the storm water drainage system for amphibians. In this case fauna friendly storm drains can help reduce trapping (Fig. 2).

Figure 2. Amphibian friendly storm drain: By setting the curb back so as to permit animals to bypass the drain. In this case the gridding is also narrower, which avoids animals from falling in.

In extended drainage systems it is not easy to locate where animals are entering. For this reason mitigation measures at the end of the system are also needed.

Constructive Principles for Escape Ramps

Detention basins vary much in their design, dimensions and capacity. For this reasons a standardization of mitigation measures is not possible. An adapted solution must be found for each situation. However certain general principles can be retained. A flotation device that can be crawled up on is needed to collect swimming amphibians. Then a ramp that can adapt to water level should be placed in such a way that animals can escape into safe habitat or in to buckets that are then controlled before release (Fig. 3 and 4).

The main principles for mitigation are:

- When designing new detention basins the sump pit should be planned with a side ramp and space for an escape ramp (Fig. 5).
- In a sewage treatment plant the escape device should be placed before pre-treatment screening to avoid later compression in the sludge.
- The escape platform needs to be placed along a basin wall. Amphibians swim instinctively along the walls searching for a structure to climb onto (Fig. 6).
- The escape platform should be in an area with no or little current. Otherwise they are simply swept by.
- The escape platform must reach to the lowest point in the basin (sump pit). The tanks are filled with water during rainfall, which is when amphibians are washed in, but stay empty for long stretches in the year. The escape devices must mitigate the driest periods, when amphibians seek the lowest and dampest sectors.
- The escape ramps should be about 20 cm wide and with a floater, so that when the tank is flooded, the device raises and is less soiled.
- Perforated plates in chromium nickel steel (Fig. 7) with 50 % 6 mm perforations have worked best (Nill 2009).
- For open basins, the escape device should be set on the shaded side or otherwise a sun protection may be necessary. Protection from scavengers should also be provided. The covering of the ramp is usually enough. Frost can also be an issue to be regarded.

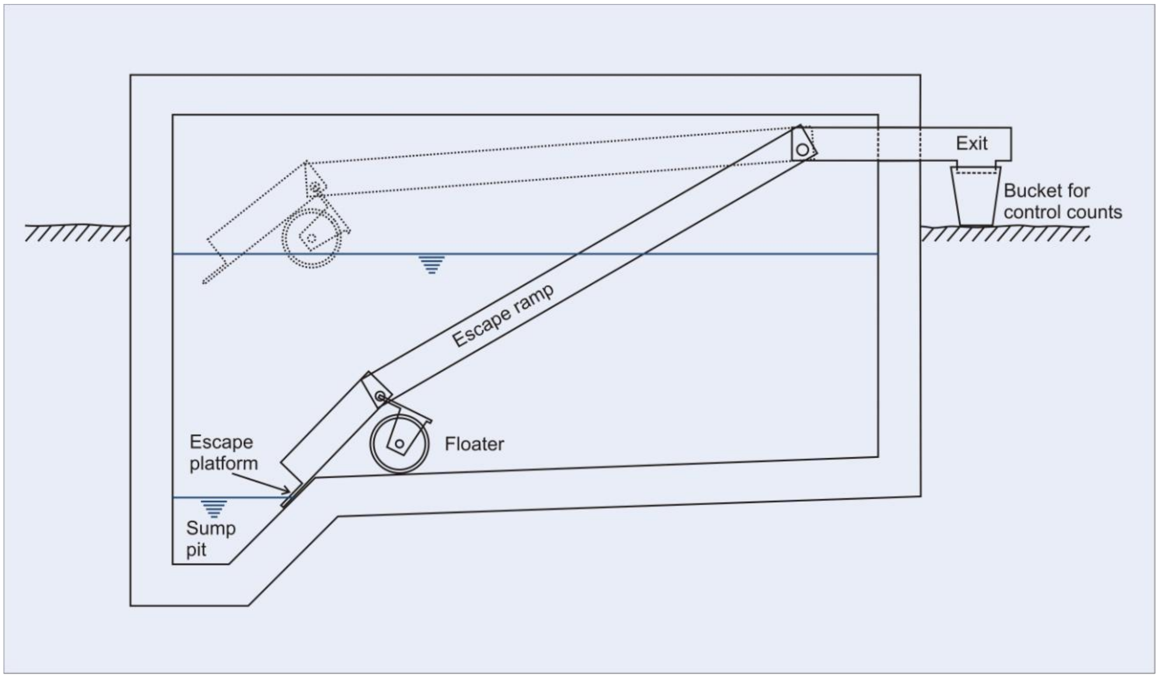

Figure 3. Construction principle with transverse section of an escape ramp in an underground storm water tank.

Figure 4. Example of an escape ramp from an underground storm water tank.

Figure 5. The escape platform must reach to the sump pit.
In narrow systems it is important that design takes such aspects in account early in planning.

Figure 6. To help the animals find the ramp it is important that no space is left between the wall and the escape platform. In this example, the space is closed with a rubber flapper.

Figure 7. Picture showing the perforated chromium nickel steel plates used.

Case Studies of Escape Devices

Escape Devices from Large Open Basins

Most open basins have generous dimensions, so that space can be found for adding an escape ramp. In this case study the storm water basins were of the number of three, each equipped with an amphibian escape ramp (Fig. 8). The escape platforms were each attached to the long side of the basin. The ramps are all articulated and alongside the wall. In this way with the floater the system adapts to the water level. With long ramps, to close the space between the wall and the floater a rubber flap was necessary, which guides animals to the platform. In this example the ramps with a length of 6 m reach the basin bottom but not the sump pit. The pit had itself a ramp and a non-skid covering was added to help amphibians climb out. The ramps have a trapeze shape with the smaller opening towards the top to avoid preying from birds.

Specific problem: The length of the ramps made them delicate and repairs were often needed.

Figure 8. Installation of ramps in every rain retention basins.

Escape Device from Small Open Basins

This escape ramp was mounted in a sewage treatment plant just after the sand catcher and before pre-treatment (Fig. 9). Dimensions were narrow in this case; however a current free area without water level variations was available in front of the baffle. The height out of the basin is so great that an intermediate platform had to be built in. The ramp makes a 90° angle. A cover was provided to protect animals from heat from the sun, so that the device looks like a long box.

Specific problems: In order to guide them towards the top a reflective material had to be used to bring daylight in the ramp. This was enough to attract them to the top. At this point the sky guided them further out.

Figure 9. Lack of space obliged the construction of a steep ramp with 60° and a 90° curve, a protection against the sun is necessary.

Escape Device from Closed Basins

Many amphibians get caught in pumping stations before they reach the waste water treatment plant. In this case study the underground facility has narrow dimensions (Fig. 10). In order to reach the bottom, three different ramps had to be mounted together, with a floater at the bottom. The ramps have a slope of more than 45°. The ramps reach through a hole in the wall and lead animals directly outdoors in freedom. A bucket can be mounted for control counts.

Specific problems: Wood was used in first trials but was found to be too slippery so replaced by perforated nickel chromium steel. The device now works well.

Figure 10. Installation of ramps in an underground pumping station with narrow dimensions.

Escape Device from Narrow Deep Basins

In this case study the dimensions of the underground pumping station were too narrow to allow the installation of ramps. Here a bucket like funnel was devised that could be let down into the sump pit (Fig. 11). The bucket has side ramps allowing the animals to climb up. Under the bucket is a floater. The whole apparatus is attached to a cable and pulley system with a counterweight. This permits the device to adapt to variations of 6 m in water level. The bucket is pulled out periodically by the maintenance personnel that then empty the bucket.

Specific problems: This escape device does not work automatically.

Figure 11. The floating bucket has a shape that does not allow animals to escape once they climb in. It is managed by a cable and pulley.

Discussion

The mortality caused by drainage and waste water treatment systems on amphibians is mostly noticed after construction of the facilities. It is then difficult to retrofit the systems and mitigate impacts. Determination and creativity are needed to resolve the problem. Certain situations cannot be mitigated. Often the strong current in front of the bar screens impede the installation of escape ramps. The narrow dimensions ask for innovative solutions.

The examples presented in this paper were all successful and show that solutions can be found even in adverse situations. However they all depend on motivated maintenance personnel.

It would however be better to design waste and drainage systems from the start with escape ramps. When planned in a fauna friendly manner from the start, the extra costs are insignificant. This is now becoming a standard demand in semi-urban and countryside settings in Switzerland. The publication of these experiences as an annex to standards for road and storm water engineers should help disseminate the gained knowledge and make them more sensitive to the issue. It is hoped that further experience can be gained and solutions optimized. For this a regular control of the success of mitigation measures with consequent reporting is important.

In the past 8 years the Swiss Association of Road and Transportation Experts (VSS) has placed mitigation of conflicts between fauna and roads high on its agenda, with 6 new standards addressing these issues, going from planning habitat and fauna friendly infrastructure through adapted routing and alignments, to mitigation measures and standards for fauna passage of different types.

Biographical sketches

Bruno Schelbert received his Master in Geomatic, Planning and Environmental Engineering of Swiss Federal Institute of Technology of Zurich in 1987 then a Master in Energy Engineering at University of Technology for Architecture, Construction und Geomatic of Muttenz in 2008.

Marguerite Trocmé received her Bachelor of Science in Biology in 1983 from Brown University, Rhodes Island, then a master in environmental engineering at the Swiss Federal Institute of Technology of Lausanne (EPFL) in 1985. After working for the World wildlife fund, she became responsible for environmental project reviewing at the Federal Office for Environment in 1989. Since 2008 she is responsible for the environmental standards at the Federal Road Office.

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'SUSTAINABLE HIGHWAY CONSTRUCTION' IS <u>NOT</u> AN OXYMORON

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<u>Abstract</u>

Sustainable highway construction means applying a broad range of industry-leading sustainable transportation engineering design elements to a major highway project. Building "Green" has become a well-known sustainability concept for office buildings, homes and even manufacturing plants, but it is in its infancy in the highway design and construction industry. "Zero Waste" has become a well-known sustainability concept in the retail product manufacturing industry, but is essentially unheard of for major highway construction projects. This presentation describes a planning and design tool for improving the sustainability of highway projects and an example of its practical application for a proposed 7-mile, $700 million project, the Mid-Currituck Crossing. This will be a Finance-Design-Build-Operate-Maintain major new bridge and highway project for the North Carolina Turnpike Authority (NCTA). NCTA identified a "Waste Free" goal for the entire project, including demolition and construction debris. H. W. Lochner, Inc. has developed an easy-to-apply yet effective Sustainable Transportation Environmental & Engineering Design tool (STEED) to help ensure proper consideration of each of the three components of sustainability: Social, Environmental and Economic, in highway projects of all sizes. Elements of this tool will be presented including their practical application to the Mid-Currituck project. The Mid-Currituck Crossing is expected to be the first major bridge and roadway project to incorporate a broad range of sustainability elements including waste-free goals. It is anticipated that a successful project here will advance the rate of incorporation of sustainability in other transportation construction projects regardless of mode. The number of people living and recreating on the Outer Banks of North Carolina has reached the point where it is no longer possible to conduct a hurricane clearance within NC's maximum standard 18-hour time period. Estimated clearance times for 2004 were nearly 26 hours and would increase to 36 hours by 2045 if nothing were done. The only feasible alternative for providing adequate hurricane clearance capabilities is to build a new corridor to the mainland and improve the capacity of adjacent highways near each end. The NCTA included industry-leading goals in its Request for Proposal. Among them:

1) Adapting the design to include climate change impacts over a 100-year life.
2) Stormwater containment and treatment, including bridge stormwater for a four-mile bridge.
3) Elimination of any offsite requirement for wasting of material.
4) Use of recycled materials.
5) Permeable pavements in parking and/or sidewalk situations.
6) Low energy use lighting and non-carbon producing power sources.

Potential Waste Free activities being considered that are atypical of new highway construction projects include:

1) Deconstruction of existing facilities for materials reuse rather than typical "wrecking-ball and haul" disposal methods.
2) Reuse/recycling of existing materials from the jobsite on the project, including existing concrete driveway paving, foundations and septic tanks, existing asphalt paving, and uncontaminated wood.
3) Identification of already-existing off-site recycled materials that are stockpiled locally for incorporation into the project.

The anticipated results will be a clear demonstration that, in addition to being the right thing to do for future generations, it is financially feasible to incorporate industry-leading levels of sustainable design and operations elements into highway construction projects.

<u>Discussion</u>

Building "Green" has become a well-known sustainability concept for office buildings, homes and even manufacturing plants, but it is in its infancy in the highway design and construction industry.

This paper describes a transportation planning and design tool developed by H.W. Lochner, Inc with the assistance of a number of its clients, for improving the sustainability of highway construction projects. It also provides an example of the practical application of that tool (Sustainable Transportation Engineering and Environmental Design, or "STEED") toward a proposed 7-mile, $700 million project connecting the North Carolina mainland to the state's Outer Banks region at a location known as the Mid-Currituck Crossing (MCC). The example project is a Finance-Design-Build-Operate-Maintain (FDBOM) new bridge and highway project for the North Carolina Turnpike Authority (NCTA).

The NCTA included industry-leading goals in its Request for Proposal. Among them:

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4) Use of recycled materials.
5) Permeable pavements in parking and/or sidewalk situations.
6) Low energy use lighting and non-carbon producing power sources.

While “Zero Waste” has become a well-known sustainability concept in the retail product manufacturing industry, like “building green” it is almost unheard of for major highway construction projects. It is possible that NCTA’s identification of a “Waste Free” goal for the MCC Project will establish it as the first major bridge and roadway project to incorporate a broad range of sustainability elements that include being waste-free. It is anticipated that successful implementation here will advance the rate of incorporation of sustainability (including “waste-free”) in other transportation construction projects regardless of mode.

NCTA’s sustainability-related goals make the MCC Project an excellent candidate for demonstrating the practical application of Lochner’s STEED rating system. STEED is designed to be an easy-to-apply tool that will help ensure consideration of each of the three components of sustainability, Environmental, Social and Economic, in highway projects of all sizes. STEED’s approach differs from other similar tools in that it is designed such that projects are evaluated at four stages; planning, environmental, design, and as-built. This approach is taken because the typical public-infrastructure highway construction project is handed off from the first group of professionals with a particular expertise to second, third and fourth groups; that is, from the Planners to the Environmental Specialists to the Designers to the Construction Managers, and there is a potential for the good intentions of one group to not be well communicated to and/or not accepted by the next group.

Moving the project’s STEED workbook from one team to the next along with the project’s other files, and having the project reevaluated according to STEED at the end of each phase, offers insight as to where the project changed, either for the better or for the worse with respect to its sustainability. This documentation is then intended to provide information useful to the planners and implementers of future projects.
Scoring elements included in the first draft of STEED that was published and distributed for comment by potential users are listed in Table 1 below:

Environmental Quality (EQ)	Social Quality (SQ)	Economic Viability (EV)
Air Quality	Aesthetics & Livability	Life Cycle Considerations
Biodiversity	Cultural & Historic Preservation	Construction Duration
Energy	Equity	Freight Mobility
Land & Geology	Safety & Security	Innovative Use of Technology & Design
Light & Noise	Land Use/Transportation Integration	Modal Connectivity
Materials Sources & Reuse	Public Involvement	Operations & Maintenance
Water Quality & Quantity		User Economic Impacts

Table 1: Rating Elements included in STEED initial published draft

A partial description of these elements as they apply to the example MCC Project follows. STEED elements are italicized. The MCC Project is currently in the Draft Environmental Impact Statement stage with design yet to follow so the anticipated sustainability elements can only be identified as being under consideration at this time.

EQ-1 Air Quality

The term "air pollution" is used to describe contaminants such as dust, fumes, gas, mist, odor, smoke, or vapor in concentrations that can be injurious to human, plant, or animal life, or to property. To improve both short and long term air quality, the EPA has developed standards for many elements and compounds including carbon monoxide, nitrogen dioxide, particulate matter, ozone, sulfur dioxide, and lead. Burning fossil fuels in internal combustion engines is a major source of the aforementioned pollutants.

Because emission rates from vehicles vary according to travel speed and rate of acceleration, improvements to highways can have a positive effect on air quality in a number of ways including changing modal travel patterns, reducing vehicle idling time, reducing congestion and improving traffic flow.

The STEED goal is to improve and/or maintain air quality to a level above that considered harmful according to the EPA. Application to the MCC Project: This project is expected to improve air quality by:

Reducing vehicle emissions through a reduction in vehicle-miles-traveled. A significant number of visitors to the Outer Banks arrive via private vehicle from Virginia and points north. The project will cut approximately 40 miles and one hour for visitors traveling from Coinjock to Corolla. The one hour is assuming free-flow conditions which seldom occur from late spring to early fall. On summer weekends the time to cover those 40 miles can stretch to several hours, with thousands of motors alternately idling and accelerating the entire time. The MCC Project is estimated to reduce vehicle miles traveled by 12.9% compared to the no-build situation.

Reducing vehicle emissions through congestion relief and improved traffic flow. Adding the Mid-Currituck crossing will effectively separate traffic heading from about Duck northward to Corolla on the Outer Banks from traffic heading for about Duck southward to Hatteras while it is on the mainland, substantially reducing congestion on both HWY 158 on the mainland and HWY 12 on the Outer Banks. The FDBOM team is also proposing a roundabout in lieu of a traffic signal at the eastern end of the new alignment which will reduce emissions associated with idling and accelerating from stop conditions at the traffic light. The MCC project is expected to reduce congested vehicle miles traveled by 39.2% compared to the no-build situation.

EQ-2 Biodiversity

Flora and fauna diversity varies around the world, and depends on climate, altitude, soils and the presence of other species. A significant number of the Earth's species have been formally classified as endangered or threatened and with the ongoing trends toward climate change some scientists estimate that there are millions more species actually endangered which have not yet been formally recognized.

The STEED goal is to protect biodiversity to the greatest practical level.

Application to the MCC Project:

The Mid-Currituck Crossing will shade the waterway under it including areas of environmentally sensitive near-shore Sub Aquatic Vegetation (SAV). The project is also in the pathway of night-migratory birds that could potentially be confused by the flare associated with typical street lights. The project is expected to protect biodiversity by:

The FDBOM team is proposing a roundabout at the east end of the project as noted under Air Quality above. If a normal signalized intersection is used the widening for turn-lane storage will have to extend out onto the structure, increasing the area of shaded SAV. Using a roundabout eliminates the need to increase the structure width beyond that necessary to carry the through lanes.

LED pedestrian- and street-lights are anticipated to provide highly focused lighting for the facility while substantially reducing any upward flare that might affect night-migratory bird species.
Waterway crossings will be designed to ensure safe passage for both aquatic and terrestrial wildlife. This will be part of the MCC Project design.

Waterway crossings will be designed such that water quality impacts are minimized and aquatic and amphibian species and their habitats are protected. This will be part of the MCC Project design.

EQ-3 Energy

The STEED goal is to encourage conservation of energy to the maximum extent possible and to have a corresponding minimized impact on the earth.

Application to the MCC Project:

Vehicle flow is smooth and synchronized by balancing capacity and signal coordination. The MCC Project is anticipated to smooth vehicle flow via the aforementioned roundabout at the eastern end of the project as well as reduce energy-consuming congestion between the intersection east of the existing Wright Memorial Bridge and the community of Duck.

The illumination system is designed and built to maximize efficiency of light sources. The MCC Project is anticipated to use LED lighting for both pedestrian and street illumination. The suggested roundabout would eliminate the energy consumption associated with operation of a traffic signal.

Total fuel consumption for the movement of people and goods will be reduced. As noted above, both total vehicle miles traveled and congested vehicle miles traveled will be significantly reduced as will the fuel consumed by excessive idling and stop-and-go traffic conditions.

Solar or another renewable energy source is used for traffic control, information or other uses. The MCC Project is anticipated to include solar energy panels to supply a portion of the energy needed for the toll booths and an operations office building.

EQ-4 Land & Geology

A transportation facility will consume land by its very existence. How the project affects the land and the underlying geology can affect project sustainability. The safety impacts of slides, rock falls and other geologic consequences can be significant. Flooding can damage or destroy roadways, bridges and other structures. Last, the economic impact of failing to adequately consider the geology and land itself can be significant. Optimal solutions lessen these impacts.

The STEED goal is to assure the least possible impact to land surfaces and minimize geological failures, both during construction and operation.

Application to the MCC Project:

The 100-year storm and flood impact has been evaluated to protect the project and to have no increased downstream impact. The MCC Project structures will be designed to a 100-year life, including best estimate allowances for rising sea level (potentially exceeding two meters) and increased storm surge associated with global climate change.

EQ-5 Light & Noise

Both vehicle lights and the lighting of the transportation facility itself can adversely affect animals and plants nearby. Light from vehicles can flash onto properties or into homes, disrupting various human and animal activities. Street lights can increase ambient light levels such that sleep patterns can be disrupted.

Transportation facilities by their very nature also generate noise. Noise is unwanted sound that adversely affects the quality of life of those exposed. Noise can disrupt conversations both indoors and outdoors, and can be so intrusive as to make normal activities difficult.

The STEED goal is to reduce the adverse effects of light and noise from the facility to levels that would exist without the facility.

Application to the MCC Project:

Luminaires, such as full cut-off fixtures, are used to minimize light dispersion beyond the facility. For the MCC Project it is anticipated that LED streetlight fixtures will be installed that will focus light on the facility and minimize glare to neighboring properties and flare and its potential adverse effects on night-migratory birds.

Energy efficient light fixtures, such as LED or low pressure sodium, are used. For the MCC Project LED fixtures are anticipated for lighting both pedestrian and street areas. If the suggested roundabout is not installed, the signalized intersection is expected to use LED signal heads.

Any abatement measure is compatible with the character of the adjacent land use. As is typically the situation, residents are interested in noise walls and businesses are interested in preserving the sightline from the highway. Measures that might be installed for the MCC Project have yet to be determined.

Noise barriers are made from recyclable materials. If noise barriers are constructed on the MCC Project this will be a consideration.

EQ-6 Materials Sources & Reuse

Transportation projects often use significant amounts of materials. Some of the materials used are recyclable. Some of the materials are from renewable sources, most are not. Consideration must be given to avoidance of hazardous materials, use of recycled and longer-lasting materials and an overall reduction in construction waste. The STEED goal is to maximize incorporation of recycled and reused materials, minimize use of non-renewable materials, and minimize construction and demolition waste.

Application to the MCC Project:

Wherever possible the design avoids the use of materials in ways which may cause harm to people, plants, or animals if released into the environment. This will be a design goal for the MCC Project.

Existing paving materials, such as concrete or asphalt are reused or recycled within this project's construction. The MCC project goal is to recycle all such materials into the construction.

Other existing materials and/or fixtures are reused within this project's construction. The MCC Project will also inventory and evaluate existing nearby but off-site stockpiles of recycled materials for incorporation into the construction.

Methods for reducing construction waste, such as using mulched material from clearing/grubbing activities for landscaping which would otherwise be taken to a landfill or incinerator are used. The MCC Project anticipates deconstructing buildings with salvageable materials. Materials with a logical use would be incorporated into the construction; other materials would be sold or donated to reuse-supply stores or organizations. Unpainted wood products too small for practical reuse as lumber are expected to be ground up for use as landscape mulch on the project. The MCC Project is the first major transportation project the author is aware of with a "Waste Free" goal having been identified by the owner.

Existing topsoil is salvaged and reused on cut and fill slopes within this project, or stockpiled by the owner for use as topsoil on another project. This will be evaluated for the land potions of the MCC Project during the design process.

Existing native plant materials are salvaged and reused within this project or kept in a nursery-like environment for use on other projects. This will be evaluated for the land potions of the MCC Project during the design process.

EQ-7 Water Quality & Quantity

Transportation projects have many potential impacts on water resources. Storm water runoff quality and quantity, water usage during construction and operations, water reuse, erosion control, and the overall impact on the receiving body of water or aquifer all can affect water quality.

The STEED goal is improve water quality to a level better than that existing before the project.

Application to the MCC Project:

Stormwater runoff from this project will be cleaner than the pre-project condition. The MCC Project anticipates using porous pavements wherever possible to maximize infiltration and the associated natural filtering of stormwater that would otherwise become runoff. These porous pavements will, in some cases, replace imperious pavements thereby decreasing runoff water quantity while improving its quality.

The landscaping maximizes use of native plants or plantings that require no irrigation or irrigation for plant establishment only. ("Plant establishment" period cannot exceed three years.) This is anticipated for the MCC Project.

Stormwater will be contained entirely within the project limits. Infiltration will be used as much as possible on the MCC Project. Stormwater from the near-shore portions of the main structure will be collected and treated prior to release.

Stormwater runoff will decrease on previously developed sites as a result of this project. Driveways and parking lots will be removed from acquired properties. New driveways, parking areas and pedestrian paths are anticipated to be constructed using porous paving materials to increase infiltration and thereby decrease runoff volume.

SQ-1 Aesthetics & Livability

A transportation project can both positively and negatively impact a community in the areas of aesthetics and livability. A project can physically divide a community, or it can be designed to blend in with the community and provide benefits beyond those for the through traveler. The project should enhance the visual and cultural character of the community while promoting a safe and efficient environment for other modes of transportation.

The STEED goal is to match the needs and desires of the community with that of the motoring public.

Application to the MCC Project:

The project uses art in the design of walls, bridge rails, concrete texturing at crosswalks or similar design amenities. Under consideration for the MCC Project.

The project enhances view sheds to and from the transportation facility. While it is arguable that building a bridge where none has existed before is not an enhancement, the MCC Project is striving for an aesthetically pleasing structural solution.

The number of trees and canopy size within the project area is increased at least 20% compared to pre-project levels. A substantial amount of logging has recently occurred within and adjacent to the proposed alignment. The MCC Project is anticipated to restore areas that are within the acquired rights-of way.

SQ-2 Cultural & Historic Preservation

Transportation projects can have major impacts on the appearance and character of a community. Planners and designers should strive for minimum disruption to the community and the environment. Impacts to historic or archaeological sites, traffic calming, wider sidewalks, preservation of scenic landscapes, retention of street trees and bridges are common concerns.

The STEED goal is that projects will be in harmony with the community by preserving historic and cultural resources.

Application to the MCC Project:

The project has been designed and constructed to preserve and/or enhance the integrity of archaeological resources. The alignment was selected to miss an historic property (the Daniel Saunders house) on the west side of Currituck Sound.

SQ-3 Equity

Equity (also called environmental justice or justice and fairness) refers to distribution of impacts (benefits and costs) across an entire community. Transportation planning and infrastructure decisions can have significant and diverse equity impacts including but not limited to; quantity and quality of transportation choices, imposition of indirect and external costs, socially unbalanced land use changes, and uneven investment outcomes. For example, economics drive project location toward least cost solutions, which may create a disparate impact on a low income neighborhood. Owners must take care that decisions are not solely cost driven.

The STEED goal is to provide equal consideration to all members of affected communities.

Application to the MCC Project:

Where applicable, adverse impacts on low income or minority groups are mitigated in a manner satisfactory to the resource agencies with jurisdiction. The NCTA is currently developing the Environmental Impact Statement. The MCC Project is not anticipated to create any disproportionate impacts to low income or minority groups.

All segments of the community were given full and fair opportunity to participate in the decision-making process and will receive similar benefits from the project. Residents of the communities of Coinjock, Aydlett and Corolla provided significant input regarding the locations for alignment alternatives.

SQ-4 Safety & Security

Safety and security have long been recognized as essential elements of civilization. Freedom to enjoy our surroundings, to work profitably, and to raise a family depend on the belief that we will have reasonable safety and security. Considering safety we note that transportation causes over 40,000 deaths each year in the United States alone. While much has been accomplished to reduce injury and death rates through a combination of factors, transportation design remains an area where further reductions can be accomplished.

The STEED goal is to minimize risk of death and injury.

Application to the MCC Project:

The project is projected to reduce motor vehicle related serious injuries or deaths by 20% or more. The proposal of a roundabout in lieu of a signalized intersection at the eastern end of the primary structure will significantly reduce the potential for serious injuries or deaths at that location by nearly eliminating the possibility for the right-angle collisions that can happen when a motorist fails to stop for a red light.

Curvilinear roadway sections are designed to reduce the probability of roadway departure, and road side obstacles are outside the clear zone or designed as breakaway. As with nearly all projects constructed on new alignments, the MCC Project will have little difficulty meeting this STEED requirement.

The project reduces the number of vehicular access points to the roadway, thus reducing points of conflict while still providing users reasonable access. Summer weekend traffic on NC 158 (the mainland side) makes entering and exiting private driveways problematic. At least one county road and a number of driveways are anticipated to be closed with new access provided via an improved intersection and new access road.

SQ-5 Land Use/Transportation Integration

Linking land use and transportation encompasses a holistic view of development. That includes planning to better coordinate land use and transportation; accommodate pedestrian and bike safety and mobility; provide and enhance public transportation options; improve connectivity of road networks; and take a multi-modal approach with supportive land use development patterns.

The STEED goal is to maximize integration of land use policies with transportation infrastructure development.

Application to the MCC Project:

The design supports the local and regional land use priorities. The primary land use on the northern end of the Outer Banks is vacation rentals, primarily single-family dwellings. Vacationers typically drive a family vehicle to reach the Outer Banks but once there may choose to walk, jog, bicycle, rollerblade, etc to reach nearby amenities and attractions. The MCC Project includes facilities to accommodate and encourage these alternative modes of travel.

SQ-6 Public Involvement

Public involvement is a common element in transportation project selection and design. Since these projects affect the businesses and neighborhoods in the vicinity, as well as the users of existing facilities, the list of those affected is large. Despite its common use, successful implementation of public involvement, and particularly its relationship to sustainability, has varied tremendously.

The STEED goal is to engage the public early, include sustainability as a specific item for input, listen to all the issues, learn from them, and reflect the results in design elements.

Application to the MCC Project:

Public Involvement has been an important part of NCTA's planning and environmental impact work that is still under way. Public Involvement during the design and construction process will be addressed in accordance with the requirements of NCTA.

EV-1 Life-Cycle Considerations

Sustainability involves creating harmony among the environmental, social and economic elements of a project. Designs based on lowest initial cost without consideration for long-term costs and efficient use of non-renewable resources can significantly increase long term costs and/or reduce positive economic and environmental attributes of an otherwise successful project. Initial design and construction costs must be controlled without sacrificing the project elements that provide the needed function for the long term as well as meeting long-term sustainability goals.

The STEED goal is to meet the project goals at the least life-cycle cost, avoiding changes during construction that would negatively affect the sustainability aspects of the project.

Application to the MCC Project:

A life-cycle cost analysis was done to ensure that long term costs were considered in the project decision-making process. Because the MCC Project is a Finance-Design-Build-Operate-Maintain project that will be funded with bonds and paid for via tolls, minimizing long term costs will be a significant factor.

The life-cycle cost included sustainability elements such as: maximizing reuse of existing materials, maximizing use of recycled materials, maximizing use of renewable resources, and minimizing use of non-renewable resources. This fits the established (by NCTA) sustainability goals for the MCC Project.

Construction specifications prevented the modification or elimination of long-term benefit or sustainability-related project elements, including via contractor Cost Reduction Incentive Proposals (CRIPs), unless the CRIP provides equal or enhanced identified long-term or sustainability-related goals. Specifications have yet to be established for the MCC Project, and since this is a Design-Build project traditional CRIPs do not apply, but given the sustainability goals established by NCTA it is anticipated that the intent of this STEED requirement will be met.

Designs are consistent with the skill set of local contractors (excluding recognized highly specialized elements where local contractors may not have the necessary expertise.)

EV-2 Construction Duration

Minimizing construction duration reduces project impacts and costs, and thereby can enhance the environmental, societal and economic elements of project sustainability. Prolonging construction time can add inflationary costs, increase congestion and access issues, increase air, noise, and water pollution, and waste resources. Duration is typically most affected with an efficient and constructible design, and contract documents designed to minimize contract time.

The STEED goal is to minimize construction duration to reduce environmental, societal and economic impacts.

Application to the MCC Project:

Accelerated construction technologies were implemented to minimize contract time. This is the nature of Design-Build work and the MCC Project is not an exception.

Materials were selected to help reduce the contract time. Examples include off-the-shelf rather than custom-built elements, elements prefabricated off-site and out of the critical path, pre-cast concrete, and high-early-strength concrete. There are many others. Minimizing the construction duration is important in getting the revenue stream flowing for toll-financed projects so this will be a significant focus area.

Detailed constructability reviews specifically considering construction duration were used in the design process. As noted above, this is the nature of Design-Build endeavors like the MCC Project.

A Construction Public Information Program is used that informs those impacted during construction, and offers alternate routes or other options to minimize impacts. The MCC Project will coordinate all Public Information with NCTA.

The project was designed to coordinate construction activities to make best use of environmental permit "windows", and to try to use less work time than allowed for in those permits. Again, the toll-financed nature of the MCC Project dictates a timely and efficient schedule.

EV-3 Freight Mobility

Our nation's internal economy and global competitiveness depend on transportation infrastructure. To meet shipper just-in-time or expedited freight deliveries many more "18-wheelers" will be using America's highways and bridges (up from 2.7 million in 2004 to 3.7 million in 2016). Truck Vehicle Miles Traveled (VMT) are expected to increase 3 percent annually through 2020, compared to 2.5 percent for passenger vehicles, and the volume of goods shipped by trucks is projected to increase 98 percent by 2035, with trucks carrying 80% of the nation's freight. As additional commerce corridors projects are planned and constructed, sustainability must be considered to preserve quality of life.

The STEED goal is to maximize the efficiency of moving freight across the country by improving freight-related infrastructure in a manner consistent with sustainability goals.

Application to the MCC Project:

The project reduces freight travel times either directly or with signed routing. There is little commercial activity on the Outer Banks that would generate or receive significant freight shipments beyond items consumed locally. The MCC Project will reduce VMT, travel time and energy consumption for freight deliveries from and to Virginia and points north.

EV-4 Innovative Use of Technology & Design

Innovation has been a major factor in societal evolution, particularly in the last 100 years. Its influence continues to expand at an increasing rate; bringing solutions that were fiction only a few years before.

Transportation has benefited greatly from this technology advance.

There is an abundance of transportation-related research and innovation in all three of the sustainability areas—social, environmental and economic. Social research and innovation ranges from public involvement techniques to highway and vehicle safety improvements. Research and innovation in the environmental area address both cleaning up past problems and avoiding future problems. And the economic sector continues to be a major driver in dealing with all of the above.

The STEED goal is to encourage innovation as a path toward an improved transportation system, with an integrated balance of sustainability. STEED points will be given if the project implements new technology and/or clear innovation over existing practice, or is identified as or becomes the de-facto pilot project for new concepts that:

- Improve project delivery efficiency.
- Improve system efficiency.
- Reduce project cost without increasing life-cycle costs.
- Reduce life-cycle costs.
- Reduce societal impacts.
- Reduce environmental impacts and/or provide environmental restoration.
- Assists any of the other elements in achieving their stated goals.

Application to the MCC Project:

All of the above are potentially applicable but because the design portion of the Project has yet to begin any applicable innovations have yet to be documented.

EV-5 Modal Connectivity

The ability to move and easily transfer between and across town, city, county or region by various transportation modes is essential to meet the multiple needs of a mobile society. Only with a comprehensive multi-modal transportation

system will the public have the flexibility to choose a mode of travel that meets their societal and economic needs. Well-designed access facilities are also essential to safely and conveniently transfer between modes for people and their luggage to reach their destinations, or to send goods to markets and customers.
The STEED goal is to provide a safe, multi-modal transportation system with efficient and convenient modal transfers.

Application to the MCC Project:

The project provides safe pedestrian and/or bicycle movement through the project area. Most pedestrian/bicycle facilities in the project area are already separated from the roadway.

The design provides easy access from various local travel modes to long distance travel modes, such as air, intercity rail, or intermodal freight systems. As noted previously, the MCC Project will reduce VMT and congestion associated with trips to and from the Outer Banks.

The project exceeds minimum ADA access requirements. This has yet to be determined, as the design phase is not yet under way. Given the typical grades and cross-slopes involved it is likely that ADA minimums will be exceeded.

EV-6 Operations & Maintenance

The overall economic efficiency of a transportation project includes consideration of its Operations and Maintenance (O&M) cost.

The STEED goal is for the project design to minimize the O&M contributions to total life-cycle cost.

Application to the MCC Project:

The preferred alternate for the project was selected in part for lowest life-cycle costs and projected over the next 25 years; the project will require an O&M outlay of less than 25% of its construction cost. The design details of the MCC Project will be selected in part for lowest life-cycle costs. The ratio of the 25-year estimated O&M outlay to estimated construction cost has yet to be determined.

The life-cycle cost analysis included labor, equipment, materials and non-renewable energy costs of operation and maintenance. The life-cycle cost analyses have not yet been done, but are anticipated to include these items.

Reusable/recyclable materials were chosen over non-reusable/recyclable materials for sustainability reasons. Materials choices have not yet been made, but are anticipated to include these criteria.

Materials selection evaluations included minimizing use of non-renewable energy. Materials choices have not yet been made, but are anticipated to include these criteria.

The project included use of longer-maintenance-cycle, and/or low power elements such as LED lighting and solar panels. The MCC Project design has not begun, but as noted in the energy section above, both LED lighting and solar panels are anticipated to be included.

EV-7 User Economic Impacts

Transportation is, and will continue to be, a key economic driver in every community and every region across the country. Transportation projects sometimes provide local, regional or national economic benefit for the users at the expense of individual economic benefit, and sustainability is oriented toward the well-being of society in general rather than the well being of each individual, with the most desirable situation being when society's needs can be met without negative impact to one or more individuals.

The STEED goal is to design a project that meets the purpose and need while minimizing adverse economic impacts to the users.

Application to the MCC Project:

All foreseeable project environmental mitigation, construction, O&M, and other direct costs have been estimated over the planned life of the facility. This effort is under way.

Travel time benefits, including time savings, vehicle operating savings, accident reduction savings, and other savings been estimated for the project using recognized methodologies. Earlier work on the MCC Project has included these types of studies.

The project was evaluated for direct and indirect economic benefits and impacts, and the evaluation shows an overall economic benefit for the community and region. While there is little doubt that the establishment of the MCC corridor will have economic benefit for the region, the primary purpose for the project is safety. The number of people living and recreating on the Outer Banks of North Carolina has reached the point where it is no longer possible to conduct a hurricane clearance within NC's maximum standard 18-hour time period. Estimated clearance times for 2004 were nearly 26 hours and would increase to 36 hours by 2045 if nothing were done. The only feasible alternative for providing adequate hurricane clearance capabilities is to build a new corridor to the mainland and improve the capacity of adjacent highways near each end.

Conclusion

The anticipated results of the MCC Project, besides providing a much needed hurricane evacuation route, will be a clear demonstration that, in addition to being the right thing to do for future generations, it is financially feasible to incorporate industry-leading levels of sustainable design and operations elements into highway construction projects.

Closing Challenge

Humans are consuming natural resources at a rate that cannot be sustained if future generations are going to survive. Every aspect of life must be adjusted to a sustainable level for the benefit our grandchildren and their grandchildren, and the construction industry is no exception.

Until we have practiced sustainable design and construction long enough that it becomes second nature to us, using a tool like STEED to help us plan, design and construct more sustainably will help us get there. Whether it is STEED or some other tool is not important. What is important is that we see the challenge to become sustainable as a responsibility, one that we owe to future generations.

Biographical Sketch

Mr. Gary Demich, PE, is Lochner's National Director of Sustainability. With a vision that is as important to him personally as it is to the firm, Gary encourages and advances the use of sustainable design solutions within Lochner's transportation projects. Gary's more than 38 years of transportation engineering experience include 13 years as a Regional Administrator for the Washington State Department of Transportation (WSDOT). Whilst at WSDOT, he was named as one of the world's top 25 construction industry newsmakers by Engineering News Record magazine.

Gary's project background includes extensive involvement with sustainable design solutions and the resolution of environmentally sensitive issues. Two such projects – the I-5 Indian Creek Natural Stormwater Treatment Facility in Olympia, and the Olympic Region's Landscape Rescue, Reuse, Restore Program – received national recognition from FHWA for Environmental Excellence.

FHWA’s Eco-Logical Program – Case Studies

ECO-LOGICAL: AN ECOSYSTEM APPROACH TO DEVELOPING TRANSPORTATION INFRASTRUCTURE PROJECTS IN A CHANGING ENVIRONMENT

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Abstract

The development of infrastructure facilities can negatively impact critical habitat and essential ecosystems. There are a variety of techniques available to avoid, minimize, and mitigate negative impacts of existing infrastructure as well as future infrastructure development. However, such techniques may not always provide the greatest environmental benefit or may do very little to promote ecosystem sustainability. Concern for ecosystem protection, along with legislation and policy initiatives aimed at fostering an ecosystem-based approach, led an Interagency Steering Team to collaborate over a three-year period to write *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects*.

The Steering Team shared a vision of an enhanced and sustainable natural environment combined with the view that necessary infrastructure can be developed in ways that are more sensitive to terrestrial and aquatic habitats. *Eco-Logical* encourages all partners involved in infrastructure planning, design, review, and construction to use existing flexibility in regulatory processes. The *Eco-Logical* publication puts forth a conceptual framework for integrating plans across agency boundaries and endorses ecosystem-based mitigation – an innovative method of mitigating infrastructure impacts in today’s changing environment.

To test the concepts presented in *Eco-Logical*, the Federal Highway Administration’s (FHWA) Office of Planning, Environment, and Realty initiated a grant program in 2007. Of the 40 applications from across the country, FHWA funded 14 cooperative agreements and 1 interagency agreement, totaling approximately $1.4 million. The number and diversity of applications indicate a changing climate in the field of transportation with a shift to more ecologically sensitive planning.

The selected grant projects incorporate tools and techniques ranging from the integration of environmental considerations in the transportation planning process to the use of Geographic Information Systems (GIS) and public involvement to integrate infrastructure and conservation plans. For example, one project tests and demonstrates how interagency partnerships and a willingness to adapt existing processes can enhance cultural and environmental stewardship in the long-range transportation planning process. The grant recipients represent state and local departments of transportation, federal and state resource agencies, Metropolitan Planning Organizations (MPOs), local governments, Non-Governmental Organizations (NGOs), and one university.

Initial findings from the grant program indicate a successful integration of ecologically sensitive principles into infrastructure planning and project development. By creating and using data-driven tools and processes, the *Eco-Logical* grant projects show that partnering with resource agencies and stakeholders early in the planning and project development processes enhances the preservation of high-functioning ecosystems.

Writing About *Eco-Logical*

The purpose of this study is to describe the origins of FHWA’s *Eco-Logical* program and explain the progress and lessons learned so far from the FHWA *Eco-Logical* grant program. The reader will learn about the following subjects:

- The challenges to providing needed infrastructure in an environmentally sensitive manner and how the *Eco-Logical* publication offers solutions to these challenges.

- The ideological and legal precedent for *Eco-Logical*. Case studies illustrate how the *Eco-Logical* process can be used by different types of agencies.

- The impact of the *Eco-Logical* grant program on both the grant recipients and the agencies that signed *Eco-Logical.*

Identifying a Need for *Eco-Logical*

Addressing the Challenges

America's infrastructure needs continue to grow and evolve. They include constructing new roads in response to changes in population and land use, maintaining and replacing obsolete facilities, and making infrastructure more robust in the face of catastrophic natural and manmade events. Every project – present and future – will have some impact on the surrounding environment.

Mitigation or avoidance of negative environmental impacts is federally mandated under the National Environmental Policy Act (NEPA), federal regulations implementing NEPA, and other laws and regulations. Balancing infrastructure development with environmental protection and stewardship can be difficult without regular interagency communication, with insufficient data, or with a historically narrow approach to mitigation (for example, prior to the U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) joint Final Rule on Compensatory Mitigation for Losses of Aquatic Resources).

Communication Challenges

Interagency communication and coordination should begin as early as practicable in the planning process and should continue throughout the project development process. However, communication can be impeded by limited resource agency staffing, differing agency missions and visions, and past miscommunications. Perceptions of certain agencies as inflexible or unwilling to collaborate with other agencies can lead to a standstill in communication. A past negative experience between agencies can result in a lack of interagency trust, making it difficult to open new lines of communication.

With the passage of the *Safe, Accountable, Flexible, Efficient, Transportation Equity Act: A Legacy for Users (SAFETEA-LU)* in 2005, Congress reconfirmed the value of early interagency communication in both the planning and project development processes. Federal regulations in 23 Code of Federal Regulations (CFR) 450 and 23 CFR 771 discuss the importance of coordination between resource and transportation agencies during both the planning process and the NEPA environmental review process. In addition, both CFR sections indicate that transportation funds may be used to fund resource agency liaisons to participate in the development of environmental mitigation and environmental stewardship opportunities in the transportation planning process as well as to provide input and regulatory review of NEPA project development documents. These agency liaisons provide a direct link between the transportation and resource agencies.

Data Challenges

Insufficient or incompatible data are often a challenge and can contribute to poor environmental outcomes:

- Data are collected and maintained separately across agencies and organizations, allowing projects to move forward without sufficient critical habitat or watershed data. Due to a lack of communication or collaboration among agencies, these data are rarely integrated or shared. In addition, different agencies collect, store, and process data in different ways, leading to technical limitations in combining data.

- Insufficient data make it nearly impossible for agencies to properly establish and prioritize environmental opportunities. Across the United States, there are large data gaps for current ecosystem information. Insufficient funding or not knowing that these data gaps exist can cause important environmental information to be excluded from infrastructure plans and environmental documents.

Permitting Challenges

NEPA and Section 404 of the Clean Water Act require that transportation projects take into account their indirect and cumulative environmental impacts. It can be difficult to identify impacts of individual projects without knowing current infrastructure plans, using project visualization tools, or understanding how several proposed projects, transportation and others, interact within a watershed or ecosystem.

Mitigation Challenges

Historically, agencies used a suite of techniques to avoid, minimize, and mitigate negative impacts of past and present infrastructure projects. These techniques often focused on environmental management at the project scale rather than at the ecosystem scale. Examining environmental impacts on a project scale or halting environmental exploration at jurisdictional boundaries does not always result in the best environmental outcomes or may do little to promote overall ecosystem sustainability.

While project-specific mitigation can be beneficial, performing mitigation based on the location and characteristics of a single project can miss opportunities for minimizing environmental impacts that could be achieved with broader mitigation techniques that operate at an ecosystem level. Without ecosystem-level mitigation, it is difficult for agencies to protect large areas and plan mitigation strategies many years in advance. When mitigation is done on a site-specific, project-by-project basis, permitting agencies must individually review multiple infrastructure and mitigation projects within the same watershed. This can be inefficient and ultimately might not provide the most ecologically sensitive results.

With these challenges in mind, transportation and resource agencies needed a better way of doing business using existing authorities. Through a new interest in environmental issues and collaborative conservation, a collective interest in developing an ecosystem-scale method for infrastructure planning began to surface. This effort and the group of resulting concepts came to be known as *Eco-Logical.*

An *Eco-Logical* Solution

To address the challenges associated with infrastructure planning and construction, an Interagency Steering Team collaborated over a three-year period to produce the publication *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects*. *Eco-Logical* puts forth the conceptual framework for integrating plans across agency boundaries and endorses ecosystem-based mitigation, an innovative method of mitigating infrastructure impacts in today's changing environment.

To address the problems associated with implementing environmentally sensitive infrastructure, *Eco-Logical* uses an eight-step framework for integrated planning. This framework addresses near-, mid-, and long-term activities and can be altered to fit each unique situation. The eight steps are:

1. *Build and Strengthen Collaborative Partnerships:* Collaborative partnerships among diverse groups help to identify where interests and concerns overlap, and thus help to form the basis for an integrated planning process. Such partnerships can begin to be assembled today, and the effects can be both immediate and long-term.

2. *Identify Management Plans:* Management plans that agencies and partners have developed independently are important sources of information in the integrated planning process. Plans could include recovery plans; resource management plans; forest management plans; United States Army Corps of Engineers' (USACE) Special Area Management Plans, and community growth plans. Map products from gap analyses and Non-Governmental Organization (NGO) plans might also be helpful.

3. *Integrate Plans:* To identify the necessary work and determine where it will be done, a regional ecosystem framework (REF) is needed. Although there is no standard for creating a REF, *Eco-Logical* recommends that a REF consist of an "overlay" of maps of agencies' individual plans, accompanied by descriptions of conservation goals in the defined region(s). A REF can afford agencies a joint understanding of the locations and potential impacts of proposed infrastructure actions. With this understanding, they can more accurately identify the areas most in need of protection and better predict and assess cumulative resource impacts. A REF can also streamline infrastructure development by identifying ecologically significant areas, potentially impacted resources, regions to avoid, and mitigation opportunities before new projects are initiated.

4. *Assess Effects:* An early assessment of the effects of proposed infrastructure projects establishes a basis for project predictability as well as environmental stewardship. The REF relates proposed infrastructure actions to the distribution of terrestrial and aquatic habitat, or resource "hot spots." It helps agencies and partners to understand the types and distribution of proposed infrastructure projects so that potential impacts can be

listed in advance of their project implementation. In terms of integrated planning, once these impacts are listed, an interagency team can describe and assess these effects.

5. *Establish and Prioritize Opportunities:* This step combines data from steps 3 and 4 of creating a REF in order to establish and prioritize opportunities. Step 3 (Integrate Plans) helps to provide an understanding of where existing conservation areas are and where additional ones could be best located. The effects assessment from step 4 elevates awareness as to how proposed projects can impact ecologically important areas. By looking at these data together, the relative importance of a state's potential mitigation and/or conservation areas can be established and prioritized.

6. *Document Agreements:* To achieve success in integrating plans, including an evaluation of mitigation opportunities, it is important to have administrative records of agreements between agencies. Agreements help ensure commitment by endorsing agencies and can help encourage flexibility in fulfilling the requirements and intentions of environmental regulations.

7. *Design Projects Consistent with Regional Ecosystem Framework:* The benefits of integrated planning should be apparent at the project level. With this approach, planned infrastructure projects that go forward should not surprise resource agencies. If an action agency has been involved during REF development and is planning a project consistent with that framework, the resource agency response(s) should be predictable. Although new information about the ecosystem may have become available since the plans were integrated, site-specific project issues can be addressed as they arise (e.g., during the NEPA process); they do not have to slow down the entire project development process.

8. *Balance Predictability and Adaptive Management:* Predictability - the knowledge that commitments made by all agencies will be honored - is needed at the project level so resources can be allotted appropriately and schedules can be met. Predictability gives agencies assurance that progress over the term of a project can occur. However, while project development can occur over a short time frame, ecosystems typically change over longer periods. For this reason, agencies will need to work to balance short-term project predictability with long-term adaptive management.

Source: [*Eco-Logical,* FHWA]

The Benefits

What sets *Eco-Logical* apart from other methods of project planning or mitigation is its emphasis on collaboration, data sharing, and developing an REF. The greatest benefit of the REF is that it identifies the most ecologically significant areas in a region and recognizes mitigation opportunities long before projects have been initiated. Having this foresight can help transportation and resource agencies tremendously, saving time and money in the project planning and development processes.

The *Eco-Logical* approach presents several advantages over a traditional approach:

- *Safer, improved infrastructure*: All agencies and stakeholders contribute to the delivery of infrastructure. The collective abilities and knowledge shared within an ecosystem approach should allow a more balanced understanding of ecological and social concerns.

- *Improved watershed and ecosystem health:* It provides systematic approach to the preventive, diagnostic, and prognostic aspects of ecosystem management and to the understanding of relationships between ecological issues and human activities.

- *Increased connectivity and conservation:* Since an ecosystem approach to infrastructure projects takes a broad view of interacting human and natural systems, it can help agencies plan and design infrastructure in ways that minimize habitat fragmentation and protect larger scale, multi-resource ecosystems.

- *Efficient Project Development:* Uncertainty during project development imposes a high cost on agencies and partners, in both time and money. An ecosystem approach fosters cost-effective environmental solutions that can be incorporated early in the planning and design of infrastructure projects.

- *Increased Transparency:* Infrastructure projects developed with an ecosystem approach provide opportunities for and encourage public and stakeholder involvement at all key stages of planning and development.

Source: [*Eco-Logical,* FHWA]

Addressing Legislation, Regulation, Policy and Guidance

Eco-Logical is a new approach to infrastructure planning using existing authorities. The concepts within *Eco-Logical* draw from many sources, including the United States' first major environmental law, NEPA. NEPA inspired a host of other laws, regulations, and guidelines that emphasize environmental stewardship and mandate certain degrees of environmental protection. The Endangered Species Act and the Clean Water Act, among others, require transportation and infrastructure agencies at all levels of government to consider the environment during the permitting phase of an infrastructure project. From the late 1970s to present, legislation, regulation, several Memoranda of Understanding, and Executive Orders have called for a more cooperative ecosystem-focused approach to infrastructure planning.

- *Clean Water Act (CWA), December 28, 1977:* The CWA expanded upon the Federal Water Pollution Control Act, first passed in 1948 but later amended in 1972. This law set water quality standards and made it unlawful for any person to pollute navigable waters. The CWA was revised in 1981 and 1987, although other laws have changed portions of the CWA. Section 404 of the CWA is particularly relevant to *Eco-Logical* as it sets guidelines for permitting discharge of dredged or fill material into navigable waters and requires the permittee to perform compensatory mitigation.

- *Endangered Species Act (ESA), December 28, 1973:* This federal action provided for the conservation of ecosystems essential to threatened and endangered species of fish, wildlife, and plants. The ESA also authorized placing species on the endangered or threatened list and prohibited unauthorized take of endangered or threatened species. The ESA was amended in 1978, 1982, 1998, and 2004.

- *Memorandum of Understanding (MOU) to Foster the Ecosystem Approach, December 15, 1995:* Fourteen agencies signed this MOU that declared that the federal government "should provide leadership in and cooperate with activities that foster the ecosystem approach to natural resource management, protection and assistance" (MOU 1995).

- *Executive Order (EO) 13274 on Environmental Stewardship and Transportation Infrastructure Project Reviews, September 18, 2002:* This EO promotes environmental stewardship in the United States' transportation system. It emphasizes the importance of expediting transportation project delivery while still "being good stewards of the environment" (EO 13274 2002).

- *Executive Order 13352, Facilitation of Cooperative Conservation, August 26, 2004:* This EO ensures that resource agencies work together to implement laws relating to the environment and natural resources.

- *Safe, Accountable, Flexible, Efficient Transportation Equity Act: a Legacy for Users (SAFETEA-LU), August 10, 2005:* As with previous transportation legislation, this legislation addressed many of the challenges facing modern transportation systems such as public and interagency coordination and streamlining project reviews while providing for infrastructure needs as well as environmental stewardship. Particularly relevant are the implementing sections of 23 CFR 450, Planning Assistance and Standards, and 23 CFR 771, Environmental Impact and Related Procedures, which lay out critical approaches to managing environmental impact.

- *Final Rule on Compensatory Mitigation for Losses of Aquatic Resources, March 31, 2008:* The EPA and the USACE joint rule issued "revised regulations governing compensatory mitigations for authorized impacts to wetlands, streams and other waters of the United States under Section 404 of the Clean Water Act" (EPA 2009). This rule sets a preference for mitigation banking over other types of mitigation. The preference for mitigation banking draws from the premise that mitigation should be based on a watershed approach, an important aspect of *Eco-Logical.*

Eco-Logical is not only a response to the preceding legislation, regulation, policy, and guidance; it also supports the environmental stewardship goals of FHWA and demonstrates FHWA's commitment to environmental protection. While the *Eco-Logical* program fulfilled an obligation set forth in legislation, regulation, policy, and guidance, it also brought new awareness to FHWA's environmental goals.

Developing Solutions

The Catalyst

In the late 1990s, the Montana Department of Transportation (MDOT) and the Montana FHWA Division Office recognized a need for a new type of transportation planning. While reviewing a Long Range Transportation Plan (LRTP), both agencies noted that over the next 20 years, the LRTP called for many large infrastructure projects along the U.S. Highway 93 Corridor. The corridor, which traversed a large amount of critical habitat, was also the site of many wildlife-vehicle collisions. These issues created a sense of urgency for developing a new method for infrastructure planning within MDOT and FHWA.

Staff from MDOT and the Montana FHWA Division Office determined that many of the required infrastructure projects would need mitigation. However, they speculated that mitigation done "out of kind" (in a location other than the project site) or prior to constructing the infrastructure projects might have a greater environmental benefit than mitigation done on site and planned concurrent to or after the project. To test this theory, an interagency team comprised of state and federal agencies traveled the entire length of U.S. Highway 93 in Montana and mapped critical wildlife linkage areas. The group analyzed the location of critical wildlife habitat and the locations of the proposed projects and compared the cost and benefits of on-site mitigation against ecosystem level mitigation. From this research, the group concluded that infrastructure planning and construction that considers wildlife at an ecosystem level is beneficial for humans and wildlife. It reduces costs and addresses potential mitigation problems well in advance of infrastructure construction.

After the interagency team shared its results with agencies outside of the research group, some agencies expressed curiosity over the initial Montana research. Non-traditional mitigation solutions, such as out-of-kind and preemptive mitigation, could be permitted under the regulations of that time but had not previously been utilized for avoiding environmental harm and mitigation. Agencies raised the concern that the legal ramifications and necessary paradigm shift for planning and resource agencies to implement ecosystem-level solutions might prevent this new type of planning from being feasible. In spite of these concerns, FHWA decided to explore the ideas developed in Montana at the national level.

Writing *Eco-Logical*

FHWA assembled an Interagency Steering Team, including members of the original Montana team, to develop a method of integrated and ecosystem-based planning that came to be known as *Eco-Logical*. This team included the Bureau of Land Management (BLM), EPA, FHWA, the National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries Service), the National Park Service (NPS), USACE, the U.S. Department of Agriculture Forest Service (USDAFS), the US Fish and Wildlife Service (USFWS), the Volpe National Transportation Systems Center, the Knik Arm Bridge and Toll Authority, the North Carolina Department of Transportation, the Vermont Agency of Transportation, and the Washington Department of Transportation.

The Steering Team spent nearly three years developing the concepts and preparing the publication *Eco-Logical*. The group deliberated over the details to be included to ensure that the needs of all participating agencies were met and that the product would be helpful to infrastructure and environmental professionals across the country.

The group began with a shared vision that drew from the work in Montana. There was also a shared belief that it is possible to achieve "an enhanced and sustainable natural environment, combined with the view that necessary infrastructure can be developed in ways that are more sensitive to terrestrial and aquatic habitats" (*Eco-Logical* 2006).

The Steering Team established four goals that became the drivers for *Eco-Logical*:

- *Conservation:* Protection of larger scale, multi-resource ecosystems;
- *Connectivity:* Reduce habitat fragmentation;
- *Predictability:* Knowledge that commitments made by all agencies will be honored, i.e., that the results and outcomes of planning and conservation agreements will occur as negotiated; and
- *Transparency:* Better public and stakeholder involvement at all key stages in order to establish credibility, build trust, and streamline infrastructure planning and development.

Source: [*Eco-Logical,* FHWA]

From these initial four goals, the team established the major components of *Eco-Logical.* After years of conversation and deliberation, in October 2002, the team drafted the final *Eco-Logical* document. The authors of *Eco-Logical* believed in the importance of the document and reached out to the highest levels of their agencies to sign the *Eco-Logical* document. In April 2006, leadership from the Steering Team partner agencies, including representatives from USDAFS, FHWA, BLM, USACE, USFWS, NPS, EPA, and NOAA, signed the document. The recognition by leaders in each of these agencies signified a joint acceptance of the document and an agreement to promote and support *Eco-Logical* into the future.

Supporting *Eco-Logical*

In the years following the publication of *Eco-Logical,* many members of the original Steering Team continued to meet and discuss how to implement *Eco-Logical*. Together, this team and several other key individuals created a vision and implementation plan for *Eco-Logical.* Major components of this plan were outreach, promotion, and support. Through these efforts, the group believed that agencies would come to adopt *Eco-Logical* and incorporate its concepts into their planning and construction activities. The team also identified additional methods and locations to target in the future.

One such opportunity for interagency coordination came on March 31, 2008, with the release of the joint EPA-USACE Final Rule on Compensatory Mitigation for Losses of Aquatic Resources. The new rule contains revised regulations governing compensatory mitigation to offset negative impacts to wetlands, streams, and other waters that fall under Section 404 of the CWA. These regulations improve wetland restoration and protection policies, increase the effective use of wetland mitigation banks, and strengthen the requirements for the use of in-lieu fee mitigation. The new wetlands compensatory mitigation standards emphasize best available science, promote innovation, and focus on results. The rule also requires coordination between EPA, USACE, and FHWA to train staff on the application of the new rule.

The release of this Final Rule presented an opportunity to promote the many *Eco-Logical* concepts presented in the rule. Members of the *Eco-Logical* Steering Team conducted a joint webinar training session on the rule and its relationship to *Eco-logical*. The session was helpful in establishing links between the two items and made great strides toward the implementation of *Eco-Logical.*

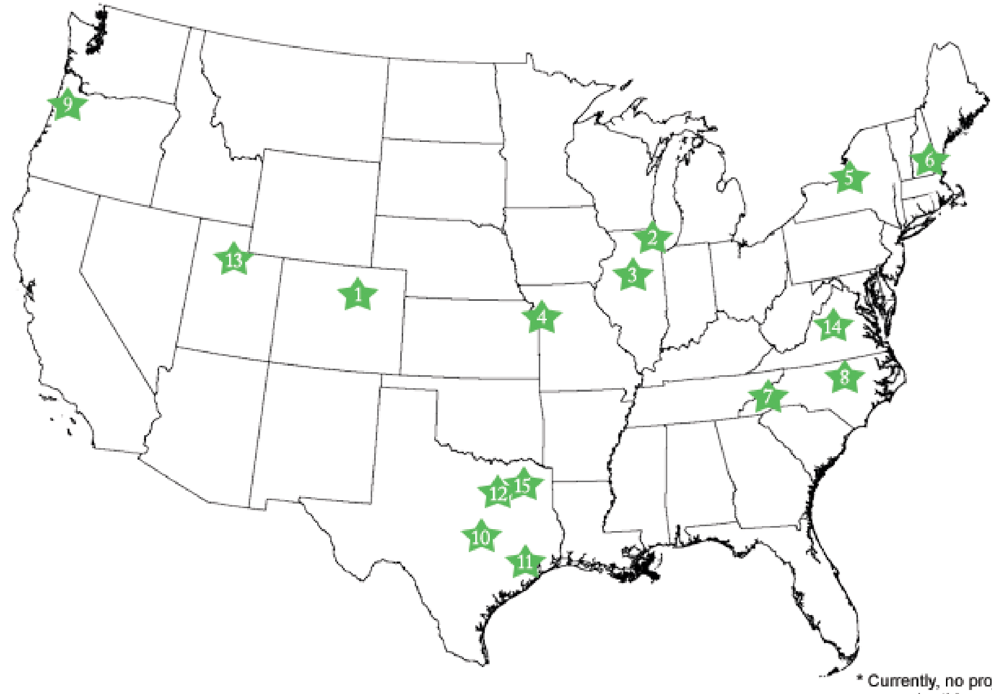
Testing *Eco-Logical* Concepts

To test the concepts presented in *Eco-Logical* for infrastructure planning and project development, FHWA implemented the *Eco-Logical* grant program. This program awarded $1.4 million in matching funds to organizations that planned to implement *Eco-Logical* in some aspect of the transportation planning, development, or construction process. To receive funding, FHWA required these projects to establish or assist in conducting an integrated planning effort and to implement ecosystem-based approaches to infrastructure projects. Federal, state, or regional agencies; universities; and NGOs were eligible to apply for funding. All applicants were required to provide a 50 percent match of non-federal funds or in-kind contributions.

On March 27, 2007, FHWA posted an advance notice for a grant solicitation entitled *Integrating Transportation and Resource Planning to Develop Ecosystem Based Infrastructure Projects,* based upon *Eco-Logical.* The official grant solicitation was open from May 9 to June 22, 2007. FHWA received 40 applications from across the country. This surprisingly high level of response indicated a growing interest in environmentally sensitive infrastructure planning and construction.

FHWA compiled an application review panel made up of 14 people representing several of the *Eco-Logical* signatory agencies. The panel embarked on a rigorous evaluation process to ensure that the projects receiving grants aligned with the goals and concepts of *Eco-Logical.* By participating in the grant review and recommendation process, agencies involved in writing *Eco-Logical* were able to share a stake in the future of the grant program.

Ultimately, the review team selected 15 pilot projects throughout the nation: 14 cooperative agreements and 1 interagency agreement. The grant recipients are state and local departments of transportation, state resource agencies, MPOs, local governments, NGOs, one federal resource agency, and one university. The grant recipients are distributed across the country as indicated in Figure 1.



1. Colorado DOT: Developing a Regional Ecosystem Framework for Terrestrial and Aquatic Resources Along the I-70 Corridor: An Eco-Logical Field Test
2. Chicago DOT: Sustainable Infrastructure Standards for Urban Ecology
3. Tri-County Regional Planning Commission: Regional Transportation, Ecosystem, and Land Use Integration Plan
4. Mid-America Regional Council: An Eco-Logical Approach to Transportation Planning in the Kansas City Region
5. Tioga County Soil and Water Conservation District: Providing Opportunities of Highway Programs in Remediate Natural Resource Concerns in New York
6. Audubon Society of New Hampshire: Creating Tools to Support Integrated Transportation and Resource Planning in New Hampshire
7. Land of Sky Regional Council: Linking Lands and Communities in the Land-of-Sky Region of Western North Carolina
8. North Carolina Department of Natural Resources: Integration of North Carolina's Conservation and Transportation Planning
9. Oregon State University: Using the Ecological Approach to Develop and Implement Conservation and Mitigation Priorities for Oregon
10. Capital Area Council of Governments: Central Texas Greenprint for Growth - a Tool for Balancing Sustainable Conservation Goals with the Infrastructure Needs of our Rapidly Urbanizing Region
11. Houston Galveston Area Council of Governments: Developing a Regional Decision Support System for the Houston-Galveston Region
12. North Central Texas Council of Governments: North Central Texas Regional Ecological Framework
13. Coalition for Utah's Future/Project 2000: Blueprint Jordan River, A Lake to Lake Vision
14. Thomas Jefferson Planning District: Integrating Green Infrastructure and Transportation Planning
15. USEPA Region 6: A Regional Ecological Assessment Protocol

Figure 1: Distribution of Eco-Logical Grant Projects

Case Studies

Of the 15 grant projects, the three highlighted below were chosen to show the diversity of the grant projects. Each project has its own nuances, but as a group, the projects demonstrate how *Eco-Logical* can be applied to many different locations and situations at any scale.

- The North Central Texas Council of Governments (NCTCOG), the MPO for the Dallas-Fort Worth metropolitan area, is implementing an *Eco-Logical* grant project that will develop an REF to integrate transportation and resource agency conservation plans and to improve collaboration between transportation, planning, and resource agencies.

- The North Carolina Department of Environment and Natural Resources (NCDENR) grant project consists of a state agency forging multi-level partnerships, gathering extensive data, and making the infrastructure planning process accessible to the public.

- The Blueprint Jordan River grant project, led by the non-profit group Envision Utah, utilized a broad public involvement process to achieve a consensus vision for improvement, protection, and conservation of the Jordan River corridor.

North Central Texas Council of Governments (NCTCOG)

The Problem

NCTCOG is the MPO for the 16-county North Central Texas region centered around Dallas and Fort Worth. NCTCOG has “over 230 members including all 16 counties [in the region], numerous cities, school districts, and special districts” (NCTCOG 2007). NCTCOG staff recognized a disconnect in their region between the environmental analyses produced to meet NEPA requirements at the transportation project level and those produced to develop “long-range transportation plans, statewide and metropolitan Transportation Improvement Programs, planning-level corridor/subarea/feasibility studies, and the Federal Transit Administration’s planning alternatives analyses” (NCTCOG 2007). NCTCOG also wanted to enhance the coordination and consultation with relevant agencies during the transportation planning and implementation processes to develop a transportation plan that integrates environmental conservation planning resources and strategies.

To encourage stronger consideration of environmental impacts and mitigation strategies during the long-range transportation planning process, NCTCOG recognized that working collaboratively with state transportation and environmental resource agencies would be required.

The Solution

NCTCOG is developing a Regional Ecosystem Framework (REF) for the Dallas-Fort Worth region. The REF includes a description of conservation goals in the region and coordinating maps. Through the REF, NCTCOG is integrating transportation and resource agency conservation plans to improve collaboration between transportation, planning, and resource agencies. When complete, the REF will:

- Allow agencies to better assess the potential cumulative impacts of proposed infrastructure developments at a subwatershed scale;
- Provide agencies with a joint understanding of the areas most in need of preservation; and
- Help agencies identify opportunities for adaptive management and ecosystem enhancements to help agencies reach their conservation goals.

NCTCOG selected three transportation corridors (two highway and one transit) within the Dallas-Fort Worth region’s Metropolitan Transportation Plan to serve as pilot corridors. These corridors are State Highway 170 Outer Loop Interim corridor, State Highway 360 Southern Extension, and the Lake Lavon Transit Line. For each of these pilot projects, NCTCOG is carrying out “a cumulative effects analysis…at a subwatershed perspective versus the traditional project level” (NCTCOG 2009).

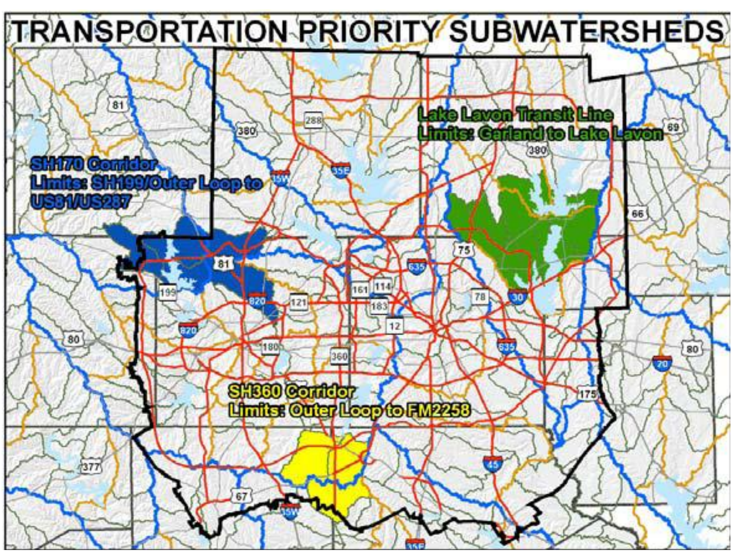


Figure 2: Transportation Priority Subwatersheds, Graphic courtesy of NCTCOG.

Through the REF, NCTCOG is characterizing the current conditions of the three pilot corridors' subwatersheds to gain a broader perspective of ecological issues facing the region. The corridor assessment portion of the REF involves a review of resource agency management plans and GIS data layers for social and environmental information. The MPO is utilizing a cumulative effects analysis to assess potential social, natural, and cultural environmental effects to the selected subwatersheds by the proposed transportation corridors. It will integrate the results of the cumulative effects analysis with the GIS data layers and develop maps that will be used to identify priority conservation areas. The REF will not be a static set of data layers but rather an ongoing collaboration between multiple partners to access and add new information.

NCTCOG will overlay the location of transportation projects included in the existing Metropolitan Transportation Plan on the new natural resource maps to assess the potential environmental impacts associated with transportation projects. Where environmental impacts are identified, NCTCOG will consult resource agencies to explore mitigation strategies that best meet the region's conservation goals. In the future, the REF will be integrated into long-range transportation planning activities to minimize environmental impacts and identify mitigation opportunities earlier in the planning process.

The REF is a critical tool for taking an ecosystem approach to infrastructure development. Through the REF, many agencies in the North Central Texas region will have greater access to the best geographic and scientific data available. This access will improve their planning processes and strengthen environmental stewardship.

The Results

Thus far, NCTCOG has developed an inventory of social, cultural, and natural data through NCTCOG's role as the region's clearinghouse for GIS information. NCTCOG has used the goals of the REF to ensure that the identified cumulative effect categories collectively represent the resources that need to be considered as potentially impacted and, in addition, address the needs defined by regional stakeholders. Cumulative effects in the identified subwatersheds are currently being assessed with GIS technology. The initial GIS base maps are comprised of overlays that represent critical habitat and essential ecosystems, providing a definition of baseline conditions for these study areas. Establishing a baseline is a necessary step in identifying and completing a cumulative effects analysis for the subwatershed-level study areas.

In addition, NCTCOG is currently assessing what future development scenarios would best suit the goals of the REF. An evaluation of the ability of several development scenarios – other than "business (development) as usual" – to account for critical habitat and vital ecosystems is currently underway.

NCTCOG is on track to achieve its final objective of "NCTCOG's Executive Board approval of the Regional Ecosystem Framework in the fall of 2010 in concert with the completion of this grant and the anticipated release of an updated Dallas-Fort Worth Metropolitan Transportation Plan, Mobility 2035" (NCTCOG 2009). The MPO has also made significant strides in interagency communication by establishing new connections and creating an enhanced dialogue between transportation and resource agencies on transportation and conservation planning.

North Carolina Department of Environment and Natural Resources (NCDENR)

The Problem

The State of North Carolina is experiencing unprecedented population growth, with an anticipated 50 percent population growth by 2030. The projected increase in the state's population will require significant improvements to the state's infrastructure. These projects, if not properly planned, will fragment critical habitat and endanger sensitive ecosystems. To provide the needed protections for critical resources, the NCDENR *Eco-Logical* grant project will implement a program to address data gaps and foster collaboration and outreach. It will also enhance and further existing work that will help conserve natural and cultural resources.

In its *Eco-Logical* grant application, NCDENR expressed a concern that "if transportation decisions are not made with adequate consideration of impacts on both cultural and natural resources, it is likely that natural resources of state and national significance will be lost" (NCDENR 2007).

The Solution

In 2004, several agencies came together to form the North Carolina Interagency Leadership Team (ILT). The ILT is comprised of 5 state agencies and 5 federal agencies. State agencies are North Carolina Departments of Transportation (NCDOT), Environmental and Natural Resources, Cultural Resources, Commerce and the Wildlife

Resources Commission. The federal agencies are USACE, USFWS, EPA, the National Marine Fisheries Service (NMFS), and FHWA. The ILT established two goals:

- Develop a comprehensive shared GIS database; and
- Develop local land use patterns and long-range transportation planning to meet “mobility, economic and environmental goals” (NCDENR 2007).

Through this *Eco-Logical* project, the ILT seeks to enhance its GIS database with new layers and to “facilitate planning for transportation projects” and “conservation of cultural and natural resources” (NCDENR 2007). The ILT has chosen Brunswick County as the test area for these principles because of its explosive growth and need for major infrastructure improvement.

To better reach its identified goals, the ILT developed an REF known as the Conservation Planning Tool (CPT). The CPT is an online resource that contains all available information about North Carolina’s most ecologically significant resources and integrates the resource information into a GIS dataset. In order to ensure that the CPT is complete and correct, NCDENR has divided the most important tasks into three major work areas: development of habitat maps, integration of the CPT into the transportation planning process, and digitizing cultural resource data.

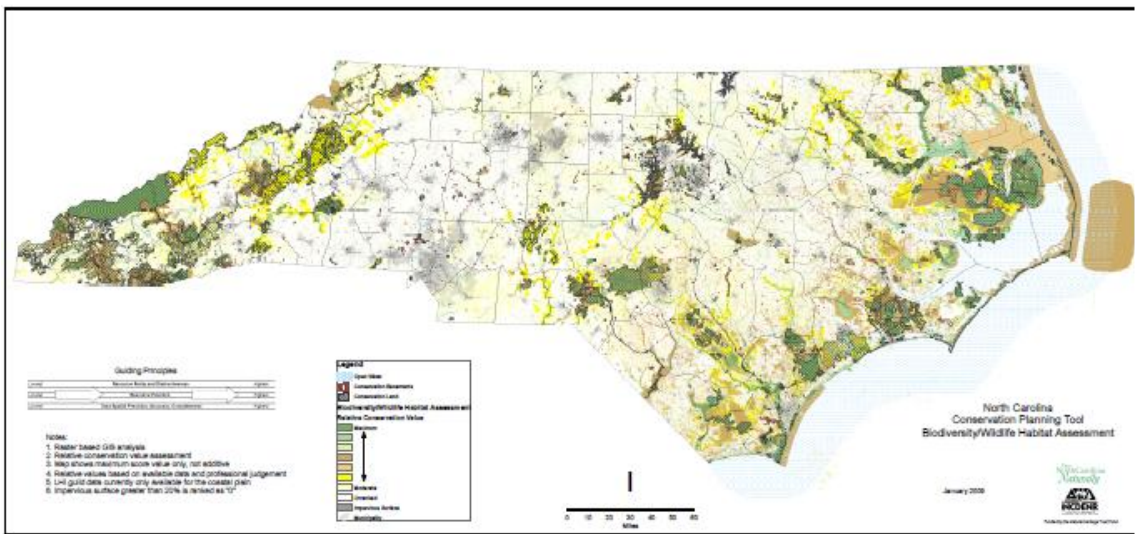


Figure 3: Map from the CPT, Graphic courtesy of NCDENR.

For the CPT to be successful, NCDENR needs to address the major gap in natural resources data. To do this, the North Carolina Enhancement Program, a program of NCDENR, has entered into an agreement with its Natural Heritage Program to develop data about wetland and riparian species (this work was started under a previous grant). NCDENR is working with this partnership to collect data for all upland and inter-basin species.

NCDENR hopes to use the habitat maps to identify the intersection of habitat connectors and proposed transportation projects. Once these intersections are established, the transportation planning community can work to avoid these critical environmental areas. NCDENR aims to use the information provided by this analysis – along with other datasets incorporated into the state’s CPT – to avoid impacts to key landscape units or, where avoidance is not possible, to help minimize the impacts or select appropriate areas for compensatory mitigation (including both preservation and restoration projects).

NCDENR worked with NCDOT to redesign its transportation planning and project development processes, including the use of a more comprehensive environmental screening process. NCDENR believes that the data collected during the screening process would benefit state-, regional-, and metropolitan-level planning. It would also allow NCDENR to work collaboratively with other planning agencies to integrate the CPT.

For over 30 years, the North Carolina State Historic Preservation Office (SHPO) collected data and information about the state's historic properties. In the past 10 years, the SHPO began a long-term project to convert its paper maps into GIS data layers so that the information could be easily shared with other agencies. The NCDENR project builds upon this work and will accelerate the conversion of maps into GIS data layers, thus enabling infrastructure development to take into account historic resources as well as environmental resources in the planning and implementation processes.

In order to understand if the CPT is effective, NCDENR and NCDOT identified an MPO in the mountain region as a pilot site to test the CPT. NCDENR also embarked on a broader implementation of the CPT and regularly presents the CPT at meetings and events across North Carolina. At these meetings and events, NCDENR explains the CPT and encourages local governments and MPOs to utilize the CPT in their planning processes.

The Results

NCDENR's promotion of the CPT has been quite effective; to date, at least eight planning groups, including MPOs, regional planning organizations, and local governments, have fully adopted the tool and committed to using it in upcoming plans. Through emphasizing voluntary utilization of the CPT, NCDENR is finding that communities and agencies are willing to consider and adopt the tool. Strategic partnerships between FHWA, NCDENR, NCDOT, and the Natural Heritage Program have been key to the project's early successes. With these four agencies endorsing the CPT and its integrated approach, NCDENR has gained stakeholder buy-in and plans to continue to develop the CPT throughout the life of the grant.

Blueprint Jordan River

The Problem

The Jordan River is 50 miles long, flowing from Utah Lake north to the Great Salt Lake wetlands. The river flows through 3 counties and 15 cities, each of which holds a major stake in the future of the river. The corridor surrounding the river was once rich with biodiversity. However, population growth throughout Utah demanded more of the river and degraded much of the natural environment surrounding it. These changes to the shape and flow of the river have displaced wetlands and native species. This lowland riparian environment is of critical importance in the region and is Utah's single most important type of habitat for birds. In addition, many citizens have come to view the river corridor as unappealing and efforts to complete a parkway trail have stalled.

The Solution

The NGO Envision Utah began a "Blueprint" process through its *Eco-Logical* grant. This involved developing a media campaign to educate the broader community about river issues, leading committee meetings, running workshops, conducting technical analysis, and drafting a Blueprint report. Envision Utah assembled a steering committee made up of government and community leaders from all the cities and counties affected by changes to the river to make sure that all of the critical stakeholders would be represented in the Blueprint process. Envision Utah also convened a Technical Advisory Committee to ensure that its recommendations were technically correct.

Between May and June 2008, Envision Utah conducted workshops, focus groups, and an online survey to understand the public's preferences for the future of the river corridor. Overall, participants indicated that natural habitat, wildlife habitat, river health, and environmental protection along the corridor were the most important subjects. Participants also shared an interest in recreational opportunities and river-sensitive development in blighted areas that would attract people to the river and create a constituency for its revival.

During public workshops, Envision Utah mapped and prioritized the most ecologically sensitive areas along the Jordan River, identifying 7,800 acres of continuous nature preserve. Workshop participants identified areas appropriate for some regional activity centers. These areas were located in places where regional transportation could spur tourism and recreational activity. These activity centers encompassed 10 percent of all mapped items.

The consensus vision statement for the Blueprint River Jordan is a one-page description that envisions the river corridor as a 50-mile-long greenway with "river centers" that are spaces for "community gathering and neighborhood renewal" (Envision Utah 2009). For this vision to become a reality, all levels of government must work with the community to restore the river environment and update the recreational amenities. The vision statement helped to generate a set of 10 guiding principles that would help the community achieve its goals.

These guiding principles for the river corridor included restoring the hydrologic function of the river, conserving wetlands, and improving water quality. The project team hoped the vision would encourage environmental education, recreation, low-impact development, and reduced automobile access to the river and trails. The consensus visioning process led to a plan to build and strengthen collaborative partnerships between state and federal agencies and among the 3 counties and 15 municipalities along the river.

The Blueprint process devised a system to rate the environmental opportunity of different actions along the river corridor. There are three categories that use the Olympics-inspired names bronze, silver, and gold. Each category has a list of species that could inhabit the area with changes and policy recommendations that would ensure environmental stability. Using this rating system, future planners will be able to determine what environmental benefits each proposed environmental opportunity will bring to the river corridor.

The Results

The Blueprint Jordan River developed a strong action plan aimed at rehabilitating a river that has great potential to improve the lives of those who live around it. The plan established goals and a vision shared by all stakeholders. The project allowed Envision Utah to determine what the region could be like if changes were made with conservation in mind. In the fall of 2008, an implementation committee explored methods to put the Blueprint into action. The committee balanced environmental, recreational, and development interests to identify feasible projects along the river in short and long terms.

Envision Utah views the Jordan River as a “valuable regional asset with unlimited potential” (Envision Utah 2007). The group hopes that the plan developed through the *Eco-Logical* project will preserve much of the river, while improving water quality and recreational opportunities, transforming the corridor into the ribbon that ties communities together. These steps should allow the river to reach its full potential as a resource for the community and regional ecology.

1.	Preserve and rehabilitate natural river features and functions to the greatest extent possible
2.	Establish buffers between the river and the built environment
3.	Restore riparian and in-stream habitats
4.	Replace structural water conveyance devices with alternatives that allow for flood management plus improvements for water quality, recreation, and habitat
5.	Reduce the use of hardscapes and impermeable surfaces in and near the corridor
6.	Manage stormwater on site
7.	Balance needs for development, recreation, and public access with river protection
8.	Incorporate the river's natural and cultural history into designs for riverfront features, public art, education, and signage
9.	Apply design standards for complementary development and redevelopment in the corridor to support increased visibility and recreational use of the river
10.	Encourage regional transportation planning to connect communities to the river corridor, emphasizing non-automobile travel

Figure 4: Blueprint Guiding Principles, Source: [Blueprint Jordan River]

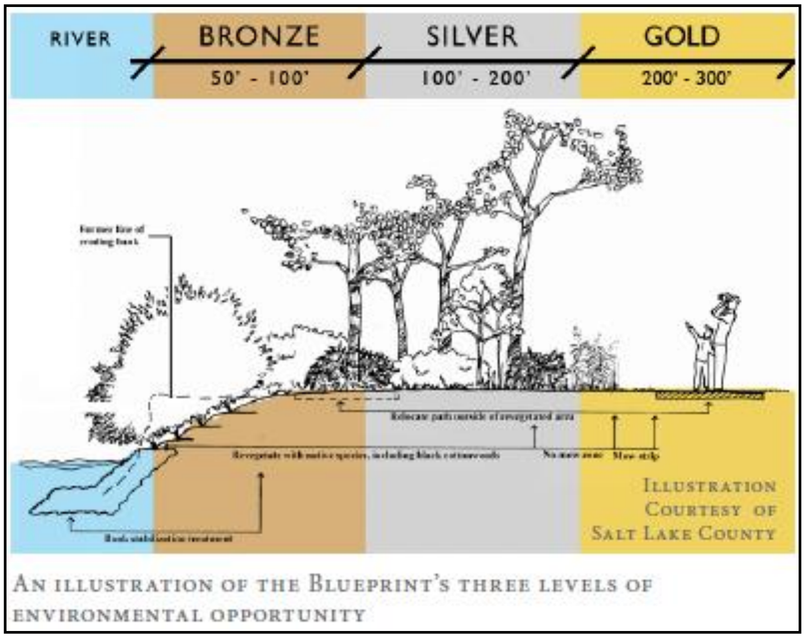


Figure 5: Blueprint Jordan River Opportunity Assessment Source: [Blueprint Jordan River]

Since completion of the *Eco-Logical* project, Envision Utah assembled an implementation committee made up of representatives from the Utah Department of Transportation, the FHWA Utah Division Office, elected officials, and representatives of other local interests. Together, this group plans to create a governance structure that will include a legal mechanism to allow these entities to work together and a funding mechanism to realize the public vision.

By implementing its plan, Envision Utah hopes to protect many acres of natural resources and make miles of recreational resources available to local users.

Conclusions

The first cycle of the *Eco-Logical* Grant program has been an important activity for both the grant recipients and FHWA. Participating in the grant program has helped all agencies involved to experiment and often succeed in developing new channels of communication. Through the grants, plans and data that were previously housed in separate agencies have been integrated and will soon be available to a wider audience.

For FHWA, the grant program has brought new visibility to the agency's environmental role and helped the agency meet legal precedents set in legislation, MOUs, and EOs. The benefits experienced by both groups can be measured through a series of factors that will surely contribute to future environmental benefit.

Visibility

In an interview, one grant recipient stated that the *Eco-Logical* grant program was a critical demonstration to those outside the U.S. Department of Transportation that FHWA holds a stake in environmental protection. While there are many FHWA programs aimed at environmental stewardship, few are as visible and tangible as *Eco-Logical*.

The broad visibility of *Eco-Logical* may, in part, be the result of the interagency involvement in the *Eco-Logical* grant program. Many agencies involved in the various stages of *Eco-Logical* have continued to implement and promote its concepts through newsletters, conferences, and trainings. Every agency has helped make *Eco-Logical* more prominent when planning for infrastructure.

Increased visibility of *Eco-Logical* concepts can help planners to understand which agencies must be involved in the development of infrastructure projects and that an environmentally sensitive method of planning might help agencies reduce costs and implementation time in the long term.

Process Improvement

The *Eco-Logical* grant program not only serves as a mechanism to implement *Eco-Logical*, but it also improves partnerships and collaboration between agencies. Many of the grant recipients indicated that the grant projects helped create successful collaborations between partner agencies that had never worked together, or that had not successfully worked together. *Eco-Logical* aims to build these new relationships to ensure a multi-agency approach to infrastructure development and compensatory mitigation.

Many of the *Eco-Logical* grant projects found that working with historically difficult or argumentative stakeholders has strengthened relationships and laid a strong foundation for *Eco-Logical* work. Through the grant projects, agencies at all levels are now working together; FHWA division offices are working with regional planning agencies, and state resource agencies are making connections to local governments. The strength of new relationships resulting from the grant program will have to be measured over time and through future projects. However, these new ties will ensure that infrastructure planning decisions will be better supported by all relevant stakeholders in a region.

Meeting the Legal Precedents

The FHWA *Eco-Logical* grant program both meets and exceeds the legal precedent outlined through NEPA and its subsequent environmental laws and through the series of EOs and MOUs that inspired the *Eco-Logical* publication. By surpassing these environmental standards, FHWA is setting a new standard in environmental consideration and stewardship.

By implementing the principles outlined in *Eco-Logical* through the grant program, FHWA stands out as an environmental leader, presenting a method to expedite transportation project delivery through planning and to work in coordination with other key agencies. In addition, the grant program extends these best practices across the country at all levels of planning and government. Since many of the projects focus on the early planning and data gathering stages of the *Eco-Logical* publication, one can assume that, if successful, these projects will use subsequent *Eco-Logical* principles in their project implementation process. The precedents set by *Eco-Logical* may help to ensure environmental sustainability surrounding infrastructure projects.

Filling Data Gaps

Many of the *Eco-Logical* grant projects include data gathering and data synthesis components. The number of grant applicants who wanted to focus on these areas confirms *Eco-Logical's* assertion that in many parts of the United States information is spread thinly across agencies or is simply not available. By consolidating existing data and collecting new data, the *Eco-Logical* grant recipients are performing a service to their regions.

Reports from the grant projects indicate that data gathering thus far has been quite successful although there were some initial challenges in gaining stakeholder support for baseline data collection. Through intensive stakeholder involvement processes such as reoccurring meetings, collective visioning, and consistent interaction with stakeholders, most projects have been able to gain the needed support to collect and integrate data.

If agencies located in the regions of the *Eco-Logical* grant projects are able to tap into the consolidated data, future infrastructure projects and infrastructure improvements should be able to avoid environmentally sensitive areas, or should have a full view of appropriate mitigation within the project ecosystem or watershed. Several of the grant projects are creating online data-sharing tools accessible to the public, further ensuring that the collected data is available to all parties who may need it in their work.

Going Forward and Environmental Benefit

The ultimate goal of the *Eco-Logical* publication is to protect and enhance the natural environment while performing necessary infrastructure expansion and improvement projects. Each of *Eco-Logical's* steps was designed to help infrastructure planning and construction achieve better environmental outcomes than in the current state of practice.

The environmental benefits of the *Eco-Logical* approach have already been demonstrated. The *Eco-Logical* grant program's intent to institutionalize the holistic approach nationally is an incremental process. The grants have shown themselves to be effective vehicles in spreading the implementation of *Eco-Logical* through building blocks of change in the grantee organizations and their partners. Future efforts will need to be focused on transferring the implementation knowledge and advancing the approach into a regular state-of-practice.

Acknowledgements
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Biographical Sketches

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MARC's Eco-Logical Project:
A Regional Approach to Linking Environmental and Transportation Planning

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Abstract

The nine-county Kansas City region spans two states, 4,423 square miles, and includes approximately 1.9 million residents. Transportation planning studies have projected that, over the next 20 years, the region is expected to see an increase in miles driven and travel times that far exceed the population growth rate. This trend means that it is becoming increasingly challenging for our region to provide transportation options to those living farther from their jobs and other destinations, greenhouse gas emissions are on the rise, and our natural amenities are at risk of being lost to new development and associated infrastructure.

Figure 1. 9-county Kansas City Region

The current process of developing a new long-range transportation plan, *Transportation Outlook 2040*, provides an opportunity to create more sustainable transportation systems that enhance, improve, and restore the environment. To foster greater interagency collaboration and partnerships, improve data sharing, and create more integrated polices, plans, strategies, and actions, the Mid-America Regional Council (MARC), the Kansas City region's metropolitan planning organization, is carrying out an Eco-Logical project via a grant from the Federal Highway Administration (FHWA).

The Eco-Logical framework supports making infrastructure more sensitive to wildlife and ecosystems through greater interagency cooperation and conservation. MARC's project focuses on three interrelated goals: education, collaboration and ecosystem-based transportation planning. Ultimate project outcomes include the following: i) multi-faceted educational programs structured to foster stronger interagency relationships and understanding of Eco-Logical approaches, ii) the development of a highly collaborative and integrative environmental-transportation planning and consultation process, and iii) a framework to support the creation of a regional, ecosystem-based green infrastructure conservation, restoration and mitigation plan.

As interagency collaboration and partnerships are key to the Eco-Logical effort, MARC convened a Linking Environmental and Transportation Planning Advisory Group in early 2008 to oversee the project. The advisory group includes representatives of natural resource agencies, departments of transportation, local municipalities, non-profit organizations, private sector agencies, and other key stakeholder organizations. One outcome of the group to-date is a *Linking Environmental and Transportation Planning Action Plan*. The action plan, comprising actions for local, regional, and state entities, includes some of the following recommendations: revising planning and funding programs to include scoring criteria for environmental preservation and restoration, collecting better data and utilizing it earlier in the transportation planning process, creating a regional vision to serve as a framework for transportation decision-making, and convening interdisciplinary teams to inform the process.

A new way of approaching transportation planning in the Kansas Region is emerging, based on work completed to-date and feedback received thus far through MARC's Eco-Logical project and *Transportation Outlook 2040*. This vision lays out a roadmap to achieving a more sustainable regional transportation system, where priority natural amenities are preserved and enhanced, prime agricultural land is retained, fewer greenhouse gases are emitted, air quality is good, and impervious surfaces are minimized. Indicators of success will guide us in measuring our progress towards these goals.

Background

In February, 2008, local officials, transportation planners, and environmental agency representatives participated in a two-day "Linking Conservation and Transportation Planning" Workshop to start work on development of an action plan for improving linkages between the natural environment and transportation planning at the local, regional, and state levels. A draft *Linking Environmental and Transportation Planning Action Plan* emerged from the workshop feedback.

The plan has been refined and finalized through MARC's Eco-Logical project, made possible via a grant from the FHWA. With this grant, MARC worked with the consulting team of Shockey Consulting Services, LLC; Parsons Brinckerhoff; and Environment International, Ltd. to 1) Conduct research of integrated planning activities from across the nation, 2) Conduct four workshops to further participants' understanding of the Eco-Logical approach and 3) Finalize the action plan with feedback from the workshops, listed as follows:

- October 28, 2008: Sustainable Transportation Planning with Hal Kassoff
- December 18, 2008: Integrating Plans, Policies, and Projects with Aron Borok
- February 9, 2009: Beyond Mitigation with Cynthia Burbank and Helene Kornblatt
- April 10, 2009: Action Plan Implementation Framework

In May, 2009, the MARC Board of Directors approved the *Linking Environmental and Transportation Planning Action Plan*. The Board's approval is a significant step towards integration of the natural environment into transportation planning in the Kansas City region, as the plan sets the policy foundation for a systematic shift in the region's transportation planning and programming processes. Equally important, in the process of developing the policy direction, stakeholders were educated on integrated planning, and support has continued to grow for this work (as is demonstrated by inclusion of action plan recommendations into the new long-range transportation plan).

Linking Environmental and Transportation Planning Action Plan

The action plan is organized by three priority areas: "Align decision-making with a vision", "Formalize on-going collaboration", and "Create a regional mitigation strategy". Below is a listing of recommendations and discussion of each priority area.

Priority #1: Align decision-making with a vision

a) *Develop transportation plans within the context of a sustainable vision.*

   Sustainable transportation systems are those which meet transportation needs in ways that improve economic, environmental and societal conditions with the capacity for continuance into the long-term future. Sustainable transportation plans include considerations such as coordination with land use and environmental planning; balanced, multi-modal transportation systems; water and air quality; economic vitality, quality of life; and public health. *Transportation Outlook 2040* includes a vision statement that is based on a regional vision of sustainability. MARC's Board of Directors adopted the region's sustainability vision in January, 2009, as part of its Strategic Planning Framework.

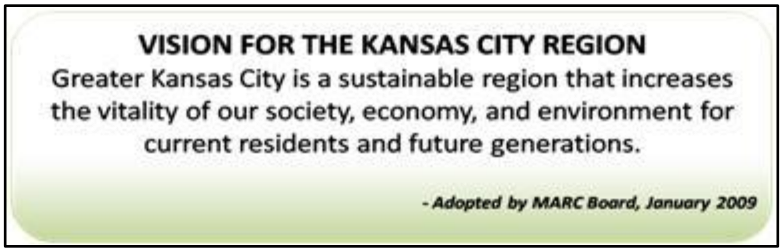

Figure 2. Vision for the Kansas City Region

b) *Assemble and merge transportation, environmental and land use data early in the transportation planning process to support the process and identify high priority natural areas which should be avoided, protected, or restored.*

MARC's geographic information systems department is developing a tool to use in identifying potential transportation-related impacts on natural resources, specifically those identified in the regional Natural Resources Inventory and MetroGreen, the regional greenways and trails plan. This tool will be used in the project evaluation process for *Transportation Outlook 2040*.

Regarding land use data, MARC's Technical Forecast Committee is developing two land use scenarios (baseline and adaptive) for transportation modeling and planning purposes. The baseline scenario projects current land use patterns to 2040. The results show decline at the core, surrounded by limited redevelopment, and widespread, scattered new development. The adaptive scenario shows projected growth, redevelopment and decline by 2040 based on adapting to climate change issues, higher gasoline and electricity prices, less consumption, demographic shifts and changing technology. Throughout the public engagement process for the long-range transportation plan, in addition to other community efforts, support for more adaptable, sustainable land use patterns has emerged.

c) *Convene interdisciplinary teams to advise decision-making processes.*

Feedback from the Linking Environmental and Transportation Planning Advisory Group regarding the long-range transportation plan supplements input gathered via MARC's long-standing transportation-related committees and Air Quality Forum. After adoption of *Transportation Outlook 2040*, MARC's committee structure and composition will be reviewed to ensure alignment with the plan's goals. It is possible that one outcome of this review will be a recommendation to incorporate the advisory group into MARC's formal committee structure.

d) *Measure success of planning efforts and link these measures with the transportation plan's vision and goals.*

Transportation Outlook 2040 will include performance measures that are linked with its vision statement and goals. These performance measures will also be aligned with sustainability indicators that are being developed in conjunction with the regional vision and goals included in MARC's Strategic Planning Framework.

e) *Align transportation project selection and funding distribution processes with the vision, goals and measures outlined in the transportation plan.*

A project solicitation process for *Transportation Outlook 2040* will take place in August, 2009. The project selection criteria will align with the plan's goals, which are accessibility, economic vitality, energy use and climate change, environment, place making, public health, safety and security, system condition, and system performance. Alignment of projects with the plan's goals is an important consideration, as it is likely that more projects will be submitted than can be funded due to fiscal constraint. Fiscal constraint means that the plan can contain only those projects for which funding is secured or can reasonably be expected to be available.

f) *Coordinate public engagement activities across agencies, where possible, to create efficiencies and synergies.*

MARC has been seeking to coordinate its transportation-related and other public engagement activities with those of the Kansas Department of Transportation and the Missouri Department of Transportation, and will continue to seek opportunities for collaboration with these agencies. Where possible, data and feedback is shared among agencies.

g) *Develop new and enhance existing environmental policies for transportation-related construction, operation, and maintenance functions, which would include the following considerations:*

- Stormwater and erosion control best management practices.
- Recycled materials.
- Alternative fuels.
- Anti-idling measures.
- Natural products for de-icing and roadway striping.
- Native plantings in rights-of-way.
- Protection of individual significant trees and areas of established vegetation.
- Protection of wildlife corridors and creation of wildlife passages.

MARC's Clean Air Action Plan and Manual of Best Management Practices for Stormwater Quality (a joint effort with the American Public Works Association) are available as resources for several items listed above. Additionally, MARC is partnering with area planning and design professionals, the 4A Collaborative which includes representatives of the American Institute of Architects, American Public Works Association, American Planning Association and American Society of Landscape Architects, on developing guidance for sustainable streetscapes and parking lots. Additional policies will be developed through the advisory group.

h) *Advocate for a stronger emphasis on the natural environment, including energy, greenhouse gas emissions, and multi-modal transportation options, in the next Federal Surface Transportation Authorization Bill.*

The current surface transportation authorization bill is set to expire at the end of September, 2009. MARC staff members have been working with other organizations to develop recommendations that result in transportation investments which maximize economic benefits, social equity, health promotion and environmental sustainability.

Priority #2: Formalize on-going collaboration

a) *Develop a process for collecting, sharing, and updating transportation, natural resource, and land use data among agencies. The first order of work is to conduct a data needs assessment. These data needs have been identified thus far:*

- Potential ecological restoration sites.
- Floodplains by soil type.
- Stream quality.
- Better wildlife habitat data.
- A more localized, high resolution natural resource data set (Version 2.0 of the regional Natural Resources Inventory).
- Greenhouse gas emissions.

A formalized process for collecting and sharing data between natural resource and transportation agencies has not yet been developed; however, this recommendation was recently identified by the advisory group as a priority area. One data-related project currently being pursued is the identification of resources to update the regional Natural Resources Inventory. Additional work on this recommendation will be pursued after progress is made on priority area #1 (as identified by the advisory group), development on memoranda of understanding (MOU).

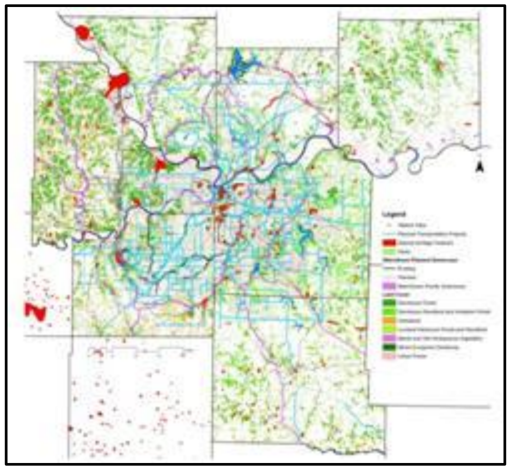

Figure 3. Merged natural resource and transportation data.

b) *Encourage transportation and resource agencies to fund a position dedicated to ensuring coordination of transportation, land use and environmental planning.*

This recommendation pertains to increased organizational capacity for interdisciplinary work. In January, 2009, the MARC Board adopted a Strategic Planning Framework that is based on the vision of a sustainable region. One goal of the framework and subsequent goals, objectives, and strategies is cross-disciplinary coordination. As such, MARC staff coordinates across departments with work teams. Several staff members are tasked with keeping integration at the forefront of their work efforts.

c) *Develop memoranda of understanding (MOUs) between natural resource and transportation agencies to formalize commitments to integrated planning and ensure on-going communication and collaboration*

Development of memoranda of understanding was recently identified by the advisory group as a priority recommendation, as they will set the stage for future inter-agency collaboration. As a first step, MARC staff is reviewing existing MOUs. A draft MOU will then be developed to fill in gaps of these existing agreements and to ensure inclusion of action plan recommendations.

d) *Assist transportation and natural resource agencies in gaining a better understanding of each others' work and planning processes.*

For more effective collaboration, transportation planners and engineers need to be educated about the work of natural resource agencies and vice versa. The advisory group will continue to serve as a forum for educating across disciplines.

e) *Review committee structure and make up to ensure interdisciplinary representation.*

In 2008, a survey was conducted regarding MARC's transportation-related committee structure. Committees have not been restructured, but this discussion is on-going. After adoption of the long-range transportation plan, committee structure and composition will be reviewed again to ensure alignment with the plan's goals. One possible outcome is the formal incorporation of the advisory group into MARC's committee structure.

Priority #3: Create a regional mitigation strategy.

a) *Develop a regional mitigation strategy, which would include the following elements:*

- A regional mitigation bank which directs mitigation dollars to prioritized ecological areas (MetroGreen priority areas) by watershed.
- An authority to manage and implement the strategy.
- Strategies for assisting communities in protecting and restoring natural areas. These include:
    - Compact, mixed-use communities.

- o Redevelopment and infill.
  - o Transit-oriented and pedestrian/bicycle-friendly communities.
  - o Conservation easements.
  - o Stream buffer ordinances.
- Performance measures and regular monitoring for mitigation sites.
- Formal documentation (i.e. MOUs) to memorialize agency roles.

Mitigation currently occurs in a piecemeal manner in communities across the Kansas City region. A regional, watershed based approach to mitigation could further implementation of the region's greenways and trails plan, MetroGreen, while also resulting in air quality, public health, and climate change benefits. Development this strategy is on-going. Resources have been identified for continued training sessions on this topic.

Figure 4. MetroGreen – regional greenways plan

Aside from a coordinated regional mitigation strategy, several local municipalities have adopted ordinances that will result in the avoidance of natural resources. For example, Kansas City, Missouri recently adopted a stream setback ordinance. According to a related fact sheet, the city adopted the ordinance to "…help avoid future liabilities by protecting new development and infrastructure from flood damage, while saving natural resources that provide multiple benefits. Limiting development near stream banks will also improve Kansas City's water quality, reduce erosion and sedimentation, prevent infrastructure damage, and protect riparian corridor habitat and greenways". Additional cities/counties that have adopted stream setback ordinances are: Platte County, Missouri; Lenexa, Kansas; Independence, Missouri; and Overland Park, Kansas.

b) *Develop a dedicated, regional funding mechanism to implement the mitigation strategy.*

Development of a regional mitigation funding mechanism is on-going. A funding mechanism will be outlined in the mitigation strategy.

Conclusion

The *Linking Environmental and Transportation Planning Action Plan* has laid a foundation for greater interagency collaboration and integration of natural resource protection and transportation planning in the Kansas City region. Recommendations from the plan are being included in the new long-range transportation, which means that the plan has real potential for influencing future transportation investments. The plan will also have implications beyond the LRTP. For example, MARC's committee structure and composition will be reviewed after LRTP adoption to ensure alignment with the plan's goals. Additionally, MARC staff is under taking a review of existing Memoranda of Understanding between natural resource and transportation agencies to identify gaps and develop supplemental agreements which would include Action Plan recommendations. These individual actions and recommendations have the potential to move our region in a new direction – one which views transportation systems as a mechanism for furthering broad community sustainability goals and offers transportation options to its residents.

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DEVELOPING AND PILOTING AN ECO-LOGICAL APPROACH TO TRANSPORTATION PROJECT DELIVERY IN MONTANA

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Abstract

The recent federal guidance entitled "Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects", encourages agencies to strategically and cooperatively target ecosystem-based mitigation toward regional conservation priorities, early in the project planning and review process, thereby prioritizing resource allocation and potentially fulfilling regulatory obligations in advance of final design and construction, thus reducing costly delays in project delivery. Eco-Logical defines ecosystem-based mitigation as “the process of restoring, creating, enhancing, and preserving habitat and other ecosystem features in conjunction with or in advance of projects in areas where environmental needs and the potential environmental contributions have been determined to be greatest.” (Brown 2006) When ecosystem-based mitigation is accomplished early in the planning of infrastructure projects, agencies capitalize on meaningful conservation priorities and opportunities that may be vanishing or becoming prohibitively expensive over time, increasing the cost-effectiveness of the mitigation investments. Simultaneously, advanced mitigation planning can be targeted to fulfill regulatory requirements to avoid costly permitting delays in project development and delivery.

Building on the guidance compiled in Eco-Logical, an interagency group in Montana created the "Integrated Transportation and Ecosystem Enhancements for Montana" (ITEEM) process. The broad objective of the ITEEM process is to streamline transportation program delivery while applying more effective ecosystem conservation. More specifically, the goal of the ITEEM process is to collaboratively identify information, issues and opportunities that will be useful in developing alternatives for offsetting adverse impacts associated with multiple transportation projects within a given region. These goals were developed based on the following desired outcomes:

- Conservation: Protection of larger scale, multi-resource ecosystems;
- Connectivity: Enhanced or restored habitat connectivity and reduced habitat fragmentation;
- Early Involvement: Early identification of transportation and ecological issues and opportunities;
- Cost Efficiency: Making the best use of transportation program funding by focusing mitigation efforts where they would be most effective;
- Cooperation: Finding solutions acceptable to all participating agencies;
- Predictability: Knowledge that commitments made early in the planning process by all agencies will be honored – that the planning and conservation agreements, results, and outcomes will occur as agreed; and
- Transparency: Better stakeholder involvement to establish credibility, build trust, and streamline infrastructure planning and development.

Concluding with the unfolding story of the pilot study progress to date, successes and lessons learned of the pilot study will be discussed. It is hoped that this case study provides encouragement and insights to help others develop their own ecosystem approach to streamline transportation project delivery while mitigating adverse impacts where the conservation efforts are most needed.

Discussion

Safe and efficient transportation is a critical component of strong economies and a high quality of life; however, transportation infrastructure can have negative consequences such as habitat loss and fragmentation for fish and wildlife populations (Evink 2002, Forman et al. 2003, National Academy of Sciences 2005, Clevenger and Wierzchowski 2006). While it is essential to efficiently construct and maintain transportation systems to serve our communities, it is equally important to avoid, minimize and compensate adverse impacts to our natural resources. In the United States, the environmental review process for infrastructure project planning and delivery requires reasonable efforts to avoid detrimental impacts to human and natural communities, as well as historic and cultural sites. Nevertheless, unavoidable impacts occur, and responsible parties are legally obligated to offset negative environmental effects to meet regulatory requirements (e.g., Section 7 of the Endangered Species Act, Section 404 of the Clean Water Act). Upon satisfying the terms of the myriad of regulations (see Brown 2006 for a complete list of regulations that must be addressed in the environmental review process), necessary permits are issued and construction is allowed to proceed.

The environmental review process for complex transportation projects is often the most time-consuming part of project delivery (Evink 2002, Government Accountability Office 2003). Traditionally, impact assessment occurs on a project-by-project basis and the task of developing appropriate measures to mitigate adverse impacts can require significant time and effort, sometimes imposing unpredictable and costly delays. Further, efforts to mitigate impacts are commonly directed toward the affected resources at the project site; while this approach may satisfy regulatory requirements, it is questionable whether the ecological integrity of the disturbed area and adjacent habitats can be fully restored. This approach often overlooks other conservation opportunities in the affected region that might offer a better return for the mitigation investments. Recognizing such shortcomings of the environmental review process, Congress incorporated provisions into the last two transportation bills (1998 Transportation Equity Act of the 21st Century and the 2005 Safe, Accountable, Flexible and Efficient Transportation Equity Act: A Legacy for Users) to improve environmental stewardship and expedite the environmental review process for transportation projects (Government Accountability Office 2008).

In response to this challenge, an interagency team compiled guidance and examples for streamlining environmental reviews while more effectively protecting natural resources and ecosystem processes (Brown 2006). Entitled, “Eco-Logical: An ecosystem approach to developing infrastructure projects”, this document encourages federal and state agencies to strategically collaborate to target ecosystem-based mitigation for regional conservation priorities, early in the project planning and review process. By fulfilling regulatory obligations in advance of final design and construction, this approach has potential to reduce costly delays in project delivery while increasing the cost-effectiveness of mitigation efforts by focusing on prioritized conservation initiatives. The product of extensive discussions between infrastructure-development and regulatory agencies, Eco-Logical has earned executive-level reassurances that a flexible ecosystem approach for environmental reviews can be implemented under existing legal mandates.

An interagency group in Montana adaptively applied the ideas in Eco-Logical to create and pilot the “Integrated Transportation and Ecosystem Enhancements for Montana” (ITEEM) process. This chapter examines the events that motivated Montana agencies to rethink the environmental review process and how Eco-Logical influenced the development of the ITEEM process. We summarize the ITEEM process and describe how the process is being debuted in a pilot study effort. Finally, we synthesize Montana’s experiences through the development and initial application of the process thus far, offering insights to other entities that may be embarking on their own path to streamline environmental reviews while improving environmental stewardship.

Historical and Political Setting for the Eco-Logical Approach

In 2002, Executive Order 13274, entitled “Environmental Stewardship and Transportation Infrastructure Project Reviews,” directed agencies to streamline environmental reviews while enhancing environmental stewardship for transportation infrastructure projects. Valid concerns were raised that that the environmental review process would be compromised in the effort to speed up project delivery. To address these concerns and find creative solutions to address the Executive Order’s charge, an interagency team of federal regulatory and infrastructure development agencies (including Bureau of Land Management, US Environmental Protection Agency, Federal Highway Administration, National Oceanic and Atmospheric Administration Fisheries Service, National Park Service, US Army Corps of Engineers, US Department of Agriculture Forest Service, US Fish and Wildlife Service, Volpe National Transportation Systems Center, the Knik Arm Bridge and Toll Authority) as well as Departments of Transportation (DOT) from several states (North Carolina DOT, Vermont Agency of Transportation, Washington DOT), was formed to explore integrated planning approaches to improve stewardship and reduce project delivery timelines. Building on related initiatives that encourage collaborative and balanced conservation approaches to address environmental reviews and mitigation efforts (Office of Environmental Protection 1995, Executive Order 13352 2004) and the “Enlibra Principles” (Western Governors’ Association 1999), the group developed the Eco-Logical guidance promoting ecosystem-based mitigation strategies to improve the environmental review process (Brown 2006).

Eco-Logical defines ecosystem-based mitigation as the practice of coordinating advanced mitigation of infrastructure project impacts by preserving, enhancing and creating habitat and ecosystem functions where such actions are most needed and where such contributions have been determined to be the most beneficial to regional conservation efforts (Brown 2006). When ecosystem-based mitigation is accomplished early in the planning of infrastructure projects, agencies capitalize on meaningful conservation priorities and opportunities that may be vanishing or becoming prohibitively expensive over time, increasing the cost-effectiveness and ecological effectiveness of mitigation investments. Advanced mitigation planning can be targeted to fulfill environmental regulatory requirements to avoid costly permitting delays while making important contributions to regional conservation initiatives. The ecosystem approach balances transportation project delivery and ecosystem conservation objectives, reflected in the following goals defined in Eco-Logical:

- *Conservation:* Protection of larger scale, multi-resource ecosystems;
- *Connectivity:* Reduced habitat fragmentation;
- *Predictability:* Knowledge that commitments made by all agencies will be honored – that the planning and conservation agreements, results, and outcomes will occur as negotiated; and
- *Transparency:* Better public and stakeholder involvement at all key stages in order to establish credibility, build trust, and streamline infrastructure planning and development.

To implement an ecosystem approach, Eco-Logical outlines three components that build upon each other through an adaptive feedback loop: integrated planning, mitigation options and performance measurement (Figure 1), briefly described below.

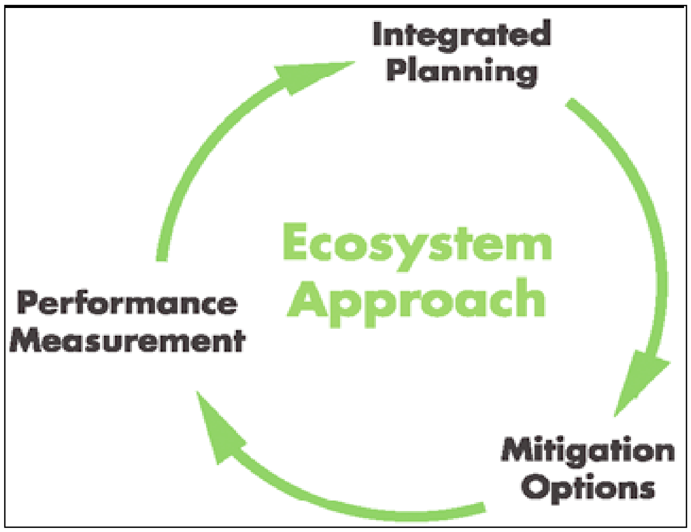

Figure 1. Components of an ecosystem approach, as outlined in Eco-Logical (Brown 2006).

Integrated Planning

Establishing regional ecosystem conservation priorities is key to ecosystem-based mitigation. Integrated planning is pivotal in determining these priorities. Eco-Logical offers an eight step approach for integrated planning. Briefly, these steps involve developing collaborative partnerships, synthesizing information to identify regional conservation concerns and opportunities, considering how anticipated project impacts might be offset by identified conservation opportunities, and prioritizing opportunities that satisfy legal mandates. A consensus-based list of opportunities to offset impacts is then incorporated into the National Environmental Policy Act (NEPA) planning and permitting efforts for the project(s) in question. The final step of integrated planning evaluates how recommended mitigation options that advanced to the NEPA process were incorporated into the final project to address the regional conservation priorities.

Mitigation Options

Eco-Logical describes and offers examples of different mitigation approaches including project-specific mitigation, multiple-project mitigation, ecosystem-based mitigation, off-site and/or out-of-kind mitigation, as well as mitigation banking, in-lieu-fee mitigation, and conservation banking techniques (Brown 2006). Benefits and draw-backs of each type of mitigation approach are explored in Eco-Logical, as are issues of accountability in ecosystem-based mitigation and conservation banking.

Performance Measurement

The final component outlined in Eco-Logical occurs as infrastructure projects are completed and collaborators assess if desired outcomes were achieved. Based on this evaluation, adaptations to improve the next cycle of Eco-Logical steps are documented. The success of the ecosystem approach depends on adapting priorities, acknowledging successes and failures, and searching for solutions to problematic aspects of the process from one cycle to the next.

The concepts behind the three components described above, along with case studies examples and the Executive-level endorsements of Eco-Logical's approach, played important roles in Montana's efforts to create their own ecosystem-based approach to transportation project delivery. Even prior to the release of Eco-Logical, however, there was momentum to create a new approach to transportation project delivery in Montana, prompted by other influential factors.

Rationale for applying an Eco-Logical approach in Montana

In 2002, multiple projects planned for the US Highway 93 (US 93) corridor in northwest Montana were identified as a high priority projects under Executive Order 13274. Legitimate concerns were raised regarding balancing environmental stewardship and expedited environmental reviews along the 460.2 kilometer (286 mile) corridor that traverses important wildlife habitats in the mountains and valleys of western Montana. Stakeholders involved in the US 93 reconstruction (not including projects on the Flathead Indian Reservation; see Becker and Basting, Chapter X) began the process of developing a new, defendable approach to increase the efficiency of the review process for multiple projects while embracing environmental stewardship approaches in the region.

To achieve this goal, an Interagency Review Team (Review Team) was formed with upper-level managers from the Montana Department of Transportation (MDT); Federal Highway Administration, including Federal Lands Highways (FHWA); Montana Department of Fish, Wildlife and Parks (FWP); Montana Department of Environmental Quality (DEQ); Montana Department of Natural Resources and Conservation (DNRC); Confederated Salish and Kootenai Tribes (CSKT); US Environmental Protection Agency (EPA); US Army Corps of Engineers (Corps); US Fish and Wildlife Service (USFWS); and US Forest Service (USFS). The Review Team designated representatives from their respective agencies to form a Working Group to explore more efficient and effective environmental mitigation methods to decrease review times, while upholding important environmental protections in the US 93 corridor.

Despite acknowledging the inefficiencies and inadequacies of the current environmental review system, the Working Group was understandably tentative about possible legal ramifications of revamping the existing review process. The Working Group's momentum slowed as unanswered questions and lack of direction overshadowed the task of finding a plausible path toward streamlining the environmental review process for the US 93 projects. In the mean time, standard planning and compliance processes for the US 93 projects were already underway, such that pursuing a new approach for these projects at that point would be counterproductive in terms of shortening the environmental review timeline.

While little new ground was broken to streamline the US 93 environmental review process, the agencies recognized that they had initiated important discussions to improve the environmental review process. The Review Team asked the Working Group to redirect their efforts toward the Montana Highway 83 (MT 83) corridor, where two future highway reconstruction projects were in the earliest stages of planning, an important consideration when applying an ecosystem approach. By then, the Eco-Logical document was garnering buy-in from leaders of infrastructure and regulatory agencies alike. The FHWA Montana Division Office staff involved in developing the Eco-Logical document recognized that the Working Group might be able to apply the ideas in Eco-Logical to make headway on issues that had previously hindered progress. Per the Review Team's acceptance of the ideas in Eco-Logical, this guidance document was adopted by the Working Group as a foundational resource offering creative approaches to addressing difficult procedural, legal and environmental issues associated with planning, environmental review and project delivery.

With Review Team oversight, a committed Working Group, a focal region with transportation projects in the earliest stages of planning, and guidance and executive-level endorsements offered in Eco-Logical, momentum and direction materialized out of a period of admitted ambiguity. The final component that helped move the process development phase forward was a project coordinator, hired by FHWA to orchestrate the group's efforts and document the resulting discussions and agreements. Over the course of a year, the project coordinator and Working Group explored an array of potential approaches, discarded dead-end ideas, and eventually arrived at a common vision and methods for testing an ecosystem approach in Montana; the outcome of their diligent efforts was the first version of the "Integrated Transportation and Ecosystem Enhancements for Montana," or the ITEEM, process (Hardy 2008).

Integrated Transportation and Ecosystem Enhancements for Montana

The ITEEM goals and desired outcomes, roles and responsibilities, dispute resolution process and tasks to apply the ITEEM process are presented below. The text below is a simplified version of the document used to guide the pilot study (Hardy 2008). The pilot study discussed later in the chapter.

Desired outcome and goals

The desired outcome of the ITEEM process is to balance environmental and transportation values by streamlining transportation program delivery while applying more effective ecosystem conservation. Schedule, cost, safety, quality, public input, regulatory requirements, ecological concerns and other factors are considered equally with no single factor dominating as the top priority. Specific ITEEM goals expand upon the Eco-Logical goals, as follows:

- *Conservation*: Protection of larger scale, multi-resource ecosystems;
- *Connectivity*: Enhanced or restored habitat connectivity and reduced habitat fragmentation;
- *Early Involvement*: Early identification of transportation and ecological issues and opportunities ("issues" refer to potential impacts or concerns associated with the transportation projects under review or regional conservation initiatives; "opportunities" refer to potential options to concurrently address mitigation requirements and conservation priorities);
- *Cost Efficiency*: Making the best use of transportation program funding by focusing mitigation efforts where they would be most effective;
- *Cooperation*: Finding solutions acceptable to all participating agencies;
- *Predictability*: Knowledge that commitments made early in the planning process by all agencies will be honored – that the planning and conservation agreements, results, and outcomes will occur as agreed; and
- *Transparency*: Better stakeholder involvement to establish credibility, build trust, and streamline infrastructure planning and development.

Roles and responsibilities

Stakeholders share responsibility of finding solutions that meet both transportation and ecosystem conservation goals. One representative and an alternate from each participating agency will commit to serving in the ITEEM Oversight Group. Individual representatives in the Oversight Group serve as their agency's point of contact, representing their agency's interests and responsibilities. The Oversight Group will strive for consensus as they negotiate to optimize ecological conservation opportunities while reducing project development time and increasing the predictability of program delivery. It is the responsibility of the Oversight Group to identify issues and opportunities; prioritize opportunities to improve long-term cost-efficiency of mitigation efforts; apply programmatic approaches or establish Best Management Practices as appropriate; document recommendations and establish work groups dedicated to implementing recommendations; establish measures of success to evaluate and adapt the process to better meet goals and objectives; and ensure open and on-going communication between agency representatives and various stakeholders such as non-government organizations (NGOs) and people affected or interested in the project and conservation efforts in the region.

Dispute resolution

In the event that consensus may not be achieved at any point in the ITEEM process, the dispute resolution process establishes a 2-week timeframe for issues to be resolved via the Oversight Group, during which time the conflicting parties will focus on resolving the disagreement via open discussion. If the unresolved issue is not critical to the process, the parties with contrasting points of view can respectfully "agree to disagree" with no further implications; these disagreements will be documented for the record. If the issues must be resolved for the process to effectively move forward and parties are unable to come to a solution within two weeks, the issue will be elevated to the Review Team for upper-level managers to make a final decision.

ITEEM process tasks

The ITEEM process consists of six tasks that may be adapted in the future based on evaluation of the process. Each task is briefly described below.

<u>Task 1: Establish regional boundaries</u>

The Oversight Group will determine the region where multiple transportation projects in the early stages of planning are programmed to be delivered in the future (e.g., 5-20 years) and where conservation issues and opportunities need to be considered in the planning process. This region may be determined based on jurisdictional boundaries but, in striving for an ecosystem approach, the region could be delineated by ecologically-relevant features such as watershed boundaries.

Task 2: Compile and prepare information

With the assistance of a facilitator, participating agencies will be responsible for providing the best available data in a timely manner to identify issues and opportunities relevant to the programmed projects and regional conservation interests. Additionally, the facilitator will hold a public open house to obtain relevant input and information from other stakeholders including the public and NGOs, ensuring transparency by accommodating public involvement early in the process. Examples of the type of information and data to be collected may include the following (see Brown 2006 and Hardy 2008 for an extensive list of information that may be important to consider in the process): land ownership, planned developments & projected land use change; traffic data & projections; conservation easements; State Wildlife Conservation Plan with fish and wildlife species ranges & critical habitat designations; road kill locations & numbers; habitat connectivity models; wetland locations; water quality impaired streams & local watershed management groups' efforts; culvert locations and fish passage data; and other regional collaborative conservation efforts.

The facilitator will organize and present a comprehensive list of the compiled data and sources to the Oversight Group who will determine the final set of information that will be referenced at a collaborative workshop, the next step of the process. The facilitator will document justification for retaining or rejecting data and summarize the final set of information that will be referenced at the workshop; this memorandum will be distributed to participating agencies allowing them to prepare statements regarding issues and opportunities to be discussed further at the workshop.

Task 3: Workshop

The facilitator will organize a workshop for stakeholders to collaboratively discuss possible impacts of the proposed transportation projects and regional conservation opportunities that may could be tapped to offset negative effects. Workshop participation will be limited to the Oversight Group, a few agency technical staff, and representatives from local governments and NGOs with regional expertise and an understanding of the ITEEM process. The workshop may occupy 2-3 days and should be conducted within the identified region to foster a sense of place and facilitate timely field review of potential impact and mitigation sites of interest.

Workshop participants will refer to the information compiled during the previous task to identify issues and opportunities in the focal region at a coarse scale. The facilitator will organize a field review to further discuss and ground-truth the information to better hone recommendations. Potential opportunities determined to be infeasible due to physical, social or land use constraints will be eliminated through consensus. Practical options deemed worthy of further consideration after field review will be documented by the facilitator, and may include the following types of details:

- location, methods and schedule for implementation of mitigation:
- how potential mitigation option(s) offset impacts of the proposed projects and address regional conservation interests, regulatory statutes, and streamlining of transportation project delivery;
- identification of other areas or impacts that could relinquish substantial mitigation improvements in trade for focusing efforts and limited funding on particular conservation opportunities;
- opportunities to leverage funds for collaborative conservation initiatives (i.e., if mitigation can contribute to on-going regional conservation efforts); and
- workshop attendees' preliminary comments on the identified opportunities(s).

Documented opportunities will be prioritized and a final list of recommendations will be established via consensus among participants. Depending on the complexity of any given recommendation (e.g., recommendations that require coordination between several agencies, conservation easements, land swaps, etc.), work groups may be identified to further detail an implementation plan, including responsible parties, estimated costs, and necessary memorandums or agreements. The final list of recommended opportunities, as well the rationale behind culling other options, will be documented by the facilitator.

Finally, workshop participants will establish measures of success to evaluate and adapt the process for future application. Three factions should be considered when establishing measures of success and performance standards. First, the ITEEM process itself should be evaluated; this may include assessing different facets of the process such as data assimilation, identification of issues and opportunities, workshop field review and prioritization approaches and agency involvement. Second, infrastructure projects themselves should be appraised in terms of how mitigation recommendations were incorporated into the NEPA process, how permitting proceeds, and overall time to project delivery. Finally, ecological benefits realized through the process should be evaluated in terms of contributions to regional collaborative conservation priorities and initiatives. The participating agencies will determine appropriate and achievable measures for variables related to desired outcomes. Because it will take years to see many of the outcomes, the Oversight Group should plan periodic follow-up meetings to evaluate measures of success (see Task 6) until the commitments are satisfied completely.

Task 4: Draft workshop report

The facilitator will compile documented recommendations and measures of success established during the workshop into a draft report. Participating agencies will have 45 days to review and comment on the draft report. After revision and agency approvals, the report will be made available for public comment for 30 days. A summary public and agency comments will be included in the final ITEEM report as an appendix, along with a summary of options not adopted.

Task 5: Finalize ITEEM report

The facilitator will finalize the workshop report, including a signatory page to document agency concurrence. The final report will be referred to as the projects are moved through the NEPA review process; ultimately, recommendations put forth in the ITEEM report should expedite the process of finalizing mitigation plans in these planning documents. Oversight Group representatives will continue to serve as their agency's contact for further correspondence regarding the ITEEM report and recommendations.

Task 6: Evaluate and adapt ITEEM process

The Oversight Group will meet periodically (e.g., semi-annually) to revisit the final report, discuss progress and outstanding issues, and to update measures of success. If changes to existing recommendations are deemed necessary, the Oversight Group will find a reasonable approach that all agencies can support. Additionally, the Oversight Group will compile necessary inputs for evaluating measures of success and will document progress, outstanding issues and suggestions to adapt the process in the future. These periodic meetings will take place until all commitments are fulfilled, which may take many years. Once agencies agree the commitments documented in the final report have been met, the Oversight Group will have a final meeting to document lessons learned and recommendations to improve the ITEEM process, resulting in an addendum to the final report, completing a single cycle of the ITEEM process.

Pilot Study: Testing the ITEEM process

The agencies of Montana took a big leap by committing resources to create the ITEEM process (referred to as "the process") as outlined above. Upper-level managers demonstrated their on-going commitment by allocating additional agency resources to implement the new approach in a pilot study. We recount how the pilot study has been carried out thus far, summarizing efforts taken to prepare for the workshop and how the workshop itself unfolded.

The pilot study began in June 2007 with the Review Team and MDT identifying two transportation projects that would be the focus of the pilot study. The two projects were reconstruction/rehabilitation projects for sections of the MT 83 corridor between Seeley, Montana, and the Clearwater Divide (Figure 2). The study area included a 15-mile corridor straddling the road where the two projects would occur and a larger region encompassing conservation interests beyond the road corridor. Issues and impacts related to the highway projects would be assessed within the 15-mile corridor. Opportunities to mitigate aquatic resource impacts would be considered across the entire Clearwater drainage plus the section of the Blackfoot drainage in Missoula County. Mitigation to offset terrestrial impacts would be considered across a larger region stretching from the junctions of MT 83 and MT 35 at the north end, and MT 83 and MT 200 at the south end, and extending from the crests of the Mission and Swan Mountain ranges to the west and east, respectively (Figure 2).

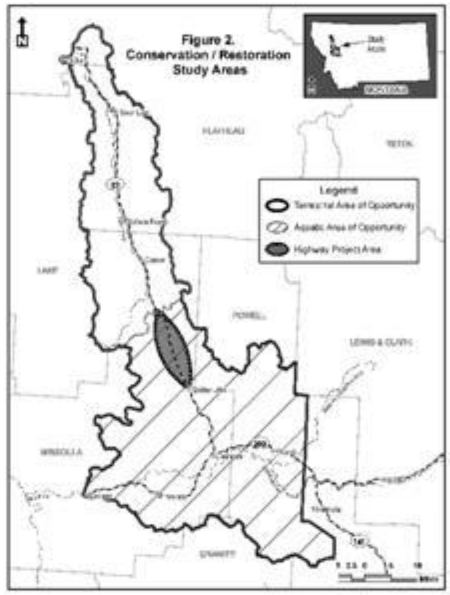

Figure 2. The ITEEM Pilot Study regional boundaries encompassing two MT Highway 83 projects (highway project area) slated for future reconstruction and the larger area where terrestrial and aquatic ecological conservation opportunities were considered as potential targets for mitigation efforts to offset unavoidable impacts associated with the two highway reconstruction projects.

Several characteristics of the MT 83 study area offered an excellent testing ground for the pilot study. First, these projects were in their earliest stages of the planning process, lending an opportunity for the pilot study to potentially influence and streamline the environmental review and permitting processes. Second, by focusing on two highway projects, the pilot study would explore the feasibility of addressing mitigation needs for "batches" of projects rather than using the traditional project-by-project environmental review process. The MT 83 study area encompasses important habitats for several federally-listed endangered or threatened wildlife species (e.g., grizzly bears [*Ursus arctos*], Canada lynx [*Lynx Canadensis*], Bull trout [*Salvelinus confluentus*]), and a number of sensitive plant and animal species as well as big game species. The presence of these species meant that the process would have to specifically address Section 7 of the Endangered Species Act as the projects could impact the listed species' critical habitats and habitat connectivity in the region. Additionally, land use and management in this region is overseen by numerous entities, requiring buy-in from numerous local stakeholders. Further, several watershed-based conservation initiatives and agency management plans were already underway in the region, ensuring that the process would need to consider collaborative partnerships directed at targeting mitigation to address established regional conservation goals.

Four levels of agency involvement participated in the pilot study: the Review Team (upper-level agency managers), Oversight Group (mid-level agency managers granted decision-making authority for pilot study implementation), Working Group (agency representatives most involved in accomplishing the steps of the process), and Technical Staff (agency representatives assisting with compiling relevant agency documents and information). Reporting to the Review Team, Oversight Group members were "the voice" of their respective agencies to make decisions and enter into tentative agreements on behalf of their agency. Working Group members served as the primary point of contact for their agency in the day-to-day tasks of the process and ultimately were the true shepherds of the pilot study. There was mentionable overlap between the Working Group and the Oversight Group members; in many cases the same person served in both roles.

Formal invitations to participate in the pilot study were also extended from MDT to the Commissioners of each of the four counties in the study area region. The invitation emphasized the importance of local buy-in to the process and incorporating future planning, zoning or development projects on the region as these actions could have notable effects on the identification and prioritization of ecological conservation opportunities.

Upon establishing agency representatives committed to the pilot study and defining the specific study area, MDT contracted a consultant to serve as a facilitator in February 2008 to compile information, facilitate the public involvement process and agency workshop, and document the evolution of the ITEEM process for one year as it is applied in this pilot study. The facilitator's multi-disciplinary team, comprised of a project manager, environmental scientists, a GIS analyst, a logistics coordinator and two professional facilitators, embraced the underlying principals of Eco-Logical and demonstrated an understanding of the objectives of the process and goals of the pilot study. A kick-off meeting was held with the Working Group and the consultant to introduce the consultant's project team, determine the list of stakeholders to invite to participate in the process, and identify appropriate contacts for obtaining data. Format and protocols for data acquisition, pilot study timeline, a review of the dispute resolution process, and refinement of the regional boundaries for the pilot study were also addressed at this meeting.

Following this meeting, MDT and the consultant submitted a letter to Working Group members and agency technical staff requesting a list of the best available data that each agency wanted considered during the process, including relevant research studies, reports, point-data, maps and geo-spatial data layers. The letter also asked each agency to prepare a summary of their initial concerns and issues relating to the highway corridor and regional natural resources, along with conservation partnership opportunities in the pilot study region.

To complete the request for relevant information, the consultant advertised a public open house to catalyze public involvement and transparency of the process. Attendance at the open house was sparse, but attendees provided important contacts with several local NGO's that are active in the regional communities and already pursuing endeavors with goals comparable to those of the ITEEM process. Participation by these groups would prove invaluable with respect to local knowledge of issues and opportunities and would later provide a promising avenue for implementation of the pilot study outcomes at the local level.

The consultant spent most of the summer of 2008 compiling and summarizing the data and information for consideration in the process along with the issues and opportunities identified thus far. The Working Group and consultant met to select a comprehensive yet manageable and relevant subset of information and data detailing critical issues and opportunities that would be discussed at the workshop and agencies presented their initial list of issues and potential opportunities that they would be advancing to the workshop for discussion. After this meeting, the consultant summarized the pilot study progress to date for the Oversight Group, including the initial list of identified issues, opportunities and compiled information and data that would be advanced to the workshop.

The workshop, facilitated by the consultant, took place in Seeley, Montana over three days in late October 2008 and was attended by the Oversight Group members and agency technical staff, as well as several local government and NGO representatives. The FHWA representative opened the workshop introductions, an overview of the ITEEM process and the pilot study's progress thus far. Five NGO representatives presented their organizations' respective missions and conservation initiatives within the greater study area. The MDT representative summarized the highway project reconstruction objectives, development process and timeline, after which the consultant provided an overview of the compiled data and maps that would be used to inform decision-making during the workshop.

The afternoon of the first day of the workshop was spent reviewing the compiled fine-scale data used to identify issues and planning considerations in the 15-mile highway corridor and broader-scale information related to potential conservation partnership opportunities throughout the greater study area. Discussions focused on regional ecological resources of interest including wildlife habitat linkages, grizzly habitats, lynx habitats, big game habitats, other sensitive species and species under special management status, bull trout and westslope cutthroat trout habitats, wetlands and recreational sites. Within the 15-mile highway corridor, identified issues fell into six main categories: wildlife permeability, wildlife mortality, aquatic organism passage at stream crossings, water quality, wetland impacts, and adjacent land-use and development (as it may affect the long-term efficacy of some mitigation investments in the highway corridor). Beyond the highway corridor, issues and opportunities within the greater study area included wildlife-human interactions (e.g. due to increasing human development and habitat fragmentation/loss, bear conflicts in residential areas), acquiring conservation easements on private lands identified as important wildlife habitat or movement corridors, watershed management and fish passage restoration, and land-use practices and development pressures on private lands. These identified issues would drive the effort to find appropriate opportunities to address associated impacts during the remainder of the workshop.

On the second day of the workshop, participants travelled the highway corridor, stopping locations where opportunities and issues had been identified, such as stream crossings and areas where wildlife linkage zones intercept the highway. Interactions amongst participants in the field provided better understanding each others' concerns and interests, with significant pay-offs realized on the following day when the group would collectively select a final list of recommendations that would be considered in the NEPA reviews for the projects in question.

The last day of the workshop was dedicated to honing the list of issues and opportunities, dropping those unsuitable for further consideration and prioritizing those remaining for action and implementation. It was suggested that agencies consider establishing a "restoration fund" to augment conservation efforts already underway. Agencies could contribute to the fund in advance of proposed projects while proponents of restoration and conservation projects could apply for monies to address conservation priorities. The securing of conservation easements on other private lands of ecological importance was also proposed. The Nature Conservancy, Trust for Public Land, and Plum Creek had been discussing transactions pertaining to a three-phased purchase of over 300,000 acres in the region over the next two years with the intent to transfer management of these lands to a mix of federal, state and private ownership. This complex transaction could take years to see through, and with these negotiations in their infancy, it was not possible to identify distinct conservation needs that could be addressed on these lands, should they be acquired. The feasibility of advanced investments of this nature requires further investigation into funding mechanisms and to determine if such funds need to be directed toward particular resource management objectives to fulfill permit obligations that the mitigation efforts are intended to address; the agencies are exploring these ideas further.

The group identified the purchase of parcels for wetland restoration as a possibility for interagency partnerships to leverage mitigation monies. The MDT had already established a wetland mitigation program in the region, but additional opportunities for compensatory mitigation were identified, such as adding additional wetlands to an existing wetland reserve or to properties adjacent to the highway corridor with potential wetland restoration opportunities that were noted during the field review. The MDT committed to look into the feasibility of wetland mitigation on these properties in an effort to establish additional wetland mitigation credits in the watershed. It was agreed that while wetland purchase and restoration may not be an immediate need within this particular watershed, if an ideal or important wetland project presented itself, the group would consider it a valid opportunity to collaborate with other stakeholders.

Research directed at understanding specific wildlife movements within the highway corridor was suggested as a potential mitigation outlet. Such research would need to consider the goals of increasing permeability of the highway to carnivore movements and reducing animal-vehicle collisions, particularly with ungulate species. Research of this nature could help identify and prioritize locations where crossing structures and exclusion fencing could most effectively intercept and accommodate wildlife movement across the road corridor, with the potential of incorporating such infrastructure into the future highway reconstruction project. Similar to the ideas suggested above, the group recognized that this would require further investigation regarding funding mechanisms and assurances of the validity of applying research to address regulations that mitigation intends to address.

While the ideas above generated more questions than explicit recommendations, the group was able to identify distinct mitigation recommendations specific to highway project planning and design considerations. Mitigation opportunities suggested for the highway corridor region included fish and wildlife passages in combination with exclusion fencing to guide animals under or over the roadway. Roadside vegetation management to facilitate at-grade wildlife crossings in selected areas where road alignments provide increased sight distances, and where wildlife warning signage or measures such as animal detection systems that warn drivers of crossing wildlife could be installed to reduce animal-vehicle collisions and increase safety. For other areas of the highway corridor, a curvilinear highway design that complemented the unique and wild character of the corridor was suggested along with the minimization of the construction footprint to reduce impacts to habitats near the highway. The inclusion of permanent erosion control facilities such as sediment basins were considered to reduce roadside animal attractants (e.g., to de-icing chemicals) and improve water quality. Potential conservation opportunities to compensate for project impacts across the broader study area included agency partnerships with local grass-roots efforts to facilitate private land acquisition and restoration (particularly in association with the recently-initiated Montana Legacy Project, an effort aimed at conserving important forestland currently owned by Plum Creek Timber Company in northwestern Montana), public education and outreach programs regarding “living with wildlife”, and cooperative efforts to open up large stream reaches to fish passage and wildlife movement corridors across private and public lands. These recommendations would be advanced to the NEPA environmental review process in hopes of shortening the time required to incorporate mitigation into project planning efforts.

The workshop concluded with an exploration of the successes and challenges uncovered during the pilot study to date. Everyone agreed that the pilot study has been a worthwhile endeavor, recognizing that the process is iterative and will be improved over time as the strengths and weaknesses of the approach materialize through implementation. The discussion turned to the transition of continued oversight and management through completion of the pilot study. It was proposed that management of the process after the workshop would shift from MDT to another entity capable of stewarding the commitments through implementation within the Seeley-Swan region over the long-term. The group agreed that, if possible, a local government or rural initiative organization would be the ideal entity for carrying the conservation efforts that emerge from the pilot study to fruition, while MDT and FHWA will be responsible for incorporating design considerations along the highway corridor into the NEPA process and scoping for the future highway projects where the ITEEM process may be applied.

The workshop accomplished many of the tasks described in the original ITEEM process, but several tasks remained after the workshop was finished. The group committed to further developing measures of success, identifying areas for process improvement, following-through on action items generated from Workshop discussions, presenting findings and recommendations to the Review Team for decision-making and documentation of agreements and commitments, and ultimately transferring the MT 83 ITEEM process to a local entity for implementation stewardship.

Following the development of measures of success, the consultant prepared a Draft ITEEM MT 83 Pilot Study Final Report in and circulated it for review and comment from the Working Group and Oversight Group members. The document included a recount of the milestones and tasks as executed through the pilot study; issues and concerns identified as planning considerations for the transportation project development; prioritized conservation partnership opportunities for the study area; and a summation of the established measures of success. A list of considerations and opportunities not advanced by the group, along with the rationale behind those decisions was included in that document.

After agency review and comment, the revised Draft Final Report will be made available for public comment. Public comments will be addressed by the appropriate cooperating agency and incorporated into the Final Report. The document will be finalized, including a list of workgroups formed to develop and execute action items and a schedule of future Oversight Group meetings intended to monitor and discuss the pilot study's progress as agreements and mitigation actions are fulfilled. Once finalized, the MT 83 ITEEM process pilot study commitments will be transferred to an appropriate local entity committed to manage the agreed-upon conservation actions with the assurances of long-term participation and support from the cooperating agencies.

Lessons Learned: Developing the ITEEM Process

Over the years of creating and piloting an ecosystem approach for transportation project reviews, road blocks were encountered. Acknowledging and addressing these setbacks ultimately improved the process, generating lessons learned along the way. We share these lessons to help other groups avoid pitfalls that may commonly be encountered in complex endeavors of this nature.

To start, while Eco-Logical was useful in the effort to develop the ITEEM process, this guidance document did not function as a cookbook with tested recipes guaranteed for success. Rather, examples therein helped participants understand the concepts of an ecosystem approach and how elements of this approach had been applied in other case studies. Further, and perhaps more importantly, Eco-Logical's endorsements by agency executives at the federal level provided Montana's upper-level agency managers reassurances that more creative and flexible approaches can be used while satisfying legal statutes of the environmental permitting processes. The Review Team's leadership was essential and having the Working Group agency representatives in direct communication with upper-level management and decision-making authority helped the group advance through difficult decisions at various stages of developing the process.

As the Working Group developed the process, it was helpful to focus on specific future highway projects. Representatives were better able to obtain relevant (rather than hypothetical) feedback from their agency colleagues by referring to the specific region where these projects would occur, particularly in regards to compiling regional data and information and the agency's initial list of issues and opportunities. Discussion of appropriate projects to focus on while developing the process also highlighted the necessity to work with projects in the earliest stages of development to successfully reduce project planning time and to capitalize on planning advanced mitigation to address regional conservation priorities before they disappear.

The importance of creating an environment of understanding, respect, and cooperation to work through challenging issues cannot be underestimated when working collaboratively to find a common vision amongst groups with different missions and interests. While agency representatives in the workshop had worked together for years, they had not previously been motivated to find the greater good for all when applying the traditional project-by-project method for environmental reviews. The traditional approach to project planning did not require agencies to understand each others' interests and missions resulting in misconceptions that initially hampered true collaboration. The agencies had to develop genuine team camaraderie to find approaches that not only satisfied their particular regulatory mandates but also the interests of the other agencies. Working Group representatives were asked to share professional, educational, personal histories and interests with each other, revealing commonalities that hadn't been discovered despite years of working together. Taking time for representatives to share their agency's mission and management plans further increased mutual understanding between agencies. One-on-one interviews between the project coordinator and representatives illuminated the history of the working relationships amongst the agencies, allowing for more responsive and strategic facilitation.

As the Working Group committed to numerous meetings to maintain momentum while developing the ITEEM process, conference calls and video conferencing were used at times to reduce travel costs, but face-to-face meetings supported team-building and helped maintain the group's momentum and accountability. A computer and projector were used to collectively view, comment on and revise interim products at the meetings, thus reducing the number of individual iterations necessary to finalize the language outlining the process. Agendas were essential to keeping the group on track and also served to document progress made on assigned action items, increasing the accountability of group members.

While developing the ITEEM approach, the Working Group held a two-day meeting in the study region of interest to examine how an on-site workshop might be incorporated into the process. Participants were better able to focus and engage with each other as they set aside other work demands. Intermingling in smaller groups, participants engaged in more effective exchanges that may not have emerged in more formal settings. The group seemed to relax more with each other as casual interactions occurred during interstitial periods and at meals, further building team camaraderie. This experience solidified the need to incorporate a multi-day workshop as a component of the process.

Along the same lines as conducting the field visit, it was useful to carry out proposed steps to reveal how each component of the process might unfold when implemented and what resources might be necessary to do so. With agency technical staff assistance, spatial data layers were compiled in a GIS and displayed to demonstrate the how this information could be used to make informed, collaborative decisions. The exercise prompted useful comments that may not have emerged had the group opted simply to envision how this step in the process might occur. For example, by viewing the digitized data, participants realized that the process should accommodate important information that may not be available in digital spatial data layers. Collectively viewing the projected data on a screen catalyzed group discussion, but the group also concluded that having complementary hardcopy paper maps could facilitate easier documentation of issues and ideas on the maps themselves. Further, while this trial only incorporated a handful of spatial data layers from different sources, agency technical staff had to put significant effort into preparing the data (e.g., converting all layers to the same geographic projection) for efficient, comprehensive viewing. Based on this experience, it was clear that this step would require specific technical skills and significant effort, which would require dedicating resources to hire a consultant to effectively accomplish this step.

Beyond logistics, this exercise also revealed how strategic conservation investment trade-offs could be collaboratively identified. For example, when the group looked at locations of culverts determined to be barriers to aquatic organism passage, it was apparent that improving just a few particular culverts to pass fish could effectively open aquatic connectivity for an entire drainage while the same level of effort at other stream locations would do relatively less good for regional aquatic connectivity. This reinforced the importance of collectively viewing and discussing relevant information as a group and helped root the group's understanding and faith in the developing and evolving process.

By vetting different aspects of the proposed process, the group was also able to drop some ideas from further consideration. Discussions about a credit/debit system to quantify project impacts related to terrestrial mitigation opportunities dominated several meetings, but the group determined that this task alone could require significantly more time and effort to develop. The group resolved simply to negotiate trade-offs, with the potential of adopting more formal procedures such as the analytical hierarchy process approach to guide decision-making (Saaty 1980) or other environmentally-sensitive adaptive planning approaches that have been applied elsewhere (Theobald et al. 2000, Beier et al. 2006, Hilty et al. 2006, Noss and Daly 2006).

The effort to develop the process was demanding but provided the necessary road map for the agencies to apply the process in a pilot study. In summary, the most important aspects of developing the process included upper-level management involvement and support, building trust and camaraderie amongst agencies, group facilitation and accountability, and using trial-and-error to explore and find feasible approaches palatable to the agencies that would ultimately be carry out the ITEEM process. Lessons learned as the agencies created the ITEEM process would ultimately be useful in directing the pilot study.

Lessons Learned: ITEEM Pilot Study

The pilot study was initiated after the ITEEM process was drafted and approved by the collaborating agency leaders. However, even with an agreed-upon and well-documented process in place, interpretation of the process was not always congruent between stakeholders for a variety of reasons. In some cases this was due to agencies appointing new representatives that had not been involved in the development of the process during the previous year. Given that the pilot study venture diverges so significantly from the traditional environmental review process, many newcomers struggled to grasp the overarching purpose of the pilot study and their roles in the process. Smooth integration of these new players into the process was labored, resulting in delayed task completion and insufficient detail with regard to documenting their agency's issues and opportunities, and feelings of frustration and confusion.

Several approaches to address intra-agency coordination challenges were suggested. Inviting all the various levels agency representation (e.g., upper-level managers, technical staff) to the initial kick-off meeting could improve intra-agency understanding of roles, responsibilities, and goals and objectives of the process. Conducting interviews with each agency's team of representatives may flesh out misconceptions and concerns early in the process. Formalizing each agency's internal commitments to the process might unify and affirm their team's efforts; participating agencies could document their approach to internally addressing staff turnover and communication issues affecting their agency's ability to contribute effectively to the ITEEM process. To improve interagency communications, a website was created early in the process for the purposes of facilitating information transfer and monitoring milestones reached and yet to be completed. Unfortunately, it was under-utilized and rarely updated. Thinking through the website function and design more carefully prior to the next cycle will likely enhance its usefulness as a communication tool used to increase the efficiency of the group.

Much of the pilot study prior to the workshop revolved around compiling relevant data that would be used to guide good decision making. The initial call for such information yielded hundreds of sources of data and maps that had to be filtered down to a manageable set of sources that comprehensively addressed issues and opportunities relative to future planning and management activities for the region. Having a consultant dedicated to this effort was essential to preparing this information for an effective workshop.

The first day of the workshop was dedicated to introductions, reviewing how the goals of the pilot study relate to stakeholder's interests, and reinforcing the tenets of the ecosystem approach. When discussing the intent and extent of the pilot study, different interpretations of the ITEEM process were revealed. While group discussion on the first day helped clarify many of these discrepancies, the less formal field trip interactions on the second day of the workshop seemed to solidify the group's understanding of differing perspectives and increased the sense of shared commitment to meet the goals of the pilot study. The field trip allowed the group to better understand MDT's approach to highway design features, including features incorporated into projects as a matter of standard practice, other features that could readily be incorporated into a highway projects and features that may not be feasible to incorporate into highway design plans due to other factors that must be balanced in highway design. The field trip allowed the group to see some of the techniques that could be incorporated in to highway design to benefit wildlife. It was suggested that the field trip might be held the first day of the Workshop, rather than the second, since it provided the group with such clarity regarding the issues of scale and practicability.

Because of the many collaborative conservation initiatives led by local government and NGO's were already underway within the pilot study region, the prioritization of new conservation opportunities seemed to be less critical than understanding how mitigation partnerships stemming from the pilot study might augment these ongoing projects. Additionally the fruition of the Montana Legacy Project seemed to dwarf the pilot study and emphasized the need for the process to adaptively integrate with these established conservation efforts. Newly acquired timber lands associated with the Montana Legacy Project would fall under management of state and federal resource agencies tasked with habitat restoration and long-term sustainability. Regional practitioners and conservation efforts would benefit most from integration of reliable but flexible mitigation commitments stemming from the ITEEM process, such as the restoration fund concept. The MT 83 ITEEM pilot study was a step behind these multiple large-scale conservation initiatives providing opportunities to direct mitigation toward established regional conservation goals, but making it challenging for the process to specifically pinpoint more than a handful of prioritized shovel-ready mitigation projects given that the transactions associated with leveraging mitigation funding required further investigation to ensure legal and financial considerations were met.

The ITEEM process was created to integrate ecosystem based mitigation and streamline transportation project development. The pilot study was initiated under those assumptions, but evolved into two distinct yet interrelated arenas of consideration. Issues and concerns pertaining to the future highway projects on MT 83 emerged as the easier, more discrete concept to address. The group's confusion began when it was discovered that the transportation projects were not clearly defined at this early stage in their conception and planning process and would not likely be programmed for a decade or more. Thus, focusing on mitigation opportunities for future potential impacts without sideboards, budgets, or a project scope resulted in collective frustration and slowed momentum. The larger-scale concept of identifying and prioritizing conservation opportunities for implementation through interagency partnerships was soon lost to the misunderstandings resulting from surreal highway project impacts and imaginary budgets. While participants were generally on board with the intent of the pilot study, the difficulty in exploring each of these scales separately (e.g., highway corridor versus the more extensive region around the corridor), while understanding their ecological connectedness and how permitting regulations could be met at both scales, required reiterative explanations and ultimately slowed progress. This challenge was not was not fully revealed until the Workshop, nor was the confusion completely overcome by all of the participants at the Workshop.

Given present-day risks to ecological integrity and the current conservation initiatives underway in the region, the group agreed that focusing more on collaborative partnerships and less on the planning considerations directed specifically at the future highway projects would result in greater realized gains for the resources within the region and help to leverage investments. The group also concurred, however, that early and on-going coordination with regard to the transportation planning process is essential in fostering a better understanding of MDT's business process, building trust, and streamlining the project development by increasing predictability and efficiency.

The conclusions reached and recommendations made through the pilot study will form the foundation of an interagency collaboration that is committed to work towards streamlining the transportation planning and project development processes along the MT 83 corridor, while conserving the unique road-side culture and diverse biological resources in the area. The lessons learned from the pilot study, coupled with evaluation of the success criteria, will be applied to improve the next invocation of the ITEEM process.

Conclusion

The path to developing the ITEEM process was not always straight given the pioneering nature of revamping the long-standing tradition of environmental review processes combined with diverse missions and interests of the respective agencies. By far, the greatest success of the pilot study was realized in renewed relationships and trust shared amongst the agency participants. Long-term success of the ITEEM process will be truly realized as interagency partnerships are formed to achieve meaningful conservation projects in advance of threats and impacts. While the recommendation-making phases of the pilot study will conclude in summer 2009 for the MT 83 region, implementation of the agreements will endure for years and the ITEEM process will be adapted to be applied in another cycle focused on other regions of ecological importance facing necessary planned infrastructure development.

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Biographical Sketch

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Deb Wambach moved to Helena, Montana in 1997 after graduating from the University of Wisconsin - Madison with a BA in Conservation Biology and a BS in Wildlife Management and Ecology. She has since been employed as a District Biologist with the Montana Department of Transportation. Her duties include biological resource analysis, threatened and endangered species coordination, wetland and aquatic resource delineations and assessments, wildlife and aquatic species connectivity, and impact analysis and mitigation. She serves as the ITEEM Pilot Study Project Manager as is an active member of several interagency collaborations, advisory committees, and working groups.

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TEXAS ECOLOGICAL ASSESSMENT PROTOCOL (TEAP): ECO-LOGICAL INFORMATION FOR TRANSPORTATION PLANNING

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Abstract

Texas Environmental Resource Stewards (TERS) was established to seek greater federal and state interagency collaboration particularly regarding transportation issues. TERS agencies agreed to (1) develop a scientifically valid, ecosystem prioritization protocol for Texas; (2) apply this protocol to existing, available data using GIS; and (3) demonstrate the protocol to identify areas of highest ecological importance in Texas. TEAP evaluates the following three ecological criteria:

1. Diversity: What areas have the most diverse land cover?
2. Rarity: What areas have the highest number of rare species and land cover types?
3. Sustainability: What areas can sustain ecosystems now and in the future?

These three layers were combined into a composite map that shows where ecologically important areas occur in Texas. Most of the ecologically important (1%, 10%) areas are located in Chihuahuan Desert Basin and Range, Stockton Plateau, and Rio Grande Plain ecoregions. Other areas that have high or moderately high ecologically important areas are the Edwards Plateau and the southern portion of the Mid Coastal Plains Western Section. Conversely, the most threatened areas are in the Blackland Prairies, Oak Woods and Prairies, Central Gulf Prairies and Marshes, and Louisiana/Eastern Gulf Prairies and Marshes ecoregions which TEAP indicates have the least sustainable ecological areas. The Nature Conservancy (The Conservancy) performed an independent accuracy assessment on the TEAP comparing the composite scores and The Conservancy portfolio sites. This assessment that showed that those areas ranked as highly important ecologically by TEAP corresponded to areas identified as very ecologically important in The Conservancy portfolio. The results of TEAP provide a tool for use in project planning and for reducing very large corridors to more manageable areas for more detailed field investigation. Identification of ecologically important areas in each ecoregion can be used as a tool to support ecosystem-driven mitigation sequencing (avoidance of impacts, minimization, and then compensation) and conservation planning throughout the state. TEAP can also be used to find high quality habitat remnants in all ecoregions in Texas. The TEAP is intended to be a supplemental tool for agency use, not to circumvent or replace agency policies, processes, or regulations.

Introduction

The TEAP is a screening level, rapid assessment tool using existing electronic data available statewide. It is a planning tool and screening-level assessment that should lead users to progressively narrow the scope of analysis. It is not an all-encompassing predictive model for each land cover type, species, etc. Most geospatial tools like TEAP use some sort of criteria or factors to evaluate the data layers used in the assessment (Steiner et al. 2000, Xiang 2001). These ranks, or scores, simplify the analysis (Serveiss 2002), normalize disparate data sets onto one nominal scale (Clevenger et al. 2002), and provide an easily understandable format to communicate the results to various audiences (Theobald et al. 2000). These ‘scores’ are helpful in comparing various aspects of projects since the ‘score’ represents the relative value of one alternative to another (Steiner et al. 2000).

Geographically-driven approaches have been used to analyze environmental problems (e.g. nonpoint source water pollution, regional studies) that do not fit into traditional programs or assessment methods (Serveiss 2002) as well as those problems needing a holistic or comprehensive analysis. Landscape-level assessments also lead to improved intergovernmental coordination and more informed decision-making on regulatory and management initiatives (Serveiss 2002).

Regionally-scaled assessments, whether landscape- or geographically-based, are more holistic than assessments performed locally, or those based on political boundaries, because of their ability to relate potentially unrelated factors (Miller et al. 1998) and for comparisons at other scales.

TEAP uses eighteen ecoregion sections developed by Bailey (1994) as the base unit for calculation. Ecoregions illuminate ecosystem patterns at multiple scales, aiding the visualization of differences between ecosystems. They can be defined as regions of relative homogeneity in ecological systems (Griffith et al. 1999). Most ecoregions include minimally impacted areas that can be used to define reference conditions necessary to provide a basis for comparison to impacted areas. Since multiple areas within an ecoregion are relatively similar, they should respond similarly to stresses or management actions. Thus, ecoregions are appropriate areas for extrapolation of monitoring, including statistical sampling or research results (Harrison et al. 2000). Ecoregions allow the development of management strategies appropriate to regional expectations. They define areas where standardized management practices can be applied after being proven in individual sites or watersheds.

The TEAP allows users to analyze ecological condition, project consequences, and suggest mitigation within watersheds or ecoregions. The EPA Science Advisory Board also suggests that reference conditions be defined so that ecological indicators can be compared and later normalized for aggregation. This concept is imbedded within TEAP by using a 0 to 100 ranking structure which serves to normalize disparate criteria values. Further details can be found in the TEAP Report (Osowski et al. 2005).

Ecological Theory and Data Used in TEAP

TEAP divides nineteen individual measures from electronic databases into three main layers. These layers are diversity, rarity, and sustainability. These layers are then combined into a composite. Data sources for each layer are found in Table 1.

Diversity

The diversity layer shows land cover continuity and diversity in Texas and comprises four individual measures described below.

Appropriateness of Land Cover

Appropriateness of land cover describes the predicted natural vegetation under no human influence (Kuchler 1964) and compares it to the current vegetation. If pre-settlement vegetation and current vegetation types are the same, then the area is ecologically stable and resistant to disturbance

Contiguous Size of Undeveloped Land

Contiguous size of undeveloped land reflects the theory that the larger the contiguous area of undeveloped land, the higher the diversity (MacArthur and Wilson 1967, Dale and Haeuber 2000). In essence the question is, “how extensive are the areas of undeveloped land?”

Shannon Land Cover Diversity Index

The Shannon land cover diversity index calculates the diversity, in terms of land cover types, for each of the contiguous polygons calculated in the previous section. In general, the Shannon land cover diversity index shows how many specific land cover types there are in these contiguous area polygons and how they are dispersed.

Ecologically Significant Stream Segments

Significant stream segments (Norris and Linum 2000, El-Hage and Moulton 2001) represent natural systems that are increasingly rare habitat and are the aquatic equivalent of the contiguous size of undeveloped land measure. Significant stream segments are ecologically unique areas determined by Texas Parks and Wildlife Department (TPWD) based on biological function, hydrologic function, riparian conservation areas, high water quality (including aquatic life and aesthetic value), and threatened or endangered species.

Layer	Database	Description	Date	Agency
Diversity	NLCD	Land use/land cover interpreted from satellite imagery	1990-1992	USGS
	PNV	PNV is the climax vegetation that occupies a location without disturbance or climatic change. It is an expression of environmental factors (e.g., topography, soils, and climate across an area).	1964 (v. 2000)	USFS
	Baileys ecoregion section map	Ecosystem geography based on plant community relationships	1994	USFS
	Ecological stream segments	Ecologically significant river/stream segments	2000-2001	TPWD
Sustainability	NLCD	Land use/land cover interpreted from satellite imagery	1990-1992	USGS
	Baileys ecoregion sections	Ecosystem geography based on plant community relationships	1994	USFS
	Reservoirs/dams STORET	Waterway impoundments	2000	EPA
	TIGER road data		2000	Census
	CERCLIS	NPL sites	2000	EPA
	RCRIS	RCRA corrective action sites	2000	EPA
	TMDLs	CWA 303(d) listed impaired waterbodies	1993-1998	TCEQ
	14 & 8-digit HUCs	Watersheds	2002	USGS NRCS
Rarity	BCD	Species elemental occurrences	1994	TPWD
	Natural heritage	G/S species rankings	1994	TPWD
Other	Conservation planning areas	Aquatic & terrestrial areas capturing a range of rare and representative native plants, animals, and natural communities	2000	TNC

Table 1. Data sources for TEAP layers.

Rarity

The rarity layer was designed to show rarity of species and land cover in Texas and comprises four individual measures described below.

Vegetation Rarity

The land cover or vegetation rarity measure is derived from the U. S. Geological Survey (USGS) National Land Cover Dataset (NLCD) and represents rarity of all natural cover types including water and bare rock. Vegetation rarity is a measure of the particular land cover types that are considered rare within each ecoregion.

Natural Heritage Rank

The ranking system ranges from G1/S1 (Critically imperiled) to G5/S5 (Secure). Species are critically imperiled globally (G1) (or in the state, S1) because of extreme rarity or because of some factor(s) making the species especially vulnerable to extinction. Typically, this rank consists of five or fewer occurrences, very few remaining individuals (< 1,000), acres (< 2,000), or linear miles (< 10). G5/S5 species are common globally (or in the state, S5), widespread, and abundant. Typically, this rank consists of species with considerably more than 100 occurrences and more than 10,000 individuals.

Taxonomic Richness

Taxonomic richness, or the number of rare taxa, is another measure of rarity. It measures the richness of broad taxonomic groupings; that is, the locations that have a high degree of rarity in multiple taxa, e.g., birds, mammals, reptiles, amphibians, etc.

Rare Species Richness

The number of rare species may indicate the amount of endemism in an area. Rare species may be keystone/umbrella species (Launer and Murphy 1994) or very productive communities or typify a particular ecological community type.

Sustainability

The sustainability layer describes the state of the environment in terms of stability; that is, how resistant to disturbance an area is, and how capable is the area in returning to its pre-disturbance state, that is, resilience (Begon et al. 1986). Sustainable areas are those that can maintain themselves into the future without human management. It comprises eleven individual measures described below.

Contiguous Land Cover Type

Contiguous land cover is based on the principle that larger areas having similar ecosystem types have greater sustainability. Contiguous area of undeveloped land supports connectivity, the opposite of the isolating effects of fragmentation (Gustafson and Gardner 1996). In essence the question answered here is, “How extensive are the cover types that make up an area of undeveloped land?”

Regularity of Ecosystem Boundary

Ecological theory suggests that perfectly circular or square habitat areas will have higher diversity and/or species abundance compared to linear habitat areas (Game 1980). It is based on the principle that the least amount of boundary results in the lowest amount of “edge effect” and maximum core interior habitat, thereby yielding the least disturbance and greatest sustainability of the ecosystem. The more complex the edge, the more opportunities for negative influences to affect the location. The more negative influences, the less sustainable the location.

Appropriateness of Land Cover

Appropriateness of land cover describes the predicted natural vegetation under no human influence (Kuchler 1964) and compares it to the current vegetation. The rationale for including this measure in the sustainability layer is that if pre-settlement and current vegetation types are similar then the seed bank is intact and therefore the area can recover from a disturbance more quickly (resilience).

Waterway Obstruction

The waterway obstruction measure is based on the principle that dams are interruptions to the continuity of waterways. Dams disturb the natural flow regime of a river, turning it into a reservoir and non-flowing system. The river environment, both aquatic and riparian, is fragmented and insularized, thus creating disturbances for the fish, aquatic organisms and plant communities associated with this habitat.

Road Density

The road density sub-layer is based on the principle that roads fragment the landscape (Abbitt et al. 2000). In general, more roads and larger roads (multilane highways, for example) occur near the population centers and also serve to connect them. The higher the density of roads, the more fragmentation and disturbance occurs to natural communities (Abbitt et al. 2000).

Airport Noise

Airport noise is a disturbance to natural communities based upon the noise level from airplanes and associated activities, maintenance on the runways themselves, and because they serve as a catalyst for development surrounding the airport. Airports with larger runways typically have wider areas of disturbance.

Superfund National Priority List (NPL) and State Superfund Sites

These are sites where hazardous substances have been released and are, by definition, disturbances or stressors on the natural environment. While efforts are made to minimize the impacts of these sites and to clean up or contain contaminants to acceptable risk level, the release of toxic chemicals may permanently alter natural conditions. These areas and natural areas adjacent to them are less likely to be self sustaining and more likely to require human management for their continued existence. However, with proper engineering, many such sites can and have been put to productive use. As a consequence, unique opportunities for low impact restoration of natural or near-natural habitat areas may be available.

Water Quality

Poor water quality (defined by Clean Water Act (CWA) Section 303(d), as not meeting designated uses) is another stressor on the natural environment.

Air Quality

Air quality can impact ecological communities due to outfall of chemicals or particulates that become incorporated in the soil or food chain. Poor air quality may be due to mobile sources such as the amount of cars or industrial activities, such as petroleum refining. High concentrations of ozone can have negative effects on flora and fauna (H. John Heinz III Center for Science, Economics and the Environment 2002). Pollutants such as lead, mercury, and others can be transported and deposited in water or soil where they may be incorporated into the food chain. Nitrogen and sulfur can acidify some water bodies, making them uninhabitable for aquatic species (EPA 2002).

RCRA TSD, Corrective Action and State VCP Sites

These sites are typically smaller than Superfund sites, but are similarly considered disturbances or stressors on the natural environment.

Urban/Agriculture Disturbance

Activities in urban and agricultural areas generate disturbances to surrounding areas. Stressors such as pesticides, fertilizers, and noise are included. The sustainability of an ecological community can be impacted by the amount of human activity, such as those related to agriculture (e.g., pesticide use, nutrient runoff, erosion, etc.) and population (e.g., urban activities including roads, cars, urban sprawl, solid waste (H. John Heinz III Center for Science, Economics and the Environment 2002, Tigas et al. 2002). Urban uses and agriculture also fragment the community and change natural landscape from desired vegetation types (e.g., wetland, forest, etc.) (Tigas et al. 2002).

Results

Due to space limitations and visual clarity, the Stockton Plateau ecoregion is presented in Figure 1. The composite map is the combination of the diversity, rarity, and sustainability layers. For presentation purposes, this article identifies "ecological importance" as percentages of the total score (theoretical maximum of 300) a grid cell can receive. The top 1% highly important ecological areas in this ecoregion are highlighted in red (darker color). The highly important ecological areas (1%, 10%) are those areas that represent the intersection of the top 1% for diversity, rarity, and sustainability. The more sustainable areas occur where there are fewer human disturbance activities (Figure 1d). Additional ecoregions, layer maps, and state maps can be found in the full TEAP report (Osowski et al. 2005).

In general, highly scored TEAP locations corresponded to the locations of The Nature Conservancy portfolio sites. Correspondence was particularly high for pixels in classes 26 to 30 which represent TEAP composite scores of 251 to 300. At lower ranked TEAP composite layer locations the match between TEAP and The Conservancy portfolio sites is lower. This relationship can also be expressed as a percentage of the TEAP pixel classes residing inside or outside The Conservancy portfolio. For example, 93.42% of the pixels in class 30 (TEAP scores of 291 to 300) are found inside The Conservancy portfolio, whereas only 6.58% of the pixels in this class exist outside The Conservancy's portfolio. The opposite trend is seen for TEAP scores located outside The Conservancy portfolio. For example, 90-100% of the pixels in classes 1 to 7 fall outside The Conservancy portfolio. This is expected since TEAP classified all lands in Texas whereas The Conservancy's conservation process focuses on identifying the highest quality ecological communities only.

Discussion

Similar to other reports that characterize the environment at a landscape-level (H. John Heinz III Center for Science, Economics and the Environment 2002, Schweiger et al. 2002), the individual measures and main layers selected for TEAP reflect important attributes relating to ecosystem condition, and by extension, ecosystem function.

The TEAP is a relatively simple model that uses stratified data that are combined to give a total or composite picture of the state of Texas at the ecoregion level. Complicated modeling and analysis tools are less likely to be used in regulatory processes. TEAP is a screening tool that can assist in overall conservation efforts (including project planning, mitigation, preservation, or restoration activities) and to identify areas where more detailed, site-specific data are needed. TEAP results should be used in conjunction with agency-specific information to support decisions. (Schweiger et al. 2002). TEAP should enable managers to consider specific decisions within an ecoregion context.

The potential intended use of the results of the TEAP include: 1) use in the NEPA planning process (scoping, alternatives development, etc.), 2) use in streamlining the authorization process for large projects (such as transportation) by narrowing the study corridor necessary for further field investigation, and 3) use in mitigation discussions to avoid ecologically important areas, minimize impacts to those areas, and compensate for unavoidable impacts. This list of intended uses is not exhaustive, nor all inclusive. The TEAP is not designed to take the place of agency policies and procedures. It is a supplemental information tool aiding in agency decision making.

TEAP uses generally accepted ecological theory as the basis for its analysis. However, an aspect that affects potential conservation and protection of ecologically important locations in Texas regards the protection of large contiguous tracts of land versus protection of small high-value remnants that are possibly unsustainable areas without intense human management.
Conservation is not the primary mission of many regulatory agencies. For these agencies, the TEAP may be useful in meeting NEPA requirements and in making project planning level analyses and decisions.

Planners should avoid negatively impacting ecologically important areas, especially in areas where there are few ecologically important areas remaining. On the other hand, the most threatened and rarest species and communities are often found in areas that TEAP would identify as less important. The key is to strike a balance between protecting and enhancing highly ecologically important areas versus protecting and enhancing vulnerable species/communities in less ecologically important areas. Harris et al. (1996) suggest a connectivity approach to protect landscapes from further fragmentation and to restore connectivity to culturally fragmented landscapes, where possible. Linking such areas may enhance landscape connectivity (e.g., organism dispersal, optimal foraging areas) and reduce the effects of fragmentation (Swenson and Franklin 2000).

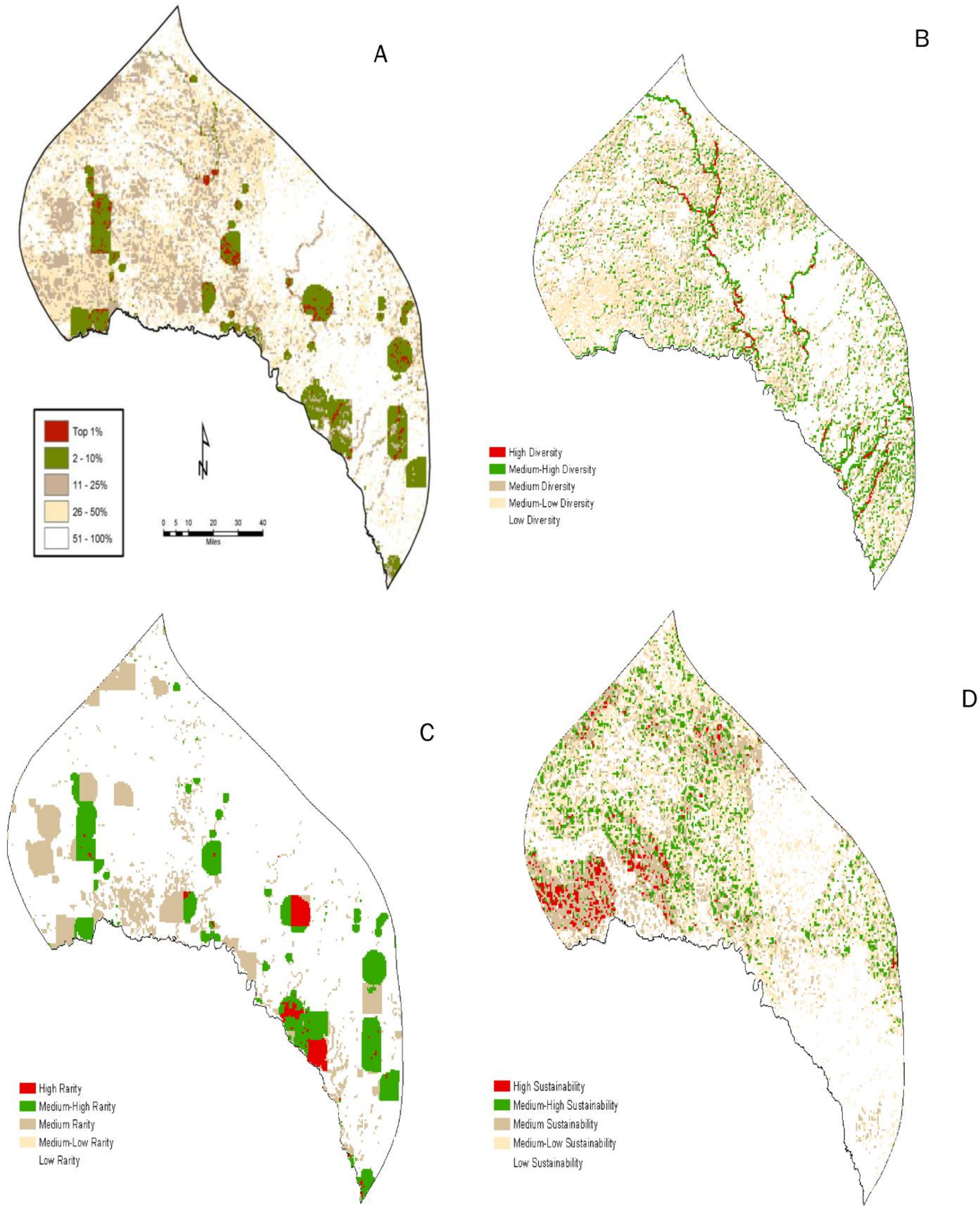

Figure 1. Results of TEAP for the Stockton Plateau ecoregion: a) composite of three main layers, b) diversity layer, c) rarity layer, and d) sustainability layer

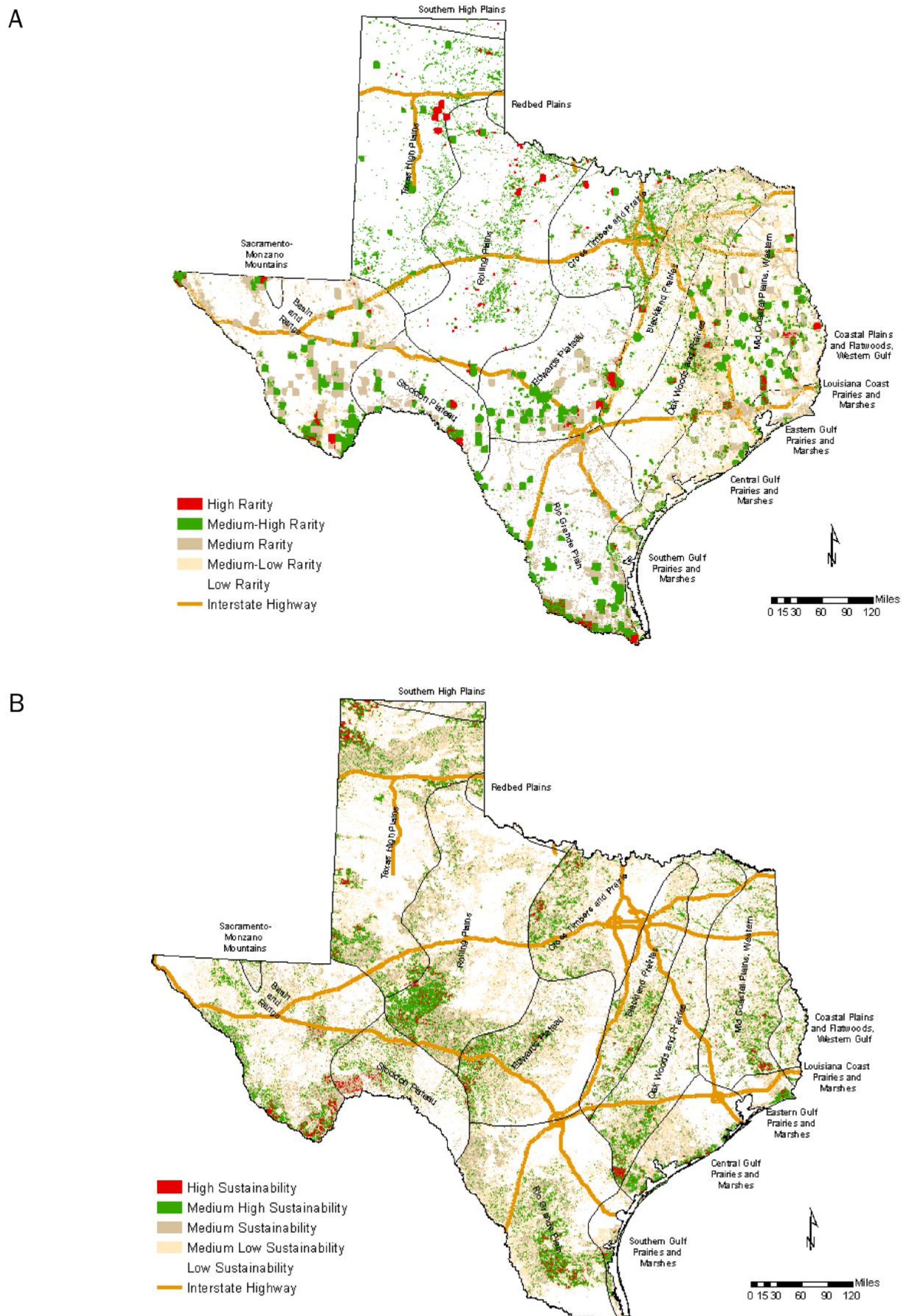

Figure 2. Overlay of TEAP: a) rarity and b) sustainability layers for the State of Texas and Interstate Highways.

The ecologically important areas identified through TEAP do not represent areas that, if left undisturbed, would capture all of the remaining biodiversity in the state, nor does it give license to destroy areas that have lower TEAP scores of ecological importance. The use of TEAP would be the first step in avoidance of impacts, not the last. TEAP identifies the top 1% ecologically important areas in each ecoregion and provides information to aid streamlining agency decisions used to protect the biodiversity of Texas. When communicating with decision-makers concerning the results of TEAP, protecting (or avoiding) every square inch of an area falling in the 1% category does not necessarily protect biodiversity per se. It can, however, help protect places that make a significant contribution to the biodiversity of Texas.

Large-scale projects present many special problems. They often affect diverse habitats, land forms and watersheds. Adequate amounts or types of lands needed for appropriate compensatory action may not be easily accessible. They may intersect numerous regulatory agency jurisdictions that must be addressed (Reid and Murphy 1995). Linear projects, like roads, are a special challenge because the avoidance of impacts in one segment may define the impact in the next. Identification of the most important resources present for an entire project is a tool that can be used to avoid impacts, minimize impacts, identify potential compensatory mitigation, and select the least environmental damaging project alternative. Such an overlay with existing Interstate highways and the TEAP rarity and sustainability layers are shown in Figure 2.

The accuracy assessment was performed by The Nature Conservancy, an independent entity not involved with the calculations of the TEAP main and composite layers. The portfolio sites used in the accuracy assessment were derived independently from the TEAP using The Conservancy's process. Both TEAP and The Conservancy's processes use GIS information at some level; however, The Conservancy's process also includes field investigations whereas TEAP does not. As explained in the results section, the match between The Conservancy's portfolio sites and highly scored TEAP composite locations is good; however, there is less of a match at lower TEAP scores. This may be due to the fact that The Conservancy's process is designed to identify the highest quality or rare ecological communities for protection rather than identifying lower quality sites for restoration or mitigation process opportunities. It is difficult to determine the degree or "goodness" of the match between TEAP and The Conservancy without further field investigations.

The TEAP effort supports streamlining and the Executive Order 13274 (Environmental Stewardship and Transportation Infrastructure Project Reviews) by providing a tool agencies can use to rapidly assess some of the environmental impacts of large projects, including transportation projects. It aids in alternatives analysis, compensatory mitigation, and preservation. The information provided by TEAP better informs agencies facilitating better decisions, thus improving the overall quality of agency decision-making.

In the past, impacts of public works projects have not been evaluated on an ecoregion scale in Texas. Inclusion of ecoregion information, such as that found in the TEAP, into the planning process of large public works projects facilitates project impact analysis and the mitigation of impacts while realizing conservation of ecologically important lands. This tool may help streamline the project development process through early identification of project impacts, and enhances the capability of avoidance and minimization of those impacts. For example, alternative alignments can be developed in order to avoid sensitive or ecologically important locations.

TEAP results can be used in discussions for mitigation opportunities and identification of key locations for more effective species protection (Abbitt et al. 2000). For example, TEAP information can be of assistance in locating, designing and establishing mitigation areas, mitigation banks, or other conservation areas. Finally, TEAP identifies strategic indicators that can be modified in subsequent iterations, can be compared across time periods, can potentially serve as reference points for project and long range planning, and can provide supplemental data to aid in regulatory discussions.

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Steve Schwelling is a GIS Analyst and special projects coordinator for the Texas Parks and Wildlife GIS Lab. He holds a MA in Biological Science from The University of Texas at Austin and an MS in Applied Geography (GIS and Remote Sensing) from Texas State University. His research includes a number of habitat prediction models for rare and endangered species using GIS and remote sensing.

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WILDLIFE MORTALITY SURVEYS ON 1014KM OF HIGHWAYS IN PORTUGAL (2002-2007): RESULTS AND LIMITATIONS OF THE PROCEDURES

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Abstract

The increasing number of road mortality studies worldwide has highlighted the need of national surveys to minimise the road mortality. Nevertheless, due to financial constraints it is quite difficult to implement a survey in a broader scale. The main goal of this study is to show the procedures that we followed to implement a large scale survey in Portugal and discuss the main results and limitations. In 2002, Brisa Auto-Estradas de Portugal, a private company that holds a 1014km of highways from north to southern Portugal started a wildlife mortality survey. This survey has been made by staff charged with the highways safety and without any training on species identification. One year later, a protocol between this company and the University of Lisbon (road ecology working group - GTEE) outlined a more accurate survey to cover a wide range of species. A wildlife guide was developed with the most common species and the main signs for a correct identification. To avoid losing information, the wildlife guide was organized in a hierarchical classification. If there are doubts on the species identity, the staff can assign to the one of the group (amphibians, reptiles, birds and mammals) or subgroups of species (n=16) that the individual belong. A total of 72 species are included in the wildlife guide, comprised amphibians (n=6), reptiles (n= 8), birds (n=28), and mammals (n=29), which include threatened species (n=14) known to be vulnerable to roads. Training sessions were realized by the GTEE team to all company staff to clarify the wildlife guide and test their ability to identify correctly the species. Additionally, owls and carnivores have been collected to identify sex and age as well to obtain tissue samples in 276km of highways, in order to study the population and genetic structure of the fatalities. Currently, the BRISA wildlife mortality database documents casualties over six years, comprising dates, location (at 100m error), species or species groups. A total of 8835 road-kills were detected by the BRISA staff from 2002 to 2007, being mammals with the highest scores (69%), followed by birds (27%) and reptiles (n= 340) and amphibians (n=32). The scarcity of amphibians and reptiles data is mainly due to the low detectability and motivation by the staff to count small-sized species. Owls represent 50% of the birds (0.8 ind/km/year) and carnivores (0.48 ind./km/year), lagomorphs (0.37 ind./km/year) and insectivores (Western hedgehogs *Erinaceus europaeus*) (0.09 ind./km/year) were the most vulnerable mammals to highways. Since 2002 the overall mortality has been improving, which highlight the importance of staff motivation to obtain more reliability data. Temporal patterns of the different taxonomic groups reveal that vulnerability to roads is seasonal and species-specific mainly due to life-traits. We have already identified owl' (n=91) and carnivore' (n=12) hotspots defined by the low mortality likelihood (0.01%) to occur in 500m road section. Hotspots appear not to raise concerns regarding the number of road-kills: 3-9 owls and 8-10 for carnivores over six years. Nevertheless, it is necessary to test the effectiveness of some measures minimize the incidence of mortality.

VEGETATION MANAGEMENT MEMORANDUM OF UNDERSTANDING BETWEEN MINNESOTA DEPARTMENT OF TRANSPORTATION AND FOND DU LAC BAND OF LAKE SUPERIOR CHIPPEWA

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Abstract

The Minnesota Department of Transportation (Mn/DOT) has the responsibility for controlling noxious weeds on it rights-of-way. Some of these roads traverse Tribal Reservations. The Fond du Lac Band of Lake Superior Chippewa, located near Cloquet, Minnesota, expressed concern over the use of herbicides on road rights-of-way within its Reservation boundaries and the loss of culturally significant plants and plant habitats. Mn/DOT has responded to this concern by not using herbicides within the Fond du Lac Reservation boundary.

Recently, new populations of invasive plants have been found on Mn/DOT right-of-way within the Reservation boundaries. These new populations presented a need for Mn/DOT and Fond du Lac to work together to attempt to eradicate these small populations. Both parties decided to cooperate on a Memorandum of Understanding (MOU) for vegetation management along Mn/DOT roads within the Reservation. The MOU defines the goals and agreements between Mn/DOT and Fond du Lac along three highways within the Reservation boundaries. Both Fond du Lac and Mn/DOT can see the benefits of using Early Detection Rapid Response (EDRR). The advantage of finding a new invasive plant in small populations is the key to being able to eradicate it. In some areas, Fond du Lac may allow Mn/DOT to spray herbicides. There are many steps that will be taken to ensure that plants in the area sprayed will not be harvested for cultural purposes. If the plant is in an area where herbicide application is not an option, Mn/DOT and Fond du Lac will work together to mechanically remove the plant.

The MOU for 2009 will be a one-year agreement. Mn/DOT and Fond du Lac will meet after the growing season to see how the MOU worked and what changes could be made to make it more effective. Future MOUs will stipulate a longer effective time frame. The MOU with Fond du Lac will be a template for future MOUs between Mn/DOT and each of the other Tribes in Minnesota.

OREGON DOT'S OTIA III BRIDGE PROGRAM: FIVE YEARS OF ADAPTING FOR ENVIRONMENTAL STEWARDSHIP

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Abstract

The purpose of the OTIA III environmental stewardship framework is to deliver projects that are sensitive to their communities and landscape while providing flexibility to adapt to changing environmental regulations, concerns, and science.

The OTIA III State Bridge Delivery Program is part of the Oregon Department of Transportation's 10-year, $3 billion Oregon Transportation Investment Act program. OTIA funds will repair or replace hundreds of bridges, pave and maintain city and county roads, improve and expand interchanges, add new capacity to Oregon's highway system, and remove freight bottlenecks statewide. About 14 family-wage jobs are sustained for every $1 million spent on transportation construction in Oregon. Each year during the OTIA program, construction projects will sustain about 5,000 family-wage jobs.

Oregon Bridge Delivery Partners (OBDP) is a private-sector firm that has contracted with the Oregon Department of Transportation to manage the $1.3 billion state bridge delivery program. OBDP, a joint venture formed by HDR Engineering Inc. and Fluor Enterprises Inc., will ensure quality projects at least cost and manage engineering, environmental, financial, safety, and other aspects of the state bridge program.

OBDP has developed a framework to integrate the myriad tools developed for the Program, including environmental performance standards, a joint batched-programmatic biological opinion, environmental and engineering baseline reports, and a web-based GIS. The purpose of this framework is to identify environmental concerns early in the project development process and communicate these concerns to design teams and regulatory agencies to promote environmental stewardship through impact avoidance and minimization.

Now with over five years of execution and more than 140 bridges through the process, we have some great successes and lessons learned to share. We have continued to adapt and develop tools to be successful – as well as shift our operating structure. The focus of this presentation will be on our framework used to maintain compliance in ever-changing circumstances and strive for environmental excellence.

To date, every eligible bridge delivered through OBDP has used the programmatic permitting strategy. More than 100 bridges have been constructed, more than 80 more bridges are in construction with nearly another 60 bridges starting, and nearly 100 bridges are in various phases of design. Hundreds of construction inspections have been conducted by environmental staff – with no permit violations. The avoidance and minimization measures outlined in the environmental performance standards have been highly effective – adapting to changing environmental regulations, concerns, and science. We have had equal successes implementing this framework with design-build and design-bid-build delivery. We look forward to continued success as we maintain our most effective tool – collaboration.

Planning for Change

FRAGMENTATION OF CHINA'S LANDSCAPE BY ROADS AND URBAN AREAS

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Abstract

China's major paved road-ways (national roads, provincial roads, and county roads), railways and urban development are generally planned and financed using public funds at a national scale and are rapidly expanding. As a consequence of this fast-paced growth, there are increasing impacts on ecosystems, including landscape fragmentation. There may be concomitant short-term benefits to commercial and agricultural interests of an expanding transportation network, but these benefits tend to be off-set by costs to ecological processes and attributes (e.g., wildlife, native plant dispersion) that depend on intact landscapes. In order to provide information to transportation and land-use planners for immediate use in landscape conservation, there is a need to quantify the magnitude of fragmentation.

We used the effective-mesh-size (Meff) method and metrics from FRAGSTATS to provide the first evaluation of the degree of landscape division in China, caused by transportation networks. The paved road system in China had been digitized previously using satellite photographs. Paved roads were buffered to delineate patches of landscape. Thus, landscape division as described here is due to paved road system development.

Using Meff, we found that fragmentation by major transportation systems and urban areas in China has an obvious spatial distribution pattern made up of 3 tiers, from the least-impacted West to the most impacted South and East of China. Paved roads and the existing urban areas seriously affect the ecological connectivity in almost all Eastern provinces and counties. Eastern-Chinese provinces have serious fragmentation by major paved roads comparable to other regions of similar size in the world, e.g. Switzerland and others in Europe, and California. Using FRAGSTATS, we also provide a detailed analysis of fragmentation of similar-sized areas of Eastern China and California's Central Valley (~40,000 km2). California has many more small landscape patches delineated by paved roads than China, but has more area in very large montane patches. China has fewer landscape patches overall, with the majority of the landscape patch area in mid-sized patches (20-1000 km2). California's landscape division by paved roads has a strong size distribution signature based on 640 acre sections (1 square mile) and their base-2 division products (e.g., 40 acres). In comparison, China has no obvious land division signature.

The observed differences in land division by paved roads may reflect different historical settlement and road-development patterns. Using paved road-delineated patches, China is comparatively less fragmented than similarly-developed areas in California and Europe. We currently don't know the impact from agricultural land and dirt road development on landscape division. Based on these analyses the authors argue that, in such a critical stage of road network expansion in China (to a paved system), planners should examine any new decisions about further road development in the context of existing land-division patterns.

An electronic copy of this poster is included in the Appendices of the Proceedings.

INTEGRATING BIODIVERSITY AND INFRASTRUCTURE CONSIDERATIONS TO PRIORITIZE TRANSPORTATION PROJECTS IN THE WILD AND SCENIC TAUNTON RIVER WATERSHED, MASSACHUSETTS

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Abstract

Poorly designed road-stream crossings can act like dams, blocking water flow and movement of aquatic organisms. As a changing climate brings more intense storms and higher temperatures, fragmentation of stream systems by road infrastructure poses a threat to both aquatic life and public safety. The Southeastern Regional Planning agency (SRPEDD) and The Nature Conservancy (TNC) joined forces to identify portions of roadways that could be improved to benefit fish and wildlife as well as transportation safety and efficiency. We jointly trained and supervised interns to assess stream barriers and roadway drainage facilities in the Taunton River watershed, a ~500 square mile ecologically significant watershed on the Southeastern Massachusetts coastal plain. The watershed hosts the largest river herring run in New England as well as numerous rare aquatic and wetland species. The Taunton is the longest free-flowing coastal river in New England and was designated a National Wild and Scenic River in March 2009.

The project joined two existing methodologies, one that evaluates impacts of roads on habitat connectivity, and one that identifies drainage structures that are impacting important habitats and/or are inadequate to protect roads from storm damage. Habitat connectivity was assessed using methods developed by the MA River and Stream Continuity Partnership; the Geographic Roadway Runoff Inventory Program (GRRIP), developed by SRPEDD, was used to analyze roadway drainage facilities located in environmentally sensitive areas on federal, state, and local roads in the watershed.

The collaboration has had several important outcomes. For example, the results are informing development of a corridor plan for a 20-mile stretch of Route 495 between Wareham and Raynham, MA, that crosses several important rivers and wetlands. Multiple values were examined including ecology & biodiversity, fisheries, archaeology and public water supply. Presentation of these issues is intended to alert MassHighway and the communities within the study area of the environmental issues that will require attention and mitigation with any potential improvements to the existing highway.

We also worked with the town of Middleboro to secure funding from the state Transportation Enhancements program to upgrade structures on the Nemasket River to address stormwater problems affecting migratory fish, a federally-listed turtle, and several state-listed fish and mussel species. SRPEDD and TNC are continuing to work together to develop an implementation and funding plan for mutual high priority sites in this important watershed.

All data and additional information are available on the internet at www.srpedd.org and www.streamcontinuity.org.

Biographical Sketches

Alison Bowden is Freshwater Program Director with The Nature Conservancy in Massachusetts and Co-Director of TNC's Eastern U.S. Anadromous Fish Program. Her work focuses on developing and implementing innovative science and policy tools to protect and restore rivers along 5 principal themes: connected river networks, flowing waters, intact river corridors, healthy headwaters, and linking freshwater and marine conservation for migratory fish. Alison has worked on a wide range of policy issues including transportation, energy, and water resource management and she is a member of the Atlantic States Marine Fisheries Commission Shad and River Herring Advisory Panel. She earned a M.S. in Water Resources from the University of New Hampshire and a B.A. in Environmental Science from American University.

Bill Napolitano is the Director of Environmental Programs at SRPEDD and has been an Environmental Planner with the agency since 1986. Bill has worked on numerous water resources related projects in southeastern Massachusetts in conjunction with local, state, and federal agencies as well as community and non-profit organizations. Some of these projects have included resource management plans for the Mattapoisett River Valley Aquifer, the Assawompset Ponds Complex, the Taunton River Watershed, the Palmer River Watershed, the Ten Mile River Watershed, and the Mount Hope – Narragansett Bay Watershed. Bill holds a BA and a BS from Southeastern Massachusetts University (now UMass – Dartmouth), and a Masters Degree from Norwich University.

ECOLOGICAL SURVEY APPROACHES IN A CHANGING WORLD

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Abstract

The results of a 2008 Transportation Research Board study are presented that address the pressing needs and new approaches to ecological surveys for transportation. Transportation agencies are continually adapting ecological survey approaches to learn of the ecological resources present near roads and how transportation activities may affect them. These ecological surveys and the data that are generated from them often require professionals to stay abreast of quickly developing scientific methods and for these professionals to develop computer and internet savvy on how to share this information. An email survey received input from 49 states' departments of transportation and 37 state wildlife agencies, along with other organizations. Participants gave information on pressing ecological survey needs and the technologies, techniques and innovative methods that are developing to fulfill those needs. This research revealed two major themes related to ecological surveys. First, transportation planning is moving beyond the traditional boundaries of limiting concerns to the road right-of-way and is developing a view of natural resources in a landscape context and over greater time scales. Secondly, this view of the world outside the road right-of-way requires increasingly higher resolution data all along the transportation planning, development, and operations process which needs to be in similar formats and easily accessible. Common characteristic of data needs and new approaches include:

1) There is a need for a better understanding of what species are present in areas of a state with potential for road development, there are new methods to help access data on those species locations, and cost-effective scientific methods for estimating the potential of species to be in a location that is not fully surveyed;

2) There is a need for the ability to access data from a single or possibly two sources, and to have that data in similar formats so Geographic Information Systems (GIS) maps can be constructed, specific state departments of transportation are creating such systems;

3) There is a need for the ability to be more proactive over an entire state and among agencies so that areas of greater ecological values can be identified and avoided in long term planning. Examples are given on how this happening and will potentially happen in the future.

Overall survey results are presented under the general theme of how agencies can adapt to changes in information collection and data sharing methods, transportation policy changes, and the developing paradigm change in which multiple agencies work together long term and over greater landscapes to protect natural resources and best plan for transportation needs to avoid and minimize impacts to those resources.

NEW FHWA MANUALS FOR MITIGATION MEASURES AIMED AT REDUCING WILDLIFE-VEHICLE COLLISIONS AND PROVIDING SAFE CROSSING OPPORTUNITIES FOR WILDLIFE

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Abstract

Under SAFETEA-LU Transportation Legislation, the Secretary of Transportation was directed to conduct a national wildlife–vehicle collision (WVC) reduction study. The study was to advance the understanding of the causes and impacts of WVCs and identify solutions to this growing safety problem. The Federal Highway Administration (FHWA) report, which reviewed over 40 mitigation measures aimed at reducing wildlife-vehicle collisions, was submitted to the U.S. Congress in 2007. In addition, a FHWA manual was compiled that focuses on the design considerations and technical specifications of the measures that are considered "best practices" for reducing wildlife-vehicle collisions. The title of the manual is "Wildlife–vehicle Collision Reduction Study: Best Practices Manual". The measures described in the manual include planning at different stages and different spatial scales, wildlife fencing, under- and overpasses for wildlife, without or combined with other uses (e.g. humans, vehicles, water), animal detection systems, vegetation management in the right-of-way, and wildlife culling. While the manual is mostly oriented to mitigation measures that reduce collisions with large wild ungulates (i.e. deer, elk, and moose), other sections of the manual focus on collision reduction measures for species or species groups for which direct road mortality is among the major threats to their survival. These species include reptiles, amphibians, birds, and mammals. A second FHWA manual, initiated before the SAFETEA-LU Transportation Legislation was put into effect, focused on the design considerations and technical specifications of safe crossing opportunities for wildlife, specifically wildlife under- and overpasses. This manual is in draft and titled "Guidelines for Designing and Evaluating North America Wildlife Crossing Systems" and includes recommended crossing structure types, dimensions, and landscape and land-use attributes that may influence the effectiveness of the crossing structures for different species. The two manuals include recommendations for monitoring the effectiveness of mitigation measures in reducing wildlife-vehicle collisions and providing connectivity for wildlife. The ultimate purpose of the two manuals is to provide transportation and natural resource management agencies with the best available information on the planning, design, and monitoring of measures aimed at reducing wildlife-vehicle collisions and measures that allow for safe wildlife crossing opportunities across roads. We expect that the two manuals will be used heavily by transportation and natural resource management agencies in projects that aim for roads that are safer for humans and more permeable for wildlife.

Biographical Sketches

Marcel Huijser received his M.S. in population ecology (1992) and his Ph.D. in road ecology (2000) at Wageningen University in Wageningen, The Netherlands. He studied plant-herbivore interactions in wetlands for the Dutch Ministry of Transport, Public Works and Water Management (1992-1995), hedgehog traffic victims and mitigation strategies in an anthropogenic landscape for the Dutch Society for the Study and Conservation of Mammals (1995-1999), and multifunctional land use issues on agricultural lands for the Research Institute for Animal Husbandry at Wageningen University and Research Centre (1999-2002). Currently Marcel works on wildlife-transportation issues for the Western Transportation Institute at Montana State University (2002-present). He is a member of the Transportation Research Board (TRB) Committee on Ecology and Transportation and co-chairs the TRB Subcommittee on Animal-Vehicle Collisions.

Tony Clevenger has carried out research during the last 12 years assessing the performance of mitigation measures designed to reduce habitat fragmentation on the Trans-Canada Highway (TCH) in Banff National Park, Alberta. Since 2002, he has been a research wildlife biologist for the Western Transportation Institute (WTI) at Montana State University. Tony is currently a member of the U.S. National Academy of Sciences Committee on Effects of Highways on

Natural Communities and Ecosystems. Since 1986, he has published over 40 articles in peer-reviewed scientific journals and has co-authored three books including, Road Ecology: Science and Solutions (Island Press, 2003).

Pat McGowen obtained his B.S. and M.S. in Civil Engineering from Montana State University, and his Ph.D. from University of California Irvine in Transportation Systems Engineering. He has been a licensed professional civil engineer in Montana since April 2000. He is an assistant professor jointly appointed between the Western Transportation Institute (WTI) and Civil Engineering Department at Montana State University where he has worked on projects relating to rural ITS, transportation impacts to wildlife, safety and travel and tourism. Dr. McGowen is a national expert on highway-wildlife interactions. He developed the Artemis Clearinghouse, a wildlife-vehicle collision mitigation web-based clearinghouse. He has been involved in projects including the Roadside Animal Detection System Testbed, the National Wildlife Vehicle Collisions Study, and Habitat Connectivity and Rural Context Sensitive Design. Dr. McGowen is the founder and co-chair of the TRB subcommittee on Animal Vehicle Collisions (ANB20-2). Dr. McGowen, along with other colleagues at WTI was awarded the 2008 Best of ITS Award from the Intelligent Transportation Society of America for Best New Innovative Practices for Partnerships for Deploying Animal Vehicle Crash Mitigation Strategies.

Rob Ament, M.Sc., Biological Sciences, is the Road Ecology Program Manager at the Western Transportation Institute at Montana State University. He has more than 25 years of experience in field ecology, natural resource management, environmental policy and organizational development. He manages nine road ecologists with over 20 active research projects throughout North America, three of which he is the principal investigator.

Amanda Hardy has a BS and MS in Fish and Wildlife Management from Montana State University. During her six years as a research scientist at the Western Transportation Institute at Montana State University, she oversaw numerous road ecology projects. Amanda is currently in at PhD program in Ecology at Colorado State University; her dissertation research is focused on the potential effects of multi-use recreational pathway activities on ungulate behavior and distribution, as well as visitor opportunities to view wildlife from park roads, in Grand Teton National Park.

Acknowledgements

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A Conceptual Framework for Assessing Barrier Effects to Wildlife Populations Using Variable Responses to Traffic Volume

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Abstract

The objectives of this study were to investigate the role of wildlife behavioral responses to highway traffic volume as a predictive tool to determine barrier effects, to organize these responses in a conceptual framework, and to provide an early warning system that recognizes the rate of traffic volume growth as a trigger for mitigation. While studies indicate that traffic volume (TV) can be a useful tool for predicting impacts to wildlife populations, investigators have been hampered in their ability to use TV predictively because responses among wildlife taxa vary widely. This paper reviews the available studies and proposes the categorization of four general responses to increasing traffic volume. Understanding the response category of target species in a project development area enables project planners to better determine the likelihood of current or future impacts as well as appropriate mitigation measures.

The four response categories are: **Non-Responders**, **Pausers**, **Speeders**, and **Avoiders**. Barrier effects are primarily caused by mortality in the first two types and primarily caused by avoidance behaviors in the second two types. This concept does not apply to species that avoid the surface of the road due to its physical characteristics such as a lack of cover or hostile surface. For such species, the road surface can be an impenetrable barrier regardless of traffic volume.

Non-Responders are characterized by a failure to detect or avoid lethal traffic, and continue to attempt to cross highways regardless of traffic volume. This group is exemplified by invertebrates or lower vertebrates such as frogs or some snakes. Complete barrier effects as TV increases are the result of a probability of successful crossing of nearly zero due to mortality.

Pausers can detect danger as traffic volume increases, but because the response is to stop in the face of danger, their risk of mortality increases with exposure such that the probability of successful crossing is nearly zero as TV increases. Pausers include a variety of taxa in all vertebrate classes that exhibit responses such as crypsis, thanatosis, coiling in snakes, and simply stopping. Complete barrier effects as TV increases are both the result of high mortality as animals stop in the traffic lane, and can also be the result of avoidance at the edge of the road.

Speeders flee from perceived danger with increased speed. Speeders can reduce the barrier effects of TV increases by increasing their speed to exploit traffic gaps as they cross highways, but as TV increases and gap distance decreases, the probability of successfully running gaps decreases. Speeders include deer, pronghorn, and rapidly-moving snakes. Barrier effects manifest at higher TV levels than the previous two groups because this group can respond with behavior that reduces mortality risk, but barrier effects do occur both as a result of mortality and ultimately avoidance of the road as these more intelligent animals choose to avoid certain death.

Avoiders avoid crossing attempts at fairly low TV or modify their temporal behavior to avoid traffic, thus they have the lowest mortality rates because they recognize vehicles as mortal risks. This group is exemplified by wary and intelligent species such as grizzly bears (*Ursus arctos*). Barrier effects as TV increases occur mostly through avoidance instead of mortality.

Future research might beneficially illuminate the approximate TV mortality and avoidance thresholds by species.

An electronic copy of this poster is included in the Appendices of the Proceedings, and can be obtained by contacting the author at sjacobson@fs.fed.us.

PEREGRINE FALCONS UTILIZE A BUSY HIGHWAY CORRIDOR IN EAST-CENTRAL ALASKA

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Abstract

In Alaska, Peregrine Falcon (*falco peregrinus anatum*) populations have largely recovered from the pesticide–induced crash of the 1960's and shown substantial increases across much of the State. In the Upper Tanana Valley of east-central Alaska, known Peregrine nesting territories increased from 3 in 1991 to 21 in 2008. In this region, Peregrines typically nest on riparian cliffs along the Tanana River and its' tributaries but have occasionally been reported nesting on low relief dirt banks (Timm and Johnson 2006). In 1995, a pair of Peregrine Falcons was discovered nesting on a quarried road- cut adjacent to a well-traveled section of the Alaska Highway (Ritchie et al. 1998). This pair was among the first ever to be reported using human altered habitats, within a high disturbance area in a remote part of North America. Since then, as many as five pairs have nested on man-altered cliffs along the Alaska Highway corridor (three on well-trafficked road-cuts and two in rock quarries).

The response of nesting Peregrine Falcons to human activities can vary greatly depending on the nature of the activity, its proximity to the eyrie, the timing relative to the breeding cycle, and its duration (Cade 1960). Falcons in urban or high visitation areas have demonstrated the ability to habituate to some disturbance while pairs in remote areas are usually more sensitive to human activity. Falcons using roadside sites in our study area encountered a number of disturbances including vehicular traffic, highway construction and maintenance, geological surveys, rock blasting and crushing, heavy equipment operation, fire suppression operations, and recreational shooting. Because of the disturbances associated with man-modified areas, these areas were generally thought to provide suboptimal habitat (Ritchie et al. 1998).

To assess the potential effects of disturbance on Peregrine Falcons using sites along roadsides, we compared productivity (young/occupied nest) between falcons nesting on man-altered sites in the highway corridor to falcons nesting on nearby riparian cliffs on the Tanana River. From 2003-2008, mean productivity was higher for birds nesting in the highway corridor (2.88 ± 0.26, 2003-2008 mean ± 95% C.I.) than birds nesting in bluffs along the Tanana River (1.85 ± 0.34). We hypothesize that wetlands adjacent to the highway provide abundant prey and when coupled with the ability of the birds to habituate to highway traffic, this may offset the energetic costs of frequent human disturbances at the roadside territories.

As Peregrine Falcon populations continue to recover and expand in Alaska, they will likely continue to make use of man-altered cliffs and ledges in the Alaska Highway corridor as other suitable sites become saturated. At the same time, the Alaska Highway corridor is experiencing increased traffic, construction, and development. Presently there are several proposals under consideration to construct a natural gas pipeline adjacent to the highway. During the planning phase of highway projects local resource managers and biologists are routinely asked for recommendations to mitigate and minimize disturbance of nesting falcons. Long-term monitoring of falcons in the region provides the basis for these recommendations.

Biographical Sketches

W. N. (Bud) Johnson is a Land Management Research Demonstration Biologist with the U. S. Fish and Wildlife Service stationed at the Tetlin National Wildlife Refuge in Alaska. Bud has spent the last 20 years of his career working on National Wildlife Refuges in Alaska.

Henry K. (Hank) Timm is a General Biologist with the U. S. Fish and Wildlife Service stationed at the Tetlin National Wildlife Refuge in Alaska. Hank has studied raptors in Alaska for over 15 years.

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COMPARING EFFORTS TO INCORPORATE GREEN STREETS PRACTICES INTO THE TRANSPORTATION PLANNING PROCESS IN NORTH CAROLINA

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Abstract

Demand for green infrastructure design in the wake of global climate change has brought changes in transportation planning to better address how infrastructure is designed, built and maintained to reduce negative environmental impacts. In North Carolina, this demand is accentuated by recent legislation mandating vehicle parking areas not exceed 80% impervious surface.

Two municipalities, Jacksonville (population 105,000) and Garner (26,000), have embarked on planning efforts that incorporate green streets and other low impact design practices. The incorporation of green streets satisfies multiple goals for these fast-growing communities: potential for cost savings, followed by aesthetics; walkability; urban heat island effects; and stormwater quality.

The Louis Berger Group sought to research and integrate low impact design policies and provide a comparative case study on how such practices can be tailored for different regions of North Carolina. This method consisted not only of incorporating context-sensitive design features, but a planning process sensitive to the unique environment (natural and built) of each municipality. Research was conducted to determine green infrastructure practices for new construction and street retrofits. A formulaic life-cycle cost analysis and calculation of impacts to buildable lots within private development was developed to supplement the research. It was determined that such practices would be beneficial to incorporate in each community. This paper will document the research, compare and contrast policies, and document the unique features of each community that led to varied design standards.

The City of Jacksonville, through its Collector Street Plan (adoption February 2009), has initiated the development of sustainable street environments to manage stormwater while reducing Total Suspended Solids. A community within the Coastal Plain region that is largely influenced by the presence of Marine Corps Base Camp Lejeune, Jacksonville's development patterns have been predicated on growth of the military facility and resulted in traditional high maintenance urban stormwater facilities that are out of sync with the flat terrain and sandy soils.

The Town of Garner has grown rapidly in the past 20 years as a bedroom community to Raleigh and is conducting a joint Streetscape Plan and citywide Transportation Plan (completion Spring 2009) to address this growth. Garner is within the Piedmont region and is typified by gently rolling hills, streets that have yet to be transitioned from traditional two-lane country roads, and a disconnected set of residential subdivisions. To effectively manage stormwater and reduce the costs of construction of urban streets, the incorporation of green infrastructure standards is first being explored for specific design features with the Streetscape Plan for Main Street and Garner Road. The outcomes of this effort will then inform the Transportation Plan in the development of new citywide roadway cross-sections and design standards.

The rapid growth of each community will likely result in immediate implementation of these design practices and the Louis Berger Group has recommended that each community test different methods to determine which will serve them best in terms of effectiveness and maintenance. Next steps include examination of the practice in other communities and development of standards for the Mountain region.

Acknowledgements

Jacksonville (NC) Metropolitan Planning Organization
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Biographical Sketches

Donald Kostelec, AICP, is a Senior Transportation Planner with the Louis Berger Group in Asheville, North Carolina. Mr. Kostelec has 10 years of experience in transportation planning and planning management through his various roles with the Chicago Transit Authority, the Ada County (ID) Highway District, and the Louis Berger Group. He was Planning &

Programming Manager for the Ada County Highway District, a regional transportation agency in Boise, Idaho; and also served as director of Commuteride, the Highway District's rideshare division. Mr. Kostelec is an expert in the Americans with Disabilities Act and his work in pedestrian-bicycle planning and transit marketing has received awards from the American Planning Association and the American Public Transportation Association. Prior to his work as a planner Mr. Kostelec was a sportswriter and freelance journalist.

Christopher Walsh, ASLA, is a Principal Landscape Architect with the Louis Berger Group in Raleigh, North Carolina. For Berger, Mr. Walsh has focused on integrating sustainable design practices with transportation planning and design through his role on street plans and pedestrian & bicycle plans. He has more than 17 years of experience dedicated to various aspects of urban and land planning. His experience includes Sustainability Planning, Community Planning, Historic Parks, Urban Renewal, Workshop Facilitation, Campus Planning, Neighborhood Planning, and Recreation Planning. Mr. Walsh is an experienced project manager and group leader with success in marketing, project development and implementation. He has successfully managed the execution of public and private projects of various scales from master planning through construction documents.

COMMUNITY-BASED ENVIRONMENTAL PLANNING: PREVENTING URBAN ENCROACHMENT ON A LAGOON CATCHMENT AREA

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Abstract

There is growing concern over the impact of urban expansion and increasing road development on the conservation of biodiversity and the condition of global ecosystems. To offset development, reserves are set-aside to preserve biota in a manner that facilitates resilience to global threatening processes. Yet protected areas are not impermeable and many threatening processes breach their borders. Roads penetrate protected areas and many high profile reserves have surprisingly high densities of roads within them, a threat often over-looked. The importance of reserves in urban landscapes for conservation has long been recognised as they often provide the last pockets of refuge for species that were once widespread and are important for both local and regional biodiversity. Sustainable land-use practises and pro-active protection of remnant fragments are essential to the preservation of biodiversity in these expanding regions. Most refugia in the peri-urban environment typically have high social, economic and ecological importance, and are crucial in shaping public perceptions and political agendas. We present an example of urban-wildlife conflict occurring in a lagoon catchment area in northern Sydney, NSW, Australia. Habitat loss coupled with increasing vehicular traffic are the main threats to the flora and fauna existing in this urban refuge. Through advocacy and education, a local conservation group is seeking to preserve the 57 km^2 catchment from encroaching urban development. Here we examine the importance of the catchment area for maintaining both floral and faunal diversity in the region by quantifying representation. Operational dilemmas and challenges associated with the practice of community-based environmental planning (CBEP) are examined, as we highlight the group's efforts to engage community and government to implement a plan of management for catchment governance. Finally, we discuss the importance of integrating ecosystem, transportation and community planning in promoting the conservation of this unique ecosystem.

Biographical Sketches

Erin Roger is a PhD candidate at the University of New South Wales, Australia. Her PhD project examines the survival and distribution of a common species in road impacted environments.

Jacqui Marlow has been involved in the protection and maintenance of the ecology and biodiversity in the Narrabeen Lagoon Catchment in Sydney Australia for more than 20 years. With degrees in science and education, her interests include road ecology and the protection of urban refugia.

Daniel Ramp is a Research Fellow at the University of New South Wales, Australia. Dr. Ramp is an applied ecologist working in the field of biodiversity conservation. He has worked extensively in kangaroo ecology and management, road ecology and the modeling of biodiversity.

PLANNING FOR CHANGE: WSDOT'S ADAPTIVE APPROACH TO COMMUNICATING ABOUT THE I-90 SNOQUALMIE PASS EAST PROJECT WITH DIVERSE GROUPS

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Abstract

Through the I-90 Snoqualmie Pass East Project, the Washington State Department of Transportation will balance large-scale ecological connectivity commitments with value engineering design objectives to ensure the continued availability of this critical statewide corridor.

Washington State citizens should have a vested interest in the I-90 Snoqualmie Pass East Project (I-90 Project) due to its far-reaching statewide economic, social, and environmental benefits. However, because of its rural location, the Washington State Department of Transportation (WSDOT) does not have a ready-made audience to communicate with in its backyard. In July 2007, we conducted a baseline survey to determine the public's attitude and awareness of the project. We found that people who knew about the project supported it; however, 84 percent of the individuals surveyed did not know about the project. This helped us understand that when people knew about the project, they endorsed it, but we were having a problem getting the message out to a larger audience. Clearly, a more innovative communications program was needed.

We developed specific communications strategies and implemented education and information campaigns that supported our overarching goal of earning and maintaining statewide support from the public and interested parties. Strategies included using reader-friendly writing, reaching audiences directly with our Web site, and presenting the project visually.

We integrated the strategy of using reader-friendly writing, or plain talk, into all of our public information materials and adopted it as a business practice for all disciplines. Throughout the public education process, we developed materials with consistent formats that presented project information in clear, understandable terms. We developed several engineering and environmentally focused information portfolios and a children's activity book featuring "Burl the Squirrel." These tools helped WSDOT reach and educate diverse audiences, from children to elected officials.

We used the I-90 Project Web site as a primary way to reach audiences with information unfiltered by other sources. We built a project library to house all public information materials, downloadable for use at anytime. Visitors could register for monthly e-mail updates about the project. We also used the Web site to conduct an online open house for the Final Environmental Impact Statement. Users were able to log on and have instant two-way discussions with project environmental planners, engineers, and managers while watching a live presentation.

Another communication strategy was to present the project visually. Due to the remote location and complexity of the I-90 Project, we determined that design visualization videos were the best way to visually present the project to the public. WSDOT and project partner I-90 Wildlife Bridges Coalition also enlisted elementary students of Washington State to draw their interpretation of a wildlife overcrossing through the statewide Bridging Futures Art and Essay Contest. The contest winner's artwork was then displayed on a billboard with messages about the I-90 Project.

These innovative communications strategies have been extremely effective, generating hundreds of stories in both print and broadcast media and contributing to over 50 presentations at different fairs, festivals and events across the state in 2008.The I-90 Project has been gaining more national and international attention. Recently, The US EPA asked the I-90 Project team to give a presentation to a delegate from the Taiwan Environmental Protection Administration, and has been requested to speak at events in Canada and in states across the US. Overall, the communication program for the I-90 Project has resulted in a higher degree of awareness for the project and contributed to a more broadly supportive public and political constituency.

An electronic copy of this poster is included in the Appendices of the Proceedings.

NEW FRENCH ENVIRONMENTAL POLICY AND LINEAR INFRASTRUCTURES: THE IMPLEMENTATION OF THE NATIONAL ECOLOGICAL NETWORK – THE "GREEN AND BLUE NETWORK"

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Abstract

France has a unique place in the world due to its world-wide known biological diversity. Because most of the geographical habitats are represented, the country has a key responsibility in the global mobilisation to preserve biodiversity. This responsibility is huge both within its own territories and its European and international activities.

In accordance with France's commitments to the Convention on Biological Diversity, the French government formalises them in a national strategy to favour biodiversity (2004). The French strategy acknowledges the need to pursue the integration of the concerns about safeguarding biodiversity in sector-based policies and worked out priority action plans within the scope of the strategy. The Linear infrastructures action plan's goal is to implement of appropriate measures for preservation of the habitats and species, in particular during the construction, maintenance and exploitation phases. Among others, the plan points out the topics fragmentation, conservation and restoration of corridors.

The French government organised, at beginning July 2007, the "Grenelle de l'Environnement" round table process on six themes among which biodiversity and natural resources. For the first time, the Grenelle brought all the civilian and public service representatives together around the discussion table (the State, unions, employers, NGOs and local authorities). The aim of the round table was to define the key points of government policy on ecological and sustainable development issues for the coming five years. Since the end of 2007, operational committees meet to define directives and objectives for operational programs among which the establishment of the national ecological network: the "green and blue network". The green network is a planning tool consisting of large natural areas of high ecological value, and corridors that link them or act as buffers, based on a mapping. It is complemented by a blue network of waterways and bodies of water and the plant-covered strips along the edge of these areas. One of the major points of this ecological network is its possible opposability with major infrastructures to be built.

In order to facilitate the implementation of this new strategy, technical department for transport, roads and bridges (SETRA) and the Technical and Scientific Network (French ministry of sustainable development) produces and spreads state of art knowledge and know how. The aim of this poster is to present this new environmental policy of France and the solutions elaborated by the technical department of transport and the technical and scientific network to take into account the "green and blue network" into transport planning and existing network.

One of the challenges is to identify fragmentation black spots due to transport infrastructures, set measures for protecting landscape's quality and ecological continuities. Landscape ecology constitutes a relevant tool for this assessment, to reveal and anticipate infrastructures effects, limiting the necessity to implement mitigation or compensation measures. This constitutes a relevant tool for the development and the management of territories.

Biographical Sketches

Sabine Bielsa is an environmental engineer of the technical department for transport, roads and bridges (SETRA) of the French ministry of ecology, energy, sustainable development and town and country planning (MEEDDAT) with experience in biodiversity and transport infrastructures.

Amandine Bommel is an environmental engineer of the same technical department who is a specialist in landscape ecology and linear infrastructure.

Eric Guinard is an engineer in ecology of the Centre d'Études Techniques de l'Équipement du Sud-Ouest (CETE SO, MEEDDAT) specialized in expertise and management assistance of ecological studies on road and motorway projects.

Motorways and Bird Traffic Casualties: Carrions Censuses and Scavenging Bias

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Abstract

Studies on the impact of motorway on bird mortality are not so numerous, especially for passerines because of their low detectability. Because birds fly, they can move without being constrained by lands structures. This increases difficulties to detect key factors implied in traffic induced mortality.

Counting dead animals from car on safe lane allows recording on long sections of motorway (>30 km). Such censuses are especially needed to evaluate the link between i) high concentrations of birds' casualties (hot spot of mortality), ii) the type of verges and neighbouring landscapes and iii) the neighbouring birds' guilds. But the counterpart of this method is the reduced precision compared to censuses on foot, potentially increasing a major bias in such analysis: heterogeneity is species detectability (e.g. small species less detectable than larger ones). Few studies have evaluated a major another source of bias in detecting mortality, i.e. scavenging of corpse before detection. Evaluations of scavenging have been conducted in the past (Göransson et al. 1978, Johnson 1989, Antworth et al. 2005) but no studies have investigated its impacts through seasons and years. This study intended to evaluate seasonal variations in scavenging activity in order to obtain more accurate birds' traffic casualties estimation.

Studied areas: 4 motorways in South-West of France, for a total of 150 km (2006-2008).

Method: Each section is studied once a season on a 3 days census period, with 5 successive counts to estimate detectability rate, using the capture-mark-recapture methodology. Counts were made by car, driving at 40-50 km.h^{-1} on the safe lane. A comparative count on foot was realised on verge in a sampled section of about 10 km long. During the first count, 2 days old dead chickens were dropped each kilometre on the safe lane, to have a better estimation of scavenging activity.

Results and Discussion: Scavenging activity is at the highest in spring, 50-60% of chick carrions disappearing per day. In winter only 15-20% of laid chickens disappear per day. Half of these disappearance happened during the night, suggesting the importance of mammal carnivores. Small birds were more scavenged than bigger ones. Hence, passerines are less detected and disappear faster than larger birds. Altogether, a better estimate of mortality can be derived from this study. Spatial distribution of scavenging can be compared with those of bird carrions. First results tend to show that scavenging is more rapid in area of high mortality. Normalisation of this methodology could permit to collect a big set of comparable data.

Biographical Sketches

Éric Guinard: Engineer in ecology (MSc in 1995 University of Lyon, France) and in environmental engineering (MSc in 2000, University of Coventry, UK / E.M.E., Rennes, France) in the Centre d'Études Techniques de l'Équipement du Sud-Ouest (CETE SO) nearby Bordeaux. I have been recruited on permanent position in the French ministry of Ecology, Energy, Sustainable Development and Town and Country Planning in 2002. Our team (DAI/GENV) is specialized in environmental evaluations of linear transportation infrastructures and in environmental assessments of urban planning and politics. I am in charge of expertise and management assistance of ecological studies on road and motorway projects. I also participate to the elaboration of methodologies and realize applied research projects, concerning mainly interactions between transportation infrastructures or urban extension and natural habitats (e.g. normalization of ecological studies on road projects, methodology and modelling on regional habitat fragmentation cartography). A part of this work is performed through a Ph-D (EPHE (Paris) / MNHN / CNRS) on the research project described above (roads and birds casualties).

Romain Julliard: Ph-D (1996, University of Montpellier, France; supervision: Jacques Blondel) on the evolution of dispersal through the study of the life history of locally born and immigrant tits (/Parus sp/) and ESS modelling. Post-doc under the supervision of Prof. Stenseth (Oslo, Norway) on population dynamic of rodents (regulation through density-dependent survival) and exploited fish (separating natural and fishing mortality). I'm currently holding a permanent research and teaching position at the French National Museum of Natural History in a scientific research team investigating the population ecology, community ecology and conservation biology in France. Our specialty is the design and implementation of volunteer-based monitoring at large spatial scale. Our partnership with a large number of volunteers has proved to be a powerful, productive and cost-effective way of monitoring wild populations, especially of birds. Volunteers record wild birds systematically using survey methods developed by us. In particular, our lab holds the French ringing scheme. We then compile the records and analyze them for publication. This work makes a direct and vital contribution to conservation, by enabling decision-makers to set priorities, especially through our indicators. It also provides a unique insight into the state of our environment and how it may be changing. Although our role is to provide objective scientific information, much of our work is hence directed to applied problems. The types of investigations carried out are mainly those that are appropriate for extensive work by volunteers, which is our unique strength. Our savoir-faire on bird monitoring leads us to develop monitoring schemes on other groups of species (bats, butterflies and plants), involving both skilled volunteers and the general public.

Christophe Barbraud: Ph-D (1999, University of Tours, France). I'm currently holding a permanent research position in CEBC – CNRS since 2001 in “the Top marine predators” research team. The ultimate goal is to evaluate the consequences of climate and ocean variability on resource distribution and on the demographics of marine predators. This program is structured around two main priorities:

- The influence of climate change on marine populations and ecosystems,
- The importance of the various top marine predator populations’ capacity to adjust to predicted environmental changes in a given marine ecosystem.

To do so, we take an original approach focused on long-term individual monitoring (demographics, biometrics, ecology at sea) of twenty species of birds and marine mammals, in order to understand populations and ecosystems.
My activities and research interests are ornithology, ecology, evolution of life-history traits, trade-offs, population dynamics, climatic variations, white stork, herons, petrels, penguins, albatrosses. My research projects are:

- Effects of climatic and environmental variations on seabird
- Detecting the trade-offs between life-history traits (survival, reproduction) associated to the cost of reproduction hypothesis in long-lived birds
- Population dynamics and conservation of a White Stork population in western France

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ROADSIDE VERGES IN INTENSIVE AGRARIAN LANDSCAPES: A POSITIVE IMPACT ON BIODIVERSITY TO BE TAKEN INTO ACCOUNT IN ROADSIDE MANAGEMENT

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Abstract

Roads are known to have negative effects on plant diversity and on environment. Despite this influence, roadsides could also constitute a refuge and/or ecological corridors in anthropogenic ecosystems.

The French roadside verges cover 5100 km^2 (near 1% of the country area), more than the total area of French National Parks (representing 3400 km^2). Thus, such large areas could play a significant role in plant and animals conservation. In specific agricultural landscapes, plant diversity is generally low and concentrated at field boundaries, groves and roadsides. Because verges represent important conservation areas, may provide habitat and thus create refuges in hostile matrix and corridors for animals, it should be interesting to encourage extensive policies of management of highway and roadside verges in these landscapes.

The aim of the present scientific research is to assess the role of roadside verges as refuges and corridors for wild plant species and habitat, corridor or/and barrier for small mammal species in a typical intensive agrarian landscape. We also interpret some results in terms of roadside management.

The study site is the intensive agricultural zone (France, 48° 32′N, 2° 39′E), mainly composed of agricultural fields used for intensive crop. Plant inventories were performed to estimate plant species, richness and composition in different spatial units. Comparative analysis of small mammals populations was also made between different habitats.

Compared with the others sites (grove, agricultural field), more than 65% of plants were observed in roadsides (representing about 25% of the total regional plant diversity). A majority of plants (51%) were only detected in this habitat. We also showed a strong negative correlation between percentages of forest plants in roadsides and distances to groves. Those relations coupled with the observation of enhanced plant diversity in groves adjacent to roadsides compared to isolated ones demonstrated the role of roadsides as corridors between natural habitats for plant communities. All the results of this study show that in intensive agricultural landscapes roadsides may often serve as refuge for native plant diversity and act as corridors for plant dispersal between isolated forest fragments. However, the presence of roads in a landscape appeared to have a negative impact on plant communities of surrounding areas, since we observed that species richness and diversity of groves increased with distance to roads.

The results obtained on small mammals showed higher densities of animals in verge habitats compared to neighbouring habitats. Population dynamic in verges show that in intensive agricultural landscapes, roadside and highway verges serve as refuge, habitat or corridor for small mammals depending on species and margin characteristics. This demonstrates the importance of these marginal zones for small mammals in intensive agrarian landscapes.

Our results suggest that the reduction of mowing from three cuts a year (ordinary management) to one single late cut had a strong effect on roadside plant communities. Plant diversity increased strongly and rapidly, and plant communities changed in their structure. With this experiment, we showed how management policies are able to conciliate plant diversity protection with public finance savings.

Acknowledgements

The research was supported by the French Ministry of Ecology, Energy, Sustainable Development and Town and Country Planning (MEEDDAT).

Biographical Sketches

Louis De Redon is a student at the Muséum National d'Histoire Naturelle, Paris. His project aims to study the possible functions of “habitat” and “corridor” of roadside verges for small mammals and plant communities in these agrarian landscapes and also show that number of anthropogenic parameters could impact those effects (roadside management (cutting), verge widths, hedgerows).

Sabine Bielsa is an environmental engineer of the technical department for transport, roads and bridges (SETRA) of the French ministry of ecology, energy, sustainable development and town and country planning (MEEDDAT) with experience in biodiversity and transport infrastructures.

STEEP CUT SLOPE COMPOSTING: FIELD TRIALS AND EVALUATIONS

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Purpose Statement

The purpose of the Steep Cut Slope Composting: Field Trials and Evaluation project is to optimize cost-effective application rates of compost materials and compost retention techniques that increase the establishment of native plants on steep slopes.

Abstract

Successful revegetation of highway right-of-ways requires creating environmental conditions conducive to the successful establishment and survival of reclamation seedings and plantings. Steep cut slopes present a challenge, given the difficulty of replacing salvaged soil with conventional equipment and retaining soil on these areas. Standard practice is to broadcast seed and hydromulch. This is problematic on steep bare slopes, often resulting in marginal native plant establishment related to low germination rates and seedling survival due to nutrient poor, rocky substrates characteristic of steep cut slopes.

The Montana Department of Transportation (MDT) is sponsoring new research to establish cost effective application rates of compost materials on steep slopes. Past MDT research demonstrated the value of applying compost to reduce harsh growing conditions on steep cut slopes. The earlier study demonstrated that compost blankets with depths of 2.5-5.1 centimeters (cm) failed to show a difference in vegetation performance and erosion control between the two application rates and losses of compost were noted due to wind and water erosion prior to native vegetation establishment on one set of plots, prompting the need for an evaluation of compost retention techniques.

A test site approximately 25 kilometers west of Bozeman, MT along Montana Highway 84 with steep cut slopes of approximately 2 horizontal (H):1 vertical (V) with minimal vegetation provided an opportunity for the establishment of treatment plots on both north-facing and south-facing slopes in November 2008. Treatments include compost blankets of three thicknesses - 0.32, 0.64, and 1.3 cm - applied over a seed mix of native grass species appropriate for the site. In addition, five compost retention techniques are being tested on 1.3 cm thick compost blankets: an erosion control fabric, synthetic netting and three commercially available compost tackifiers.

The first year results will be collected in summer 2009 and reported in the poster. The results will include preliminary native plant establishment data for the three different thicknesses of compost blankets on both north- and south-facing slopes and the relative effectiveness of the five different compost retention techniques.

The results will demonstrate whether there are similar benefits that result from less compost being applied to hostile soils on steep cut slopes and provide evidence on the success of five different compost retention techniques. This will allow for an evaluation of the cost effectiveness of both compost application rates and retention methods.

MONITORING AND ENHANCING WILDLIFE MOVEMENT ACROSS FREEWAYS IN URBAN SOUTHERN CALIFORNIA

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Abstract

Freeways can act as barriers to movement and cause significant mortality in wildlife, potentially resulting in adverse population effects. In highly fragmented urban landscapes such as those in southern California, freeways commonly separate remaining natural areas. At Santa Monica Mountains National Recreation Area, a national park just west of Los Angeles, freeways separate the Santa Monica Mountains and the Simi Hills, the two largest areas of open space, from other suitable habitat. Since 2002, National Park Service (NPS) and California Department of Transportation (Caltrans) biologists have utilized planned freeway improvements, specifically lane additions, to facilitate monitoring of wildlife movement across two freeways and investigate the potential of mitigation measures to reduce wildlife mortality and increase use of crossings points. Along State Route 23 (SR23) in the Simi Hills, we conducted wildlife mortality surveys along a 3.2 km stretch for 34 months. Using remote digital cameras, we simultaneously monitored wildlife use of three underpasses along the same stretch of freeway, two of which were significantly obstructed by debris. We documented 222 wildlife mortalities, including 47 rabbits and 43 coyotes, and extensive use of the open culvert by various species, but especially by coyotes, which were detected at a rate of 0.9 photos/day. However, the two blocked culverts received significantly less use. During the construction of the two new lanes, Caltrans maintenance personnel cleared the two blocked underpasses, and the construction contractor built an entirely new right-of-way fence along the freeway, including 12 one-way wildlife gates that are designed to allow animals to exit the freeway area but not enter it. We are beginning to monitor wildlife mortality, underpass use, and use of the one-way gates, post-construction and mitigation efforts. Recently, we have also begun to monitor wildlife use of three crossing points (two underpasses and one road bridge), along Highway 405 in the Beverly Hills area, one of the busiest stretches of freeway in the U.S. Here, we are using digital cameras both at the crossing points and in open space areas near the freeway, and we are monitoring wildlife movement and activity before construction, during the construction phase, and again after the construction and mitigation phases. Initial monitoring has detected all of the larger local wildlife species near the crossing points, including bobcats, deer, and mountain lions, and a (smaller) number of species utilizing the crossing points themselves, specifically bobcats, raccoons, coyotes, and skunks. Although mitigation efforts to increase connectivity and decrease mortality for wildlife along freeways are increasingly common, it is rare to have the opportunity to rigorously evaluate these efforts. Through long-term close cooperation between a federal conservation agency and a state transportation agency, we are gathering valuable information about mitigation efforts along busy freeways and about wildlife movement in challenging urban landscapes.

OCCURRENCE OF ROAD AND TRAFFIC ASSOCIATED HEAVY METALS IN SOIL SEDIMENTS IN SOUTHERN NEW MEXICO

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Abstract

Roads and the associated vehicle traffic can release heavy metals to the environment, including through the abrasion of tires and brake pads (Cd, Cu, Sb, Zn), vehicle corrosion (Cd, Cu, Fe, Ni, Zn) and from fuel additives (Cd, Mn, Pb, V, Zn). These heavy metals can accumulate along roadsides, potentially at levels that are harmful to the vegetation and animals living there. Here we report preliminary results on a study measuring the concentrations of Cd, Cu, Fe, Mn, Ni, Sb, V, and Zn in surface soils near Interstate 10 in southern New Mexico (the northern Chihuahuan Desert). Soils were collected at distances of 0, 5, 10, 14, 20, 30, 40, and 50 m from the road. The samples from two sites were acid digested in aqua regia and analyzed with ICP-OES (Cu, Fe, Mn, Ni, Pb, V, Zn) and ICP-MS (Cd, Ni, Pb, Sb, Zn). Heavy metals released from roads and vehicles are expected to show decreasing concentration with distance from the road. Fe, Mn, and V showed no pattern with distance from the road, with similar concentrations found at all distances. The remaining heavy metals (Cd, Cu, Ni, Pb, Sb, Zn) all showed decreasing concentrations with distance from the road, with concentrations typically reaching background levels at 10 or 15 m from the road. The samples from the roadside (0 m) were a mixture of small (< 1mm) asphalt particles and soil, and these samples typically had concentrations of these metals at least double that of the background. At these two sites there is little vegetation until about 6 or 7 m from the road. Given that the heavy metal concentrations are decreasing to background levels by 10 to 15 m, this suggests that there might be a relatively low risk of plants uptaking these metals and introducing them into the food web. However, determining the spatial distribution of these heavy metals could help to inform potential mitigation measures, such as keeping vegetation mowed to distances of 15 to 20 m. Future work will include analyzing more sites on this road, as well as sites along a smaller, less heavily traveled road in the region.

Biographical Sketches

Kevin Floyd is a doctoral candidate at UTEP studying the impact that roads have on lizard populations. He received his M.S. in the Ecology Graduate Group at the University of California, Davis, in 2002.

Jason Parsons is a postdoctoral research assistant in the Chemistry Department at UTEP.

Jorge Gardea-Torresday is the chair of the Chemistry Department at UTEP.

Elizabeth Walsh is a professor in the Department of Biological Sciences at UTEP.

Carl Lieb is a professor in the Department of Biological Sciences at UTEP.

Inter-Species Associations at Wildlife-Crossing Structures: An Analysis of Long-Term and Daily Patterns of Wildlife Movement Along the Trans-Canada Highway, Banff National Park, Alberta

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Introduction

Wildlife crossing structures used to mitigate the negative effects of roads on wildlife movement and mortality. An under addressed but central question in evaluating the performance of wildlife crossing structures has been the role of inter-specific interactions; namely, do predators exploit crossing structures to increase prey capture rates, do competitive species avoid each other at crossing and does human use of the crossings negatively affect wildlife use.

Methods

We used tracking records for cougars, coyotes, wolves, black and grizzly bears, and ungulates (deer, elk, moose sheep) collected every 2-4 days between November 1996 and October 2008, at 22 crossing structures along the Trans-Canada Highway in Banff National Park. We calculated a species interaction factor (SIF) for each paired-species comparison. SIF is calculated by taking the probability of 2 species co-occurring (i.e., number of co-occurrences/ number of crossing structure checks) and dividing by the product of the two species individual occurrence probabilities. An SIF of 1 indicates species co-occur independently of one another, a SIF <1 indicates avoidance and a SIF >1 indicates greater co-occurrence then expected by chance. We calculated the SIF for paired large carnivore competitors and between carnivores and ungulates.

Next, we used data from motion-sensitive cameras that record the timing of animal movements placed at two crossing structures. We calculated the elapsed time between the most recent crossing event by Species A to each crossing event by Species B ($T_{previous}$). We then calculated the elapsed time from each crossing event by Species B to the next most proximate crossing event by Species A (T_{next}). If the crossing events by the two species do not interact, then the means of $T_{previous} = T_{next}$. However, if Species B use of the crossing delays Species A from using the crossing structure then $T_{previous} < T_{next}$. Conversely, if Species B attracts Species A to the crossing structure, then $T_{previous} > T_{next}$. We used a Wilcoxon rank sums test to determine of $T_{previous}$ is significantly different from T_{next} among large carnivore competitors, between large carnivores and ungulates and between humans and all species.

Results

Using the track data, the overall SIF was > 1 for all species except for wolves and cougars (0.69). We found no evidence of avoidance among large carnivore species. Using the camera data, ungulate use of the crossings were only delayed by coyotes (by an average of 2.14 days) and not other large carnivore species. Ungulates significantly hastened the use of the crossings for wolves by 57%, but not for coyotes or cougars. We found no significant effect of human presence at the crossing structures on the timing of use by other species.

Discussion

We found few instances where competing species negatively affected the use or timing of crossings by one another. Indeed, with few exceptions, use of crossing structures by competitive or exploitive species appears to be positively correlated in time and space. These results suggest that site (location, type of crossing) or seasonal (weather, traffic volume) variables may explain more variability in crossing structure use than inter-specific relationships.

Biographical Sketches

Adam T. Ford is a wildlife research associate working with the Western Transportation Institute from Montana State University and is based in Banff National Park, Alberta, Canada. He is conducting research on the effects of roads on wildlife populations within Banff, as well as monitoring wildlife movement through crossing structures along the Trans-Canada Highway. Adam has worked for government and non-profit agencies on wildlife and ecology research issues for

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Tony Clevenger has carried out research during the last 12 years assessing the performance of mitigation measures designed to reduce habitat fragmentation on the Trans-Canada Highway (TCH) in Banff National Park, Alberta. Since 2002, he has been a research wildlife biologist for the Western Transportation Institute (WTI) at Montana State University. Tony is currently a member of the U.S. National Academy of Sciences Committee on *Effects of Highways on Natural Communities and Ecosystems*. Since 1986, he has published over 40 articles in peer-reviewed scientific journals and has co-authored three books including, *Road Ecology: Science and Solutions* (Island Press, 2003).

EVALUATION OF MITIGATION MEASURES FOR BIRD ROAD-KILL ON HIGHWAY

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Abstract

Birds are major road-kill victims on National Freeway No. 3 in Taiwan. Although acoustic barrier and roadside hedgerows are often suggested to be the mitigation measures for bird road-kill, only a few studies have been conducted to evaluate their effectiveness and the results were often contradictory.

We examined the effects of acoustic barrier (3m high) and roadside hedgerows of different height on the fly height of birds across road along viaducts or embankment respectively in National Freeway No. 3. Between April-June and September-November 2008, we recorded bird behavior along road sections of known road-kill hotspots. The major bird victims are Columbidae, *Passer montanus, Pycnotus sinensis*, and Hirundinidae/Apodidae.

Proportion of birds flying below 3m (height of acoustic barrier) were significantly lower at road sections with acoustic barrier on either viaducts or embankment, moreover the proportion was lower along road sections with acoustic barriers on both side than on one-side, which means that acoustic barrier on both side could effectively facilitate birds to maintain their fly height when flying across road, but one-side acoustic barriers cannot. Proportion of birds flying below 3 m were significantly lower along road sections of high hedgerows than along mid and low hedgerows, and the proportion along road sections of mid hedgerows were also significantly lower than that of low hedgerows on embankment. However, no significant difference was found between the proportions along road sections of high and low hedgerows on viaducts. Although more birds flying over road sections with acoustic barriers on both sides and high hedgerows could maintain a fly height of 3m, such height is not enough for birds to avoid collision with trunks which are up to 4.5m in total height.

Our results reveal how acoustic barriers and roadside hedgerows can help reduce collision risk of birds by facilitating them to raise and maintain their fly height when flying across road. We suggest that acoustic barriers above 4.5 m high on both sides of a road should be tested to see if it can help reduce road-kill of birds more effectively.

Keywords

Acoustic barrier, Roadside hedgerows, Road ecology, Bird conservation, Road casualties

Biographical Sketches

Yung-Hui Hsu is currently a graduate student in the Institute of Ecology and Evolutionary Biology at National Taiwan University. Hsu's research interests are the impacts of the roads on wildlife and how these impacts can be mitigated. Education: M.S. in Ecology and Evolutionary Biology (2006) and B.S. in Zoology (2005), National Taiwan University, Taipei, Taiwan.

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The Importance of Pre-Construction Data for Planning and Evaluating Wildlife Crossing Structures

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Project Description

The authors discuss pre-construction wildlife data applications from three extensive highway mitigation projects in western North America.

Abstract

Wildlife crossing structures, in concert with fencing, are increasingly being installed along major highways in an effort to improve landscape permeability for wildlife movement. Few road projects, however, have conducted extensive wildlife monitoring prior to the implementation of measures designed to mitigate highway effects on wildlife populations. Pre-construction monitoring can potentially inform the location of wildlife crossing structures, and provides critical baseline data for evaluating the performance of mitigation measures. At the most basic level, pre-construction presence data yield important information about which species can potentially be expected to use structures. Further, although the use of crossing structures by wildlife can be documented during the post-construction phase, it is difficult to assess whether *changes* in wildlife crossing success have occurred without relevant baseline data. Baseline data are also critical for assessing the effectiveness of fencing in reducing the rate of animal-vehicle collisions (AVCs). Finally, pre-construction baseline data can be coupled with power analyses to help guide the intensity and duration of post-construction monitoring.

Our poster describes pre-construction data applications from three highway projects in western North America: U.S. Highway 93 in Montana, Interstate 90 at Snoqualmie Pass in Washington, and the Trans-Canada Highway in Banff National Park, Alberta, Canada. The first two projects employ data gathered specifically to meet pre-construction monitoring objectives, which include assessing wildlife-vehicle collisions, quantifying rates of wildlife movement across the highway, measuring wildlife crossings via the use of existing structures (e.g., drainage culverts), and evaluating population distributions of select focal species in the vicinity of the highway. Remote cameras, track beds, snowtracking, noninvasive DNA sampling, and telemetry are among the field methods used to acquire pre-construction data. In contrast, the Banff application employs models of pre-existing data to help inform the placement of crossing structures during a later phase of the project.

We discuss objectives, methods, and relevant findings from each of the projects described above. We also illustrate how pre-construction monitoring can be used to help address larger, population-level objectives regarding habitat connectivity and gene flow—including for low-mobility species. Lastly, we offer recommendations for those engaged in planning highway mitigation projects; for example, monitoring efforts must be designed to yield sufficient statistical power to detect differences between pre-construction and post-construction data.

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Biographical Sketches

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Do Forest Roads Influence Wildlife Boundary Locations?

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Abstract

Our overarching goal of this study is to investigate the interaction between forest roads and fire in the context of fire boundary creation. Studying fire boundary locations may lead to more effective fuel treatment practices, and more efficient to fire suppression activities. Historically, a considerable amount of research has focused on fire ignition locations on forest landscapes in relation to transportation corridors. The relationship of fire boundary locations to roads, however, is largely unknown. Therefore, our first phase of analysis quantifies the relationship of fire boundaries to various landscape variables: distance to forest roads, slope, terrain shape index, heat load index, distance to streams and canopy cover. We analyzed six fires within the Wenatchee National Forest in the eastern Cascades mountain range of central Washington State. Data on canopy bulk density fuels, terrain were obtained from the LANDFIRE project; data on fire perimeters were obtained from the Monitoring Trends in Burn Severity (MTBS) project; and data on roads and streams were obtained from the Wenatchee National Forest.

Case points were sampled on all fire boundaries at 200 meter intervals, and 10 matching control points were sampled at 100 meter intervals insides and outside the boundary for each case. A matched case-control logistic regression was performed to identify the environmental difference between each case and its set of sampled control points. The differences were then expressed as a coefficient for each landscape variable.

The level of significance of these landscape predictors to fire boundaries varied among the fires. We found that fire boundaries tend to be closer to roads, evident in the Deep harbor, Deer point, and Pot peak fires. At the same time, terrain attributes, such as heat load index, terrain shape index, and slope, vegetation variables, such as canopy cover and fuel model, are important determinants in stopping of other fires: Rex Creek, Icicle and Fischer fires. Fire boundaries tended to be located close to the roads, in flat areas, and in areas with low canopy cover. Fire suppression activities are more effective close to roads because of ease of access and because roads act as a physical barrier to a moving fire. Fire behavior is also less extreme in flat areas, and in areas with low canopy fuel loads.

Identifying potential fire boundaries may help managers to locate fuel treatment effectively, which can enhance fire suppression activities. Furthermore, this information can assist land managers in the decision making process concerning construction, maintenance, and the decommissioning of forest roads. Future research effort including additional fuels data and with different types of roads (paved vs. gravel) will advance this research and improve the understanding of fire boundary locations.

Structure, Function, and Ecosystem Services of Interstate Forests in Louisville, KY

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Abstract

Highways are hotspots of air pollutant concentration in the urban landscape, since motor vehicles produce a large portion of the fossil fuel combustion in cities. Forests alongside highways are important systems to study since they experience high levels of inputs from nutrient pollutants (e.g., CO_2, NO_2), while maintaining ecosystem processes (e.g., community succession, decomposition) that do not occur in systems directly manipulated by people (e.g., gardens, street trees). My research focuses on investigating the ecological structure (woody vegetation community) and function (ecosystem productivity) in forests adjacent to interstates, as well as modeling their potential to provide ecosystem services (e.g. pollutant filtration, carbon storage/sequestration). To determine the vegetation structure, function, and ecosystems services of forests alongside interstate corridors in Louisville, Kentucky, we studied the woody plant composition and primary production in twenty-one 100-m^2 plots, and estimated their ability to store/sequester carbon and capture pollutants using the UFORE (Urban Forestry Effects) model. In addition to harmful pollutants, some vehicle emission products stimulate plant growth (carbon dioxide and nitrogen dioxide). To determine the exposure of woody plants along highways to these nutrients, I am studying carbon dioxide (CO_2) and nitrogen dioxide (NO_2) movement through these urban forests by measuring their atmospheric concentrations.

Woody plant communities along these interstates exhibited species composition distinctions that correlated with the abundance of an exotic, invasive shrub, Amur honeysuckle (*Lonicera maackii*). Communities dominated by honeysuckle had lower mean tree seedling density (13 ± 0.8 vs. 302 ± 72 seedlings per 100 m^2), higher mean exotic tree species (29% vs. 0.3%), and half the species richness (10 vs. 20 species) than plots with low densities of this exotic shrub. While mean tree basal area was similar between these two community types, there was a trend for lower primary productivity in honeysuckle-dominated plots (322 vs. 381 g senesced leaves m^{-2}; $p = 0.08$). Lower foliar primary productivity was associated with 24% less carbon storage and sequestration by trees. The UFORE model also estimated 36% lower particulate matter and 18% lower ozone capture by trees in honeysuckle-dominated plots. Atmospheric concentrations of NO_2 were higher in a honeysuckle-dominated plot vs. a low density honeysuckle plot. NO_2 concentrations decreased linearly up to 20 meters from the interstate in both plots. CO_2 concentrations did not demonstrate a pattern with increasing distance from the interstate. This was probably due to ecosystem processes (photosynthesis and respiration) constantly using or producing CO_2 and so masking CO_2 derived from fossil fuel emissions.

These results suggest that Amur honeysuckle negatively affects the ability of these narrow woodland patches along interstate corridors to act as pollutant filters, while also altering the ability of these woodlands to provide future ecosystem benefits by reducing tree seedling recruitment. Investigating these often overlooked highway ecosystems improves our understanding of their importance in capturing and storing fossil fuel derived carbon and nitrogen in the urban landscape, and how different plant species may be managed to improve this ecosystem service.

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Biographical Sketches

Tara L.E. Trammell is a doctoral candidate in the Department of Biology, University of Louisville. She has received a University Fellowship from the graduate school and a research assistantship from the USDA Forest Service, Northern Global Change Program to conduct her research in Urban Forest Ecology. She received a M.S. in Biology from the University of Louisville and a B.A. in Mathematics from Berea College. Her research interests include mathematical modeling, ecosystem ecology, and urban ecology.

Margaret M. Carreiro received her Ph.D. from the University of Rhode Island in Botany and Mycology, and is presently an Associate Professor in the Department of Biology, University of Louisville. Her research program centers on understanding the condition and responses of vegetation and soils in urban and suburban landscapes, and the effects of urbanization on ecosystem processes and ecosystem services in natural habitats. She is also collaborating with social science researchers, urban decision-makers, environmental managers and other practitioners to understand how green space conservation and management can be applied to make cities and suburbs more resilient to environmental perturbation, and healthier and more pleasing places for people to live. She was lead editor of an international book on urban forests published by Springer in 2008. Her research interests include ecosystem ecology, soil ecology and urban ecology.

ECOLOGICAL CONSIDERATIONS FOR THE MANAGEMENT OF NON-NATIVE SPECIES DURING THE MAINTENANCE AND OPERATION OF NATIONAL ROAD SCHEMES IN IRELAND

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Abstract

During road construction non-native invasive species can be disturbed by machinery and brought into or out of a route corridor, in the form of plant fragments or seed, either within the soil load or on the tyres or tracks of machinery. Cutting of roadside vegetation can also distribute seeds and plant fragments of invasive species, which can then be carried along the road corridor by wind or on tyres of vehicles including cars (see Wace 1977; Wilcox 1989).

Dolan (2004) identified the following invasive species typically found in roadside landscapes in Ireland: Japanese knotweed (*Fallopia japonica*), Winter Heliotrope (*Petasites fragrans*), Giant Rhubarb (*Gunnera tinctoria)*, Traveller's Joy (*Clematis vitalba*) and Himalayan Balsam (*Impatiens glandulifera*) (see Reynolds, 2002).

Prevention, early identification and management of non-native invasive species can avoid or reduce the need for long-term maintenance regimes (with associated costs) and impacts on the Irish landscape. While awareness and early detection of invasive species prior to or during construction will provide a means to implement management regimes at an early stage in an invasion event, it is the prevention of an invasion that is likely to be the most environmentally sound approach.

The key areas that determine invasion success are a combination of a habitat's degree of susceptibility to invasion (Pyšek and Prach 1993; Burke and Grime 1996), plus the traits of the invading plant species (Pyšek and Richardson, 2006). Although, susceptibility is easy to categorize, it is the identification of consistent traits which is proving more difficult (Thompson et al. 2001), as different traits may be more advantageous in different habitats (Alpert et al. 2000). Furthermore, the establishment of non-native invasive species also appears to be determined by the presence of mature native plant communities (Lugo and Gucinski 2000; Lundgren et al. 2004).

Whereas the mature native plant communities within the general Irish landscape may be somewhat resilient to invasion, the removal of vegetation and topsoil provides ideal opportunities for non-native species to invade adjacent ecosystems, alter plant community structure and composition (e.g. Saunders et al. 2002), limiting their ability to perform ecological functions and services (Dolan et al. 2005).

As Ireland is currently undergoing a large extension to its national road network, it is clear that much of Ireland's land area has recently, and will, become more susceptible to non-native invasive species.

To date the management of non-native invasive species on Irish national road schemes is absent, inappropriate (e.g. mechanical flailing) or predominantly herbicide based - the latter appearing to 'control' rather than to eradicate.

Given the amount of disturbance that accompanies road building, this research project (part of SIMBIOSYS: multi-disciplinary research across Trinity College Dublin, University College Cork and University College Dublin) aims to utilize field and simulated environment (cold greenhouse) based research to investigate and identify various environments (and subsequently techniques) e.g. various soil types, nutrient levels pH, soil moisture, degree of light exposure and soil microfauna; which may provide resistance or unfavourable conditions for the establishment of non-native invasive species within Irish roadside landscapes.

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Biographical Sketch

Rosalyn Thompson is currently a PhD student at University College Cork (UCC). Part of the SIMBIOSYS group – set up in 2008 to examine the sectoral impacts of transport, bioenergy and aquaculture on biodiversity – her focus is on invasive plant species and invasion resistance. Originally from Caerleon, South Wales (UK), she graduated from Bath Spa University with an honours degree in Environmental Science in 2008.

THE INTEGRATION OF ECOSYSTEMS NEEDS AND TRANSPORTATION FACILITY DESIGN: THE IRISH HISTORICAL CONTEXT

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Abstract

The modern landscapes of the world have been shaped by thousands of years of human activity as evidenced by the presence of various landscape types and their associated ecosystems, land-uses and built cultural heritage including techno- ecosystems such as road ecosystems (see Lugo and Gucinski, 2000; Dolan, 2003; 2004).

Semi-natural ecosystems are known to provide the *critical ecological services* or *life support systems* within the landscape such as waste assimilation, erosion and flood control (Dolan, 2004). Structure, diversity and integrity are important components and attributes of ecosystems as the flow of services between ecosystems and ultimately from the landscape, often requires that they function as intact systems (Roseland, 2000).

What is not yet fully understood is the extent of ecological services provided by road ecosystems and how road ecosystems should be integrated into the landscape in order to provide for the "needs" of semi-natural ecosystems. What is clear is that the integration of road ecosystems into semi-natural ecosystems requires a thorough understanding of how these ecosystem types interact with each other at the landscape or road network scale and over a period of several generations.

As landscape diversity has been identified as an indicator of biodiversity and change in land use type, this project examines changes in landscape diversity and land-use in Ireland as a result of road construction over the past 160 years. Landscape diversity is assessed based on changes to ecological infrastructure within the landscape i.e. loss of semi-natural grasslands, woodlands, hedgerows, riparian corridors, ponds etc versus the provision of roadside verges and corridors, "sealed" habitat beneath road pavements, soil compaction, borrow pits and other associated elements of road infrastructure.

Historic landscape diversity has been extrapolated from Ordnance Survey mapping undertaken in the 1830's, six-inch town land maps, black and white aerial photographs from the 1950's and finally aerial colour photographs from the 1980s in order to identify changes in landscape diversity throughout this period. Biodiversity will be examined from the 1830's onwards by extrapolating information from regional and county flora and fauna archives and on a contemporary assessment of the invertebrate, flora, avian and mammal diversity of the contemporary Irish landscape undertaken as part the SIMBIOSYS project (a multi-disciplinary research project across Trinity College Dublin, University College Cork and University College Dublin, Ireland funded by the Irish Environmental Protection Agency (EPA)).

This information will be used to create an index of landscape diversity relative to biodiversity which will allow an examination of the effects of changes to landscape structure on biodiversity over the past 160 years as a result of agricultural intensification and road development.

The needs of an ecosystem are the various natural elements, resources and assets such as biodiversity, water, soil, air, climate, light and energy which are required to sustain an 'intact' or functioning ecosystem which is capable of maintaining the necessary flow of ecological services within a landscape. This project aims to identify whether road

ecosystems have had a positive or negative impact on landscape diversity and biodiversity over the 160 years relative to changes in biodiversity, water and soil.

Biographical Sketch

Lisa Dolan is currently a post-doctoral research assistance in University College Cork (UCC). Part of the SIMBIOSYS group – set up in 2008 to examine the sectoral impacts of transport, bioenergy and aquaculture on biodiversity – her focus is on the impacts of road ecosystem services on biodiversity and the agri-environment.

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EFFECT OF CULVERT BARRIERS ON TOPEKA SHINERS AND OTHER WARM WATER FISH SPECIES IN SOUTH DAKOTA

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Abstract

The Topeka shiner (*Notropis topeka*) is an endangered species that lives in the James, Vermillion, and Big Sioux watersheds in South Dakota, and portions of several other Midwestern states. There is concern that barriers, such as culverts, may limit the movement of Topeka shiners. Because Topeka shiners are typically found in the upper-most reaches of watersheds that sustain permanent water, a series of road crossings may fragment populations. Connectivity between distant habitats is required to allow refounding of metapopulation segments following local extinctions and to maintain the viability of the overall Topeka shiner metapopulation. Because of these concerns, the South Dakota Department of Transportation sponsored this research.

The purpose of the research is to better understand the factors that may prevent, limit, or allow the movement of Topeka shiners, and other warm water fish species, through culverts in South Dakota, and to investigate the effect of culvert barriers on their genetic diversity.

The research approach combines stream hydrology, geomorphology, culvert hydraulics and fish ecology. The study began in 2007 and will be completed in early 2010. The project is investigating the physical conditions (culvert type, width, height, diameter, length, slope, outlet drop, material, and others) that may or may not limit the movement of Topeka shiners and other warm water fish species by performing a series of weir trap experiments at nine different road-stream crossings. These experiments directly measure fish movement through culverts and through a paired control reach located in a nearby section of natural stream channel. Passage windows, which define the range of passable flow conditions for each fish species identified at each study crossing, are also developed and used to further identify limiting factors. Genetic testing is used to assess the effect of culvert barriers on the genetic diversity of Topeka shiners.

The poster describes the project background, objectives and methods used to perform the research. Data and preliminary results from the first two field seasons, 2007 and 2008, are presented.

Upon completion of the project, we anticipate the final results will identify which types of culvert installations work best for passage of Topeka shiner and other warm water fish species. In addition, we anticipate the research will further the present state of knowledge regarding the effect of barriers on the genetic diversity of Topeka shiners in the study area.

Biographical Sketches

Matt Blank is an Assistant Research Professor in the Western Transportation Institute and the Department of Civil Engineering at Montana State University. Matt earned his Master of Science and Ph.D. in Civil Engineering at Montana State University. He earned his Bachelor of Science in Geological Engineering at the University of Wisconsin-Madison. His research focuses on the interactions of infrastructure and riparian corridors with an emphasis on aquatic connectivity.

Joel Cahoon is a Professor of Civil Engineering at Montana State University. He teaches undergraduate and graduate courses in hydraulics and serves as Program Coordinator for the Civil Engineering degree programs. Dr. Cahoon studies riparian hydraulics, specifically focusing on human activity in and around rivers and streams, and the effects of this activity on ecologic issues.

Robert G. Bramblett is an Assistant Research Professor in the Department of Ecology at Montana State University-Bozeman. His research interests include large river fish ecology, biological indicators of aquatic ecosystem integrity, prairie stream ecology, fish passage, prairie amphibians, reptiles, fishes, and birds, temporal and spatial dynamics of prairie fish assemblages, and native species conservation and management.

THE EFFECTIVENESS OF VERTEBRATE PASSAGE AND PREVENTION STRUCTURES: A STUDY OF BOECKMAN ROAD IN WILSONVILLE

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Abstract

Wildlife collisions are a serious issue resulting in costs from property damage, injury and possible death, as well as fatal results for wildlife. In addition, roads fragment habitats and affect the stability and evolution of the surrounding wildlife community. Therefore, it is crucial to examine whether wildlife passage and prevention structures can effectively reduce road mortality while maintaining habitat permeability. Here we examine the effectiveness of the structures of a new (2008) road in the city of Wilsonville, Oregon, USA, the Boeckman Road Extension, which took wildlife passage into great consideration. Boeckman Road provides a unique opportunity to examine the efficacy of multiple types of passage and prevention structures in a suburban wetland where no road existed previously.

This summer we addressed three main questions about wildlife movement at this road. Are the species and numbers of animals using the passage structures representative of the populations in the area and their movements at distance from the road? Does moderate light level influence terrestrial vertebrates use of passage structures? To what degree will small and medium mammal crossings change after installation of a “critter crossing” device?

We assessed movement through the passage structures by placing motion detect cameras at the entrances to three randomly selected passage structures and recorded for one week before the cameras were randomly reassigned to other passage structures. A camera was also placed at the end of the prevention fencing to record animals circumventing the structures. To evaluate whether community composition, diversity, and movement through the passage structures differ from movement in the area, transects were established at 100m, 25m and 2m parallel north of the road and 2m south of the road. Three motion detect cameras were moved weekly along each transect across randomly-selected subsamples of the predetermined stations, which were approximately the same distance apart as the passage structures. Pit trap arrays were established at all transect stations to assess the community composition of small vertebrates and their movement at distance from the road. Trapping events occurred for three consecutive nights for two sessions. Captured animals were marked to determine movement patterns assessable from recapture.

Two sand strips were placed under the largest passages structure, a bridge, and animal track data were collected pre and post introduction of artificial light, which was activated from dusk until dawn. To assess the effectiveness of

installing a critter crossing device in a passage structure with standing water spanning its width, a motion detect camera was placed at the entrance pre and post installation. Frequencies of successful passage attempts, species, date, time and temperature were collected and compared before and after installation.

Data are still being collected and analyzed. The results of this study will provide information about the community-level effectiveness of different passage structure types and so can help determine what types of passage structures are needed in similar areas. This project is an important first step in a broader study that includes comparison with other roadways and additional types of passage structures.

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Biographical Sketches

Leslie Bliss-Ketchum is currently pursuing a graduate degree in environmental science from Portland State University in Portland, Oregon. She graduated with honors and received a Bachelor's of Science in environmental science and a minor in biology from PSU in 2007. She has completed several internships with organizations such as Americorps, the City of Portland Bureau of Environmental Science, PSU and the City of Hillsboro. Leslie is also holds the Director position for the student run club, Student Water Resources Group (SWRG). She was also recognized by the Environmental Science program at PSU in the spring of 2009 for outstanding departmental service. Leslie finds the issues of urban and more specifically road ecology particularly pressing in regards to natural system functions as the human population continues to increase and the effects of climate change are realized.

Catherine E. de Rivera is an Assistant Professor in Environmental Sciences and Management at Portland State University. She has a BA in Biology from Earlham College and a PhD in Biology (emphasis in Behavioral Ecology) from University of California San Diego. She conducted her postdoctoral research at the Smithsonian Environmental Research Center. She teaches courses in road ecology, invasions ecology, environmental sustainability, marine ecology, and environmental problem solving. Her research interests are in behavioral ecology, invasions ecology, and road ecology. More specifically they include: 1) Investigating factors that limit abundance, distribution, and habitat connectivity; 2) Modeling the potential spread of species; 3) Developing and testing approaches to managing populations, especially of species that are spread or blocked by human transportation systems; 4) Quantifying the community-level effects of the addition of and removal of invasive species; and 5) Studying predator-prey interactions and how ecological factors affect mating systems for estuarine invertebrates.

Kerry Rappold is the Natural Resources Program Manager for the City of Wilsonville. He has a B.S. in Forest Administration from the University of Wisconsin – Stevens Point and a M.S. in Environmental Planning from the University of Wisconsin. During his 7 years with the City, Kerry has had responsibility for program development; compliance with local, state and federal requirements; managing enhancement and restoration projects; stormwater management; and environmental education. Kerry's previous work experience includes silviculture and urban forestry, watershed management and monitoring, and regulatory review and permitting.

Designing New Highways to Reverse Habitat Connectivity Loss Due to Old Highways and Land Use Change: A Case Study in Nayarit, Mexico

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Abstract

Road effect on ecosystems is well documented. Highways create barriers for animal movement and dispersion, producing changes in ecological processes. They affect animal populations by increasing mortality and promote habitat loss, fragmentation and degradation. Indirect impacts include barrier effects, reduction in population permeability, modification in animal behavior and species loss.

Under and overpasses have helped avoid fragmentation caused by highways on developed countries, but they are not the case in undeveloped countries, where most roads, especially in the past, were built with no ecological concern. In Mexico, large animal corridors and habitat have been altered by roads. Endangered tropical mammal populations, such as jaguar, cougar and ocelot are being affected. Also, there is corridor interruption by human modified landscapes related to roads.

In this work, we want to show how a Mexican highway route and design were addressed to reduce landscape fragmentation, restore habitat connectivity, and protect endangered species on the state of Nayarit, western Mexico. A 3,000 km^2 study area was defined at the Sierra Vallejo, Sierra de Tomatlán and the Ameca river region. Border effect on vegetation fragmentation was analyzed using fractal dimension comparison between three road routes. The least-impact route was chosen and the project was modified to allow jaguar and other large mammal movements.

Felid corridor identification is important to mitigate adverse effects caused by roads. One of the most used techniques is “least-cost path modeling”. This procedure models the relative cost for an animal to move between two habitat patches considering landscape features such as slope, vegetation, and human population. Jaguar presence was registered using 60 trap-cameras from June to September 2008. Corridor models were run using a GIS to calculate movement resistance and least displacement route was estimated. Theoretical modeled corridors followed optimal habitat areas with the least possible barriers. Existing roads and the projected highway were analyzed considering modeled corridors and actual animal crossings through drainage structures, also monitored during a one month period using trap-cameras.

As a result, 10 jaguar, 13 cougar, 15 ocelot and 24 deer registers were found in the sampled area. Corridors were modeled and road/corridor conflict zones were identified. Drainage structures on a 30 year old road are being used by most types of mammals encountered. None of such results indicated jaguar use of drainage, but deer, cougar, ocelot and other mammals were frequent users.

Drainage structures for the new highway were designed intended to work as animal crossing passes as well as hydraulic infrastructure; most designs include mimetic features to increase probabilities of use. Overpasses were proposed for existing roads on conflict sites, therefore structures in old and projected roads were located and designed in order to restore connectivity along corridors in the region. Habitat modification at certain sites needed to be restored so that corridors would endure. A vegetation restoration program was proposed.

Landscape fragmentation, corridor interruption and habitat loss, as a consequence of past actions, can be reduced and reversed using economic resources and ecological friendly designs in projected modern roads.

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Biographical Sketches

Norma Fernández Buces is a landscape ecologist with twenty years of experience in environmental impact assessment of different types of infrastructure projects like hydraulic power plants, touristic developments, oil extracting wells and pipelines, airports, bridges and specially, roads and highways. She has a B.S. in Biology by the National Autonomous University of México (UNAM), a M.S. in Ecology and Environmental Sciences and a Ph.D. in Sciences also from UNAM, with several studies in statistics and geostatistics. She has coordinated more than 90 environmental impact assessment studies, while working for three private consulting companies; Grupo Selome being the latest. She has also worked for the Mexican Secretariat of Ecology (formerly SEDESOL) as a World Bank environmental impact consultant, and as Assistant Researcher at the Edapho-Environmental laboratory at the Geology Institute, UNAM. Her work has been published on peer-reviewed journals such as Journal of Arid Environments and she has participated in several national and international congresses of soil science, as well as oral presentations in several courses related to environmental impact. She has published chapters in two books, most recently in 2009, in CRC Press, Taylor and Francis Group.

Sergio A. López Noriega is a restoration biologist with sixteen years of experience in environmental impact assessment of roads and highways. He has been Chief executive officer of Grupo Selome since 1998, organizing and supervising more than 70 environmental impact assessments, as well as studies on fauna management in order to avoid aviation hazards; ecological restoration designs for highways; including a setting up of a cloud forest plant nursery. He also has vast experience in urban impact studies, remote sensing and GIS, project environmental feasibility studies, and in particular, ecological restoration and reforestation projects for highways. He has authored one book chapter on restoration ecology and three more on multitemporal deforestation analysis.

Gustavo P. Lorenzana Piña is a wildlife ecologist with ten years of experience carrying field studies on distribution and abundance of mammalian carnivores, especially jaguars, using camera traps. He has a B.S. in Ecology by the State of Sonora Higher Studies Center (Hermosillo, MX) and a M.S. in Conservation Biology by the Institute of Ecology A.C. (Xalapa, MX). His work has been carried on in several Mexican states, including the semiarid thorn-scrubs and oak woodlands of east-central Sonora, the mesic forests of northeastern Querétaro, and the tropical forests of southern Nayarit. Part of his work has been published in peer-reviewed journals such as Mammalia and Natural Areas Journal. Also he has been involved as a wildlife specialist consultant in several Environmental Impact Assessments for energy (natural gas) and infrastructure (roads) development projects. His main interest is to contribute to the knowledge and conservation of large carnivores, both in natural preserves as in human-modified landscapes.

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OOSTVAARDERSWOLD CORRIDOR: DESIGNING FOR NATURAL SYSTEMS WITHIN THE HUMAN MATRIX

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Abstract

Human-built infrastructure, created to provide safe transportation, food, water and shelter systems, has focused on protecting people by controlling the vagaries of natural systems. These practices have alienated and physically separated people from the natural environment. Behaviors expressive of this alienation have furthered the degradation of natural systems which provide the ecosystems services that support human, and all, life. This thesis project, a 10 km-long wildlife migration corridor connecting Oostvaardersplassen Nature Reserve and the Horsterwold forest in the province of Flevoland, the Netherlands, remediates this alienation and physical separation. The design integrates the demands of a fluctuating hydrologic regime, a high-quality wildlife habitat, and a burgeoning urban region all within the engineered infrastructure of the polder. It is recognized that diversity affords ecological resiliency. By designing for landscape diversity that also re-embeds work, education, trade and recreation into the land, cultural and economic resiliencies are afforded. These combined resiliencies strengthen the likelihood of ecological, cultural and economic success across local, regional, and global scales.

The corridor is located between Almere and Lelystad on land that was diked and drained from the former Zuider Zee in 1968 and is entirely below sea level. It is part of the National Ecological Network, a web of nature areas across the country designed to protect ecological systems and people's access to nature, and the Pan-European Ecological Network. Currently agricultural land, the corridor includes existing transportation infrastructure consisting of European and National highways, two major canals, local roads, a railway line, and bike and pedestrian paths. Existing wildlife populations in Oostvaardersplassen Reserve include migrating and resident birds and introduced grazing mammals, including wild herds of Heck cattle, Konik horses and red deer. Research for the project includes the history of land reclamation and creation in the Netherlands, Dutch cultural relationships to water and land, Dutch landscape typologies, a review of current literature on road ecology, and interviews with major agency stakeholders. The Province of Flevoland is currently planning the corridor, which is scheduled for realization in 2014.

The project can be viewed and downloaded at: http://cynthialapp.posterous.com/

The Province of Flevoland OostvaardersWold website: http://provincie.flevoland.nl/omgevingsplan/oostvaarderswold_2/

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Biographical Sketch

Cynthia Lapp is a recent graduate of the Master of Landscape Architecture program at the University of Minnesota. She earned a B.A. in History and Environmental Studies from World College West in Petaluma, CA, and a B.F.A. in

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PROPOSED CROSSING DESIGN TO ACHIEVE ROAD PERMEABILITY FOR MULTIPLE SPECIES ALONG A RIPARIAN / UPLAND CORRIDOR IN SOUTHERN CALIFORNIA

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Introduction

The California Department of Transportation (Caltrans) contracted EDAW, Inc. to conduct a wildlife movement study to determine potential effects on wildlife movement and the current wildlife usage of underpasses along the existing State Route 76 (SR-76) from S. Mission Road to Interstate 15. Two build alternatives are proposed to relieve existing and future traffic congestion and improve motorist safety, one along the existing SR-76, and one to the south. This study focused on the proposed build alternative along the existing SR-76. This alternative occurs along the San Luis Rey River corridor, identified as a habitat conservation area within the San Diego North County Multiple Species Conservation Plan (MSCP). Both resident species such as toads and small mammals, as well as species with large home range requirements such as large mammals were considered to make recommendations to achieve overall permeability. The goal was to determine how this proposed build alternative could be designed to minimize potential impacts of the roadway and provide a net ecological benefit to regional connectivity, both along the river corridor and across the riparian/upland ecotone. Species specific wildlife crossings were proposed based on the results of the data.

Methods

We collected three and a half years of data using toad surveys, tracking stations, transects, roadkill surveys and incidental observations to characterize wildlife movement for focal species including amphibians, reptiles, and several size classes of mammals. We performed spatial analysis of overall activity, directional movement, and road mortality in order to propose locations and design specifics of wildlife crossings.

Results

We found wildlife mortality occurred across the majority of the survey area for most focal groups. Mammal activity varied by size class at both existing underpasses and possible surface crossings. Directional data of mammal movement indicates some movement between riparian habitat and adjacent uplands.

Discussion

This wildlife movement study highlights the importance of road permeability for species to reach available resources on both sides of the proposed build alternative. Based on this study size class and species specific wildlife crossings were proposed for the approximately 6-mile proposed realignment. Spacing of crossings was determined using allometric scaling based on home range sizes. The crossing design features were determined by integrating survey results, existing literature, expert opinions and consultation with project engineers.

Conclusions

By studying wildlife movement on the current roadway, we were able to assess the effects on wildlife movement and mortality. This allowed for collaboration with engineers to propose a feasible crossing network design for the proposed build alternative to improve conditions for wildlife a along regional corridor and an important ecological resource. Knowledge gaps for future research include better understanding toad crossing requirements in semi-arid systems, barrier effects from roads adjacent to regional corridors, and changes in ecotone resources on population viability of wildlife species.

BOLINAS LAGOON: AN INCREMENTAL IMPROVEMENT

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Abstract

Bolinas Lagoon, a 1,100 acre Ramsar Convention designated wetland of international importance is located in the California County of Marin. It is bordered on its eastern side by approximately 5 miles of Highway 1, and is managed by the Gulf of the Farallones National Marine Sanctuary (NMS). The Lagoon has been undergoing increased siltation since the late 1850's as a result of, among other things, anthropogenic influences within the surrounding watersheds. The NMS has prepared a plan outlining the Bolinas Lagoon Ecosystem Restoration Project. This plan details specific actions that may reduce the rate of lagoon siltation. Improvements to Highway 1, and its drainage infrastructure, are identified as a potentially significant factor for reducing the land-based sedimentation entering the Lagoon.

Mean High Tide (5.0' NAVD 88) is the jurisdictional boundary of the NMS. Highway 1 ranges in elevation from 5 to 20+ feet (NAVD 88) within these boundaries and, may according to some predictions, be inundated with sea level rise. Highway 1, owned and operated by the California Department of Transportation (Caltrans), proposes a project to repair damaged rock slope protection (RSP), replace cross culverts, install new asphalt pavement in areas of pavement failure, and pave with porous pavement existing dirt pullouts within 2 of the 5 miles adjacent to the Lagoon.

The culverts to be replaced have structurally failed or are undersized for the drainage area. Some of the culverts are severely cracked terracotta pipe or corrugated metal pipes that have materially failed (rusted out). Each of the new cross culverts will be smooth interior high density polyethylene (HDPE) pipes with a minimum diameter of 18". Use of HDPE in this highly corrosive environment will extend the useful life of the culverts past other culverts types. The culverts will be installed with drainage inlets that include a 0.4 cubic yard sediment sump to capture sediment generated upstream and prevent it from entering the Lagoon.

Existing RSP, used to protect the roadway prism, was installed without RSP fabric. Without this fabric, fines from behind the RSP are washed out with each tidal cycle, causing roadway prism pavement failure. The installation of RSP fabric will prevent the movement of the fines during episodes of wave action or storms.

Paving of the dirt pullouts with porous pavement is proposed. This pavement will eliminate the erosion and rutting that occurs during the rainy season and will provide for treatment of surface runoff.

While these actions may be small, their combination will greatly reduce sedimentation associated with the roadway prism. This project is listed in the Bolinas Lagoon Ecosystem Restoration Project plan and, as other roadway projects along this section of Highway 1 are planned, similar sediment reduction techniques will be employed. These actions will protect the roadway against a minor amount of sea level rise.

This project involves extensive intergovernmental coordination between Caltrans, Gulf of the Farallones NMS, the County of Marin, the California Coastal Commission, the adjacent landowners, and the Golden Gate National Recreational Area.

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings

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Abstract

To ensure the productivity and viability of river and stream ecosystems, we must protect and restore the quality of the physical environment (habitat), maintain intact communities of aquatic organisms, and take care not to disrupt critical ecological processes. One of our goals should be to provide for the passage of *Aquatic Organisms*.

Stream simulation is a method for designing and building road-stream crossings intended to permit free and unrestricted movements of any aquatic species. San Dimas Technology and Development Center (SDTDC) has developed training workshops for the assessment and design of Aquatic Organism Passage at road stream crossings. After conducting these trainings across the country for several years, SDTDC has recently completed a technical design guide*, and an e-Learning WEB based application. Our poster presentation will display these new instructional tools that address a best practice for road-stream crossing design which clearly demonstrates an example of *integrating ecosystem needs with transportation facility design.*

Habitat fragmentation is an important factor contributing to population declines of many fish, and crossing structures that are barriers are a large part of the problem. Stream simulation provides continuity through crossing structures, allowing all aquatic species present to move freely through them to access habitats, avoid adverse conditions, and seek food and mates. Stream simulation applies to crossing structures on any transportation network, including roads, trails, and railroads. The premise of stream simulation is that since the simulation has very similar physical characteristics to the natural channel, aquatic species should experience no greater difficulty moving through it.

The workshops, the technical guide and the e-Learning training, promote three guiding principles for the design of road-stream crossings.

1. Crossing designs must accommodate the stream's geomorphic processes and anticipated changes over the life of the structure, not simply road or transportation needs. ID teams must factor both systems into the design.
2. Crossings should present the least possible obstacle to stream processes. Streams move water, wood, sediment, and organisms. Crossings should be designed, constructed, and maintained to permit movement of these components to the greatest degree possible.
3. Crossings should not fragment aquatic habitats. Avoiding fragmentation means reproducing the natural conditions of the stream being crossed. The key is matching the structure to the stream, both in form and process.

The primary audience for the workshops, technical Guide and the e-Learning application are designers and interdisciplinary teams, given the challenge to provide for aquatic passage at road-stream crossings.

Designing culverts to avoid channel constriction and maintain appropriate channel conditions within the structure is a relatively simple and effective approach for accommodating the normal movements of aquatic organisms and preserving (or restoring) ecosystem processes that maintain habitats and aquatic animal populations. Ultimately, our goal should be to create a transportation infrastructure that does not fragment or undermine the essential ecological infrastructure of the land.

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* http://www.fs.fed.us/eng/pubs/pdf/StreamSimulation/index.shtml

A COMPREHENSIVE WILDLIFE CROSSING MITIGATION APPROACH IN RIVERSIDE COUNTY, CALIFORNIA

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Abstract

The approximate 32-mile-long Mid County Parkway (MCP) will serve as a major east–west connection within western Riverside County, California, and will also provide for regional movement within Riverside County, Los Angeles County, and Orange County. The proposed action would adopt an MCP alignment and construct a major, limited-access transportation parkway to meet current and projected 2035 travel demand from Interstate 15 (I-15) on the west to State Route 79 (SR-79) on the east. It is likely that the segment between I-15 and Interstate-215 (I-215) will be replaced by improvements to an existing two-lane road as a County Circulation Element roadway. The alignment, design, and environmental review of the road improvements are in the early stages, but some of the concepts developed for the MCP project will be applicable to this project. This area is undergoing substantial population and employment growth. Population in Riverside County overall is expected to double between 2000 and 2030 from 1.5 million to 3.1 million. The proposed alignment essentially replaces current travel routes along existing less-suitable roadways and is expected to translate into a safer and more utilized facility. The project occurs within the vicinity of several habitat and species reserves and is within the boundaries of the Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP) area.

The MSHCP was created so that large-scale, regional transportation corridors, like the MCP, could receive a streamlined permitting process through Section 7 of the Endangered Species Act. In the project planning stages, and working with other state, federal, and local agencies, it was determined that the environmentally superior alignment would minimize impacts and fragmentation to the Lake Mathews Stephens' Kangaroo Rat (SKR) Reserve. However, the project would still impact portions of two reserves for the federally listed endangered SKR and other reserve lands. Therefore, a series of measures was incorporated into the project to accommodate wildlife movement. Design (Donaldson 2005; Jackson and Griffin 1998; Foster and Humphrey 1995; Reed et al. 1979) and frequency (Ford 1980) of the measures were developed by the project team and then approved in concept by the wildlife agencies (i.e., U.S. Fish and Wildlife Service and California Department of Fish and Game) through coordination.

The resulting proposed project is anticipated to include directional fencing, wildlife jump-outs, 13 bridges, seven wildlife-specific culverts, a number of smaller drainage culverts, and two wildlife overcrossings (land bridges) to accommodate SKR and other wildlife. These are among the first wildlife overcrossings proposed in southern California and will be among just a very few across the United States. Implementation of these measures are intended to aggressively mitigate impacts to wildlife movement and fragmentation in this important area of the MSHCP, while still allowing for construction of an important road facility.

As the project is implemented, monitoring of post-construction wildlife usage of culverts, bridges, and overcrossings will be a component of the monitoring plan.

Biographical Sketch

Brock Ortega is a wildlife biologist with Dudek, an engineering and environmental consulting firm based San Diego County, California. Over his 17-year professional career, he has specialized in endangered species, wildlife management, and connectivity issues. He has a background in ecological assessments and endangered species management plan authorship and holds federal 10(a) permits for several avian and invertebrate species. In addition to wildlife management issues, he has managed several large-scale wildlife movement and connectivity studies throughout southern California and the southern Sierra Mountains of California and has performed corridor modeling for several species using a variety of methods. He obtained a Bachelor of Science degree in wildlife management from Humboldt State University in Arcata, California.

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HIGHWAYS PERMEABILITY FOR CARNIVORES IN PORTUGAL: WATER-EFFECT AND EFFECTIVENESS OF DRY LEDGES

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Abstract

The barrier effect of highways represents a serious threat for mammalian carnivores. This impact can be, however, minimized through regular use of culverts, originally designed to manage water flow. The main goal of this study is to evaluate the culverts use by carnivores and the effectiveness of dry ledges in the wet seasons in two highways of southern Portugal (A2 and A6 - Alentejo). In Fall 2005 and Winter 2005/2006 we surveyed 15 culverts for ten consecutive nights in each season using video-surveillance to count carnivore crossings. Furthermore, each culvert was characterized on the basis of structural and environmental attributes, to evaluate which factors promote its use; association between the species-specific crossing-rates and these variables was tested using Redundancy Analysis (RA). A total of 208 completed crossings of carnivores were recorded (1.28 crossing/culvert/day during Fall and 1.49 crossing/culvert/day during Winter). In what concerns to complete crossing index (CI) during these two seasons, we had 0.37 and 0.29 by Eurasian badger (*Meles meles*), 0.14 and 0.21 by otter (*Lutra lutra*), 0.07 and 0.13 by stone marten (*Martes foina*), 0.04 and 0.07 by common genet (*Genetta genetta*) and 0.03 and 0.05 by red fox (*Vulpes vulpes*), in Fall and Winter respectively. The RA showed that, with the exception of the otter, the presence of water is a limiting factor for carnivores for crossing culverts in these seasons. As a consequence, dry ledges were installed in 14 culverts over the A2 and A6 (five of which are equal to the previous sampling) to facilitate carnivore movements under highways. In Fall 2008 and Winter 2008/09 we surveyed for seven consecutive nights in each season. A total of 139 completed crossings were registered (0.57 crossing/culvert/day during Fall and 0.67 crossing/culvert/day during Winter). The CI are 0.21 and 0.31 by stone marten, 0.15 and 0.07 by otter, 0.11 and 0.20 by genet, 0.06 and 0.07 by Eurasian badger and 0.04 and 0.01 by fox, during Fall and Winter respectively. There was only one record of European polecat on dry ledges in winter. The response to dry ledges varied among carnivore species. The presence of water was recorded in 92% (with a maximum of 30 centimeters depth and 100% of water coverage) of the culverts and stone marten and genet responded positively to dry ledges, which increased the number of crossings comparing with the previous survey. For both species the CI are always higher on dry ledges than in the culvert floor. For otter, Eurasian badger and fox the water deep or proportion is not a limiting factor for complete crossings, since they use culvert floor or dry ledges equally. It was registered by video-surveillance that badger can make a complete crossing with 20 centimeters water depth. Although that overall results of the second survey are lower than the first survey (without dry ledges), these data indicate that dry ledges appear to be successfully used by all carnivores and highlight the importance of these measures to enhance the carnivore's movement between both sides of the highways.

WILDLIFE-FRIENDLY EROSION CONTROL MATTING: THE STANDARD FOR VERMONT

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Abstract

In response to incidents of wildlife entanglement in erosion control matting (ECM), the Vermont Agency of Transportation (VTrans) and the Vermont Agency of Natural Resources (VANR) proposed a sweeping change in the type of erosion control matting used on construction projects in Vermont. An ad-hoc work group set out to develop an interagency approach to what has been identified as a perennial problem inherent to ECM containing plastic mesh netting (Stuart et al. 2001; Barton and Kinkead 2005; Walley et. al. 2005). Rather than respond on a project-by-project basis, VTrans elected to eliminate the use of polymer-based matting as a temporary erosion control method on all construction and maintenance projects. Following the VTrans change, the VANR updated the Vermont Standards and Specifications for Erosion Prevention and Sediment Control to require loosely woven natural fiber ECM to reduce potential wildlife entanglement.

Temporary Erosion Control Matting (ECM) is a vital component of environmentally responsible construction projects. However, the environmental protection provided by certain erosion control products has an unintended consequence. ECM with plastic mesh often entangles wildlife, including mammals, birds, fish, reptiles, and amphibians (Stuart et al. 2001; Barton and Kinkead 2005; Walley et. al. 2005). Wildlife Entanglement can quickly become a considerable regulatory problem if Threatened or Endangered Species are harmed. Moreover, the plastic mesh in temporary ECM has been found intact on project sites up to 8 years after installation (Walley et. al. 2005).

It is widely believed that snakes suffer the highest rate of mortality as a result of entanglement with ECM containing monofilament mesh. Snakes trapped in netting often die of their injuries, or from prolonged exposure to the elements.

Loosely woven natural fiber ECM does not pose the same risk to wildlife, and has been used successfully in areas where Threatened or Endangered snakes are present. Additionally, it is biodegradable and will not remain on the landscape long after the vegetation has been established on a project site. Biodegradable natural fiber ECM is slightly more expensive than ECM containing monofilament mesh. However, when VTrans calculated the cost increase of natural fiber matting into the budget of a typical project, the increase on a $2 million project was approximately $2,500, or 0.125% of the project budget. VTrans management felt that the environmental benefits of natural fiber matting far outweighed the cost.

VTrans' proactive action on this issue helped chart the course for ANR to similarly rewrite the Vermont Standards and Specifications for erosion control that apply to all public and private jurisdictional construction sites in Vermont.

Multiple agencies and divisions within Vermont State Government voluntarily collaborated to solve a clear environmental challenge. Despite the different mission statements among this diverse work-group, a common vision was found, and within a few months this vision changed how business is done on construction sites in Vermont. It is anticipated that this change will result in a dramatic decrease in wildlife mortality caused by entanglement in ECM – providing an obvious stewardship benefit as well as a regulatory precaution.

Biographical Sketch

Chris Slesar is an Environmental Specialist at the Vermont Agency of Transportation, and a member of the Vermont Reptile and Amphibian Scientific Advisory Group. Chris is a graduate of Rutgers University, and has an MA in Environmental Studies from Antioch University, Seattle.

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An electronic copy of this poster is included in the Appendices of the Proceedings.

GETTING THERE: THE ROLE OF WILDLIFE CROSSING STRUCTURES IN RESTORING TERRESTRIAL HABITAT CONNECTIVITY ACROSS ROADS

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Abstract

Roads are an expanding and pervasive component of the developed landscape. Roads increase fragmentation by dividing the landscape into ever smaller patches surrounded by paved surfaces and road verges of controlled vegetation and hostile microclimates. This fragmented landscape crisscrossed by roads results in a barrier for many species of wildlife. The extent of road impacts has been increasingly documented over the past decade. That research has led to the emergent field of road ecology, and led conservationists, managers, and engineers to use crossing structures for wildlife. Crossing structures are incorporated in road design to provide conduit corridors that allow safe wildlife movement across roads, protect species of conservation interest, improve human safety by decreasing wildlife-vehicle accidents, and permit healthy ecosystem function. In this paper, I review the advances in road ecology that have led to our current understanding of crossing structures and analyze 45 crossing-structure studies with respect to location, purpose of the structure (wildlife versus transportation/hydrology), type of crossing structure, monitoring method, monitoring duration, and openness (m^2/m) for each structure. These 45 studies constitute 576 crossing structures in 10 countries. Crossing structures built and studied for 1-2 species are significantly more often built for wildlife, while those with multiple-species focus are more often structures built to facilitate transportation (e.g., drainage culverts). Most studies are relatively short (74% less than 1 year). Based on openness, crossing structures were separated into tunnels with very narrow passage and small openness values, culverts that are larger than tunnels and smaller than other structures, and wildlife and bridge underpasses and overpasses which did not differ significantly in openness. This suggests that there are three major categories of structures from a wildlife perspective, although there is wide variance around these values. There is an opportunity for increasing habitat connectivity across roads as low-volume roads are upgraded to multi-lane highways. Lessons learned from these initiatives can help researchers and managers more effectively plan and implement wildlife-crossing structures, continue to improve road-crossing designs, and facilitate habitat connectivity across roads. Based on these lessons, I offer a nine-step process for planning crossing structures during the road-upgrade process.

WILDLIFE ECOLOGY FOR DUMMIES: DESIGN ELEMENTS OF WILDLIFE CROSSING STRUCTURES – A LITERATURE REVIEW

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Introduction

This poster describes a unique resource available to transportation professionals – planners, project managers and engineers – who are not ordinarily familiar with wildlife ecology, but who must make decisions about the utility and the design of wildlife crossing structures.

Methods

We surveyed existing literature and summarized in a table format specific recommendations for design elements of wildlife crossing structures. Each recommendation cites the source from which it was taken. The tables are divided into the following sections:

1. Crossing Structures
2. Fencing and Other Barriers
3. Approaches and Transition Zones
4. Animals
5. Traffic
6. Alternatives
7. Citations

Results

Transportation planners and designers have found this document to be useful in answering specific questions about siting, dimensions, materials, and context of wildlife crossing structures.

Discussion

Transportation professionals generally are not conversant with wildlife ecology literature, and existing transportation ecology studies usually have been designed to answer biological questions instead of engineering questions. We know of no other reference available to transportation professionals that extracts the information they need from this daunting collection.

Much more work is needed to make statistically valid generalizations involving all the elements of wildlife crossing structure design. A research project is underway specifically to strengthen and expand these guidelines that transportation professionals can actually use.

Biographical Sketches

Heather Chasez received Bachelor of Science degrees in Biology and Environmental Studies at Rollins College. She is now pursuing a Master's degree in Biology along with a Certificate in Conservation Biology at the University of Central Florida. Heather has worked at several veterinary clinics and with wildlife organizations over the past 11 years. While working as a Biologist with EMS Scientists, Engineers, and Planners, Inc. she was involved with many projects centered on threatened and endangered species and became involved with wildlife crossing planning for the Florida Department of Transportation. Currently, she is working on wildlife crossing research under Dr. Daniel Smith and Dr. Reed Noss in cooperation with the Florida Department of Transportation.

Ray Emmett, Ph.D. completed his undergraduate and graduate degrees in botany and plant ecology at the University of Texas at Austin. Dr. Emmett has since amassed over 15 years of professional experience performing bio-ecological investigations as a private-sector consultant. Much of Ray's experience has focused upon environmental analysis involving various kinds of upland and wetland communities, utilizing various types of qualitative and quantitative data collection and analysis techniques. He has received formal training and acquired substantial experience in wetland determination, impact analysis, and mitigation planning. Rare species habitat assessments and presence/absence surveys are also specialties, as is quantitative vegetation sampling. Among other projects throughout the state, Dr. Emmett has directed a team of scientists that devised a wetlands mitigation plan for a many thousand-acre airport and adjacent development project in north Florida, and been a key participant in the development of a habitat connectivity plan to minimize impacts associated with the widening of an over 40-mile long segment of highway through an ecologically sensitive region of central Florida. In addition to his proficiency as an ecologist, Dr. Emmett has become adept at dealing with regulatory compliance issues. This experience includes providing support services that allow projects to comply with federal and state dredge/fill and protected species regulations and, especially, the National Environmental Policy Act (NEPA). Dr. Emmett has been a key participant in numerous NEPA-compliant Environmental Impact Statement, Environmental Assessment, or Categorical Exclusion investigations.

Tom Roberts, a graduate of Stetson University, has spent over 18 years with EMS providing environmental surveys, assessments and permitting needed for a wide variety of public and private projects. His areas of specialization include wetland assessments and functional analysis; protected species surveys and assessment; mitigation bank development and permitting; and transportation related studies requiring Florida PD&E (NEPA) documentation, especially with regard to the effects of and mitigation for habitat fragmentation. He is also a regular speaker and panel member at environmental conferences dealing with issues such as federal wetland permitting, mitigation banking, and endangered and threatened species.

Daniel J. Smith, Ph.D., A.I.C.P. has over 15 years experience in the fields of ecology and environmental planning. Previous work includes comprehensive ecological impact assessments, wildlife movement pattern, behavioral and corridor studies, habitat loss/fragmentation, connectivity and landscape change analyses, highway linkage and ecological hotspot modeling, ecopassage siting projects, and development of standards for the design of wildlife crossing structures. Research methods employed include mark-recapture, telemetry, track and road-kill surveys, spatial analyses using Geographic Information Systems (GIS) and landscape genetics. Daniel earned a Ph.D. in Wildlife Ecology and Conservation (2003) and master's degrees in Forest Resources and Conservation (1995) and Urban and Regional Planning (1989) from the University of Florida. He is currently a Research Associate at the University of Central Florida and is a member of the American Institute of Certified Planners, International Association of Landscape Ecologists, The Wildlife Society, Ecological Society of America and Society for Conservation Biology. His primary focus is on understanding spatial patterns of biological phenomena and integrating conservation, transportation and land-use planning.

Stephen D. Tonjes has a B.S. in Zoology from the University of Michigan and a M.S. in Oceanography from Oregon State University. He served 3 years in the US Coast Guard in Texas, and then taught for a year at Seacamp in the Florida Keys. He worked two years managing the Coast Guard bridge permit program in Juneau, Alaska, and worked a year in the Office of Endangered Species of the U.S. Fish and Wildlife Service in Washington, D.C. He has worked since 1986 with the Florida Department of Transportation District 5 Environmental Management Office writing and reviewing NEPA documents, applying for permits, managing mitigation contracts, coordinating commitment compliance, moving or mitigating for gopher tortoises, assessing trees, moving bats, managing wildlife crossing research and doing a few other things.

PERMEABILITY OF LINEAR FEATURES TO THE MOVEMENTS OF SONGBIRDS IN AN URBAN LANDSCAPE

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Abstract

Urbanization is widely regarded as a major threat to global biological diversity. As cities expand, naturally productive habitats are permanently lost and fragmented. Urban landscapes contain a number of linear features, both natural and anthropogenic, that likely inhibit the mobility of birds and other wildlife. By far the most ubiquitous of such features are transportation corridors, whose arterial networks form the fabric of city landscapes worldwide. Riparian corridors are another central component of many urban landscapes given their importance as transportation routes and sources of fresh water to human settlers. Movement through urban and other highly fragmented landscapes is critical to the persistence of populations because it supports the use of multiple small patches within home ranges and the re-colonization of more isolated habitat patches that are otherwise susceptible to stochastic local extinctions. In 2005 and 2006, we conducted audio playback experiments designed to assess the relative permeability of selected linear features of the urban landscape of Calgary, Alberta, Canada to the movements of forest songbirds. We used an avian mobbing call to lure birds across four types of features: 1) roads of varying widths and traffic volumes, 2) conventional railways and light transit lines, 3) transportation bridges across riparian corridors, and 4) rivers. In 591 experiments involving 2241 birds, we found that the size of the gap in vegetation was the most important determinant of movement across these linear features. For roads and bridges, as the gap in vegetation approached 30 m, the likelihood of movement sharply decreased. By 45 m, birds were only 50% as likely to move across a gap as they were to move an equivalent distance in continuous forest and by 75 m, they were less than 10% as likely to do so. Traffic volume emerged as a significant, albeit secondary, factor with a negative effect on movement and explained more variation in the data than ambient noise. When comparing the relative permeability of the features tested, we found that railroads were the most permeable, owing most likely to their relatively narrow width, which never exceeded 30 m. Rivers, the only natural feature considered in our study, proved to be the least permeable feature we tested, particularly at gap widths <50 m. Our results also showed that the factors affecting movement were relatively consistent among species and seasons. Our results suggest that urban landscapes present a number of impediments to the movements of forest songbirds and point to the importance of vegetation management as a potentially effective strategy for mitigating the barrier effects caused by human infrastructure in cities. We present examples of simple, relatively inexpensive solutions, like the strategic placement of trees along transportation corridors, to enhance functional connectivity for wildlife and thus, promote the integrity of natural systems within urban and other fragmented landscapes.

Biographical Sketches

Marie A. Tremblay holds a Master's degree in Environmental Design (Environmental Science) from the University of Calgary and is currently in the final stages of a Ph.D. in Ecology at the University of Alberta. Her research focuses on the movements and distribution of forest songbirds in the urban landscape of Calgary, Alberta. Most recently, Marie was selected as a finalist for the 2009 Society for Conservation Biology Student Awards in Beijing, China. Marie's professional background includes several years as an instructor of biology, ecology, environmental science, physical geography, and geology at Mount Royal College and the University of Lethbridge. She also works part-time as a wildlife consultant focusing on spatial habitat modeling and the effects of human activities and facilities on the movements of wildlife. In 2008 Marie joined the ranks of Parks Canada where she is involved in their species at risk program.

Colleen Cassady St. Clair is an Associate Professor in the Department of Biological Sciences at the University of Alberta. Colleen completed a B.Sc. at the University of Alberta, an M.Sc. at the University of Canterbury, and a Ph.D. at the University of Oklahoma before returning to Edmonton. Her research targets the emerging discipline of Conservation Behaviour by using behavioural theory and methods to address conservation problems. She and her students have used this approach to study the movement of animals in human-altered landscapes and the conflict that sometimes results when humans and wildlife share habitats. Colleen teaches courses in Behavioural Ecology, Conservation Biology and Advanced Ecology. In her spare time, Colleen enjoys camping, gardening, hockey, skiing, canoeing and music.

ODOT's Biology and Wetland Monitoring: An Improved Approach to Data Collection and Reporting

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Abstract

The Oregon Department of Transportation (ODOT) completes many new projects each year to ensure a safe and efficient transportation infrastructure throughout the state. Although avoiding and minimizing impacts to natural resources are paramount in ODOT's design considerations, some impacts do occur as a result of ODOT's projects. ODOT devotes considerable resources to monitoring and maintaining their biology and wetland mitigation sites to ensure that ecological objectives and permit conditions are met. To achieve desired ecological benefits and monitoring efficiencies, ODOT identified a need to improve its regulatory compliance program.

To streamline and standardize ODOT's mitigation compliance efforts, ODOT contracted with Mason, Bruce & Girard, Inc. (MB&G) to develop two hand-held software applications that could be used to electronically document mitigation site conditions and maintenance prescriptions in the field. Mitigation monitoring software applications were developed to run on a resource-grade, hand-held Global Positioning System (GPS) and designed to aid field biologists. Data collected during the 2008 field season provided up-to-date compliance status reporting, as well as spatially accurate maintenance prescriptions that were easily interpreted by contractor maintenance crews. Initial monitoring efforts produced project boundary, re-vegetation, invasive species, and aquatic enhancement feature GIS shapefiles, which became part of the site's base map to be used for subsequent monitoring visits. This approach standardizes data collection methods and creates consistency among different biologists throughout the monitoring period.

Hand-held applications and the spatial data they produce have improved communication among field biologists, maintenance crews, mitigation program managers, and the regulatory agencies. Prior to these applications, site features were rarely mapped, making observations of maintenance or corrective needs difficult to relate to maintenance crews. As a result, corrective actions often did not get implemented, resulting in site failure and expensive compensatory mitigation to attain permit compliance. In addition to increasing the consistency and accuracy of field data, ODOT's use of hand-held technology has enabled monitoring results to be reported in a more efficient and thorough manner.

Thus far, ODOT's Monitoring Program has identified two primary shortcomings of the hand-held applications. First, biologists have occasionally experienced difficulty in acquiring sufficient satellites to survey features. Primary causes for signal interference are large structures (i.e., bridges), time of day, topography, and cloud cover. Secondly, there is a learning curve associated with effective use of the monitoring application. Although ODOT provides a training program, biologists typically need to collect data at several sites before gains in accuracy and efficiency are realized.

The utility of hand-held technology is also being considered for other statewide projects including culvert inventories, geologic hazard mapping, wetland delineation, project scoping, archaeological resource documentation, and fish and wildlife passage evaluations. It also has the potential to streamline site management decisions by prompting field biologists with decision trees pertaining to ESA compliance, invasive species encroachment, vegetation establishment, and other permit compliance elements. Implications for the future may include a web-based program for Oregon's natural and historical resources. Such a program would foster responsible land uses and efficient transportation planning throughout the state and, perhaps, the nation.

Biographical Sketches

Bob Carson is the manager of MB&G's Environmental Services Group. He has served as environmental project manager or task leader on over 200 projects, including over 100 transportation projects in Oregon and Washington involving NEPA permitting, wetland permitting, ESA permitting, and biological resource studies. His technical expertise includes wildlife, wetland, forest, and range ecology and management. He is well-versed in habitat analysis and characterization. Bob has managed very large, complex environmental permitting projects and is an expert in preparing the appropriate environmental permits and documentation, including wetland permit applications, wetland mitigation plans, NEPA Environmental Assessments (EAs) and Environmental Impact Statements (EISs), Biological Assessments for ESA compliance, and Biological Evaluations for NFMA compliance.

Daniel Covington has expertise in wetland and terrestrial habitat consulting. As a biologist, he uses his education and experience in resource conservation, botanical sciences, and watershed management to conduct wetland delineations, habitat assessments, and prepare permit documentation in the early planning stages of a wide variety of land use activities. He specializes in a variety of natural resource inventories that allow him to integrate current site conditions with proposed activities to evaluate ecological impacts of projects. He has experience with planning and monitoring stream and river restoration projects aimed at salmonid habitat improvement, balancing erosion and deposition budgets, and returning natural morphological characteristics to structurally impaired waterways.

Wendy Wente is an ecologist with 13 years of experience in research design and implementation. Her professional expertise includes wildlife surveys, habitat assessments and field research designed to meet the needs of public sector clients. She specializes in federal permitting documentation, including Biological Assessments (BAs), Biological Evaluations (BEs), and Environmental Assessments (EAs). Prior to joining MB&G, Wendy worked as a post-doctoral researcher with the US Geological Survey, where she conducted research on problems of applied ecology including a multi-year study of regional amphibian decline and an experimental study of the effects of cattle grazing on wetland water quality. Her dissertation research focused on speciation theory using as a test case the behavior, sensory physiology, and ecology of the Pacific tree frog.

Melinda Trask is an Environmental Program Manager for the Oregon Department of Transportation, with a Master of Science in Plant Ecology from Oregon State University and a Master of Environmental and Regional Planning from Washington State University. Melinda has a broad educational and professional background in ecology of the western United States. She has taught ecology and botany laboratory classes, organized and led field surveys crews for rare plant studies, conducted desert tortoise and peregrine falcon surveys, assisted with fish salvage operations, delineated wetlands, prepared numerous Biological Assessments for Section 7 Endangered Species Act consultations, monitored environmental protection measures during various types of construction projects, and developed site restoration plans. Melinda is currently the co-chair of the Oregon Wildlife Movement Strategy, and interagency working group to address wildlife passage in Oregon.

Josh Ahmann has experience working on a variety of GIS, GPS, IT, and environmental resource projects. His project work at MB&G has included programming GPS units, identifying hot spots for wildlife crossings, adjusting and growing timber data, determining acreages for property valuations, and training personnel on new GPS applications. Josh's project work requires him to use a diverse set of GIS skills including programming in several languages, spatial modeling design, aerial interpretation, geodatabase development, applied spatial statistics, and Public Participation GIS. In addition to his GIS skills Josh's technical knowledge extends to server architecture, information system development, as well as SQL and Access databases. Josh's experience beyond GIS includes performing highest and best use analyses, urban and rural property valuations, and creating regional land use planning models. Josh was awarded the Oregon Chapter of the American Planning Association Student Achievement award in 2006 as well as the American Institute of Certified Planners award for Best Student Project in the same year.

Poster Presentation Abstracts

Innovative Tools and Techniques

IDENTIFYING WILDLIFE LINKAGES AND WILDLIFE-VEHICLE COLLISION HOT SPOTS ON OREGON HIGHWAYS

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Abstract

Barriers to fish and wildlife movement are one of the six key conservation issues in Oregon (Oregon Conservation Strategy, 2006). To respond to this issue, the Oregon Department of Fish and Wildlife (ODFW) and Oregon Department of Transportation (ODOT) established a collaborative workgroup, the Oregon Wildlife Movement Strategy, in 2007. Initial goals for the workgroup included: (1) identify wildlife-vehicle collision hot spots on Oregon highways and (2) identify key travel corridors for wildlife (i.e., "wildlife linkages"). This poster presentation provides an update on progress towards achieving these goals.

ODOT and their contractor, Mason, Bruce & Girard, Inc. (MB&G), analyzed roadkill data collected by ODOT maintenance personnel along state highways throughout Oregon to identify wildlife collision "hot spots". Wildlife-vehicle collision hot spots for deer and elk were identified using a pool of over 17,000 ODOT deer and elk carcass records. These records were plotted and a visual assessment of the data indicated a clustering of the collisions. We performed statistical analyses on the wildlife-vehicle collision data to test the null hypothesis that wildlife-vehicle collisions were randomly distributed along highways. A Nearest Neighbor Analysis indicated the data were significantly more clustered than expected by chance alone (Nearest Neighbor Index = <1 and $p < 0.001$). The Ripley's K Distribution statistic indicated that the data were clustered at spatial scales ranging from 1 to 10 miles. We then used a Kernel Density Evaluation to map wildlife-vehicle collision hot spot isopleths along state highways and the Jenks Natural Breaks method to classify the hot spots into five categories (High, Med-High, Medium, Med-Low, Low). These statistical analyses support the conclusion, drawn from the more subjective visual assessment of the plotted data, that wildlife-vehicle collisions are concentrated in identifiable hot spots.

ODFW (with agency partners including ODOT) compiled the results from four regional wildlife linkages workshops held throughout Oregon in 2007. Participants in the workshops identified key movement areas for wildlife based on expert opinion, with an emphasis on identifying wildlife travel corridors crossing paved roads. Similar to other states and regions, the linkage analysis was limited to a suite of focal species including big game, small mammals, forest carnivores, and herptiles. Over 700 wildlife linkages were identified throughout Oregon. For each wildlife linkage area identified, the participants were also asked to indicate the focal species, type of linkage (e.g., riparian corridors), and physical barriers present, among other factors. The Oregon Wildlife Movement Strategy working group identified approximately a dozen high priority wildlife linkage areas where significant opportunities exist for improving connectivity, based on threats to linkages, land ownership (with priority given to occurrences within ODFW Conservation Opportunity Areas and other public lands), and wildlife hot spots.

The wildlife linkages and wildlife collision hot spots data will be available in 2009 for transportation managers to consider wildlife movement needs during highway project development. However, since there are no regulations requiring wildlife passage, partnerships with adjacent land owners or other stakeholders are vital to effectively restore habitat connectivity in Oregon.

Biographical Sketches

Francesca (Fran) Cafferata Coe holds a Bachelor of Science degree in Fisheries and Wildlife Science with emphasis on forest-wildlife interactions. Fran has a wide range of experience completing environmental surveys for sensitive, threatened, and endangered plant and animal species and their habitats. She is experienced with ESA permitting to assess the anticipated impacts of development activities on federally listed species. Her work involves wetland technical investigations for identification and delineation, mitigation planning and permitting, NEPA Environmental Assessments (EAs) and Environmental Impact Statements (EISs), Biological Assessments for ESA compliance, and Biological Evaluations for NFMA compliance.

Audrey Hatch works at the Oregon Department of Fish and Wildlife (ODFW) where she is the technical coordinator for the Oregon Conservation Strategy (OCS). Audrey has a Masters degree in Eco-Toxicology from Wright State University in Ohio and a Doctorate in Amphibian Ecology from Oregon State University. At ODFW, she oversees statewide projects that help keep the OCS up-to-date and current. One of these projects is the Oregon Wildlife Movement Strategy, co-led with Oregon Department of Transportation.

Melinda Trask is an Environmental Program Manager for the Oregon Department of Transportation, with a Master of Science in Plant Ecology from Oregon State University and a Master of Environmental and Regional Planning from Washington State University. Melinda has a broad educational and professional background in ecology of the western United States. She has taught ecology and botany laboratory classes, organized and led field surveys crews for rare plant studies, conducted desert tortoise and peregrine falcon surveys, assisted with fish salvage operations, delineated wetlands, prepared numerous Biological Assessments for Section 7 Endangered Species Act consultations, monitored environmental protection measures during various types of construction projects, and developed site restoration plans. Melinda is currently the co-chair of the Oregon Wildlife Movement Strategy, and interagency working group to address wildlife passage in Oregon.

WEB-BA: AN INNOVATIVE TOOL FOR STREAMLINING BIOLOGICAL ASSESSMENTS (BAS) UNDER THE FEDERAL ENDANGERED SPECIES ACT

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Brief Description

Web-BA is a Web-based Endangered Species Act (ESA) Section 7 guidance database and content management system to help project proponents prepare complete Biological Assessments (BAs) for projects where the Federal Highway Administration (FHWA) is lead federal action agency (see http://esafhwa.org).

Introduction

Paper-based decision-making systems are inherently inefficient; development, submittal and review of BAs is no exception. While the current BA life-cycle is not entirely paper-based — documents do start in electronic form — the process doesn't take full advantage of modern technology.

Problems with development of BAs include:
- Sharing and managing files can be a challenge.
- Finding good and relevant examples of prior BAs to start new BAs can be difficult.
- Researching listed species can be time-consuming and incomplete without adequate access to federal information and datasets.
- Processing and formatting requirements vary from state to state.

Problems with submittal of BAs include:
- Mailing hard copies adds time and increases uncertainty.
- Maintaining detailed administrative record is cumbersome.
- Documents lack consistency in structure and layout.
- Inadequate instructions lead to incomplete or incorrect BAs.

Problems with review of BAs include:
- Review and response cycles can be long and irregular.
- Review process is not always transparent and can be inconsistent.

Solution

Develop a Web-based ESA Section 7 guidance database and content management system to help project proponents prepare complete BAs for projects where the FHWA is lead federal action agency.
- Help BA-preparers adequately prepare BAs for consultation with federal services agencies.
- Expedite internal assurance reviews.
- Increase consistency from project-to-project and region-to-region.
- Reduce project delays from incomplete BAs and requests for additional information.
- Streamline decision-making review and transaction times, increase quality of documentation and submitted materials and promote accountability and transparency through tracking and reporting.

Methods

- Leverage tools used in similar applications (e.g., WA JARPA permitting process).
- Standardize and document BA development business practices.
- Use contemporary methods and technologies:
  - Service-oriented architecture — http://en.wikipedia.org/wiki/Service-oriented_architecture.
  - User-centered design — http://en.wikipedia.org/wiki/User-centered_design.
  - Mashups — http://en.wikipedia.org/wiki/Mashup_(web_application_hybrid).
  - Agile software development — http://en.wikipedia.org/wiki/Agile_software_development.

Pilot

- Test:
  - Test usability, functionality and performance in 2008 through State DOTs (NY, TX, WA).

- Rollout:
  - Develop prioritized list of improvements based on pilot testing.
  - Incorporate priority updates as time and funding allow.
  - Rollout nationwide Web-BA site in 2009.

Results / Discussion

Value and benefits of Web-BA tool were validated. Pilot testers liked: easy-to-use and understand interface; collaborative file sharing and document review capability; ability to build complete and accurate repository for future use; and timeline and accountability metrics. Solution attributes include:

- Faster.
- More collaborative.
- Efficient information, documentation sharing.
- Solution for staff-turnover.
- Builds administrative record.
- Provides centralized document repository.
- Provides standardized forms.
- Builds project-specific teams.
- Provides consistency in workflow.
- Offers accountability and status tracking.

Nationwide rollout will include enhanced performance metrics, real-time feedback and suggestion capability, automatic e-mail notification and searchable archives.

Conclusion

Web-BA has proven an effective tool to expedite development, submittal and review of BAs under federal Endangered Species Act and to facilitate efficient and collaborative review and decision-making. Continue to advance and build-on Web-BA by incorporating new functionality like GIS mapping and analysis, information and data exchange and additional environmental document development.

Biographical Sketches

Scott Boettcher, Senior Business Analyst, Cherry Creek Environmental, Inc is an 18-year veteran of state government. Scott's big picture understanding of and relationships with agency personnel provide him with the ability to be a definitive change agent. Scott's work is largely focused on improving multi-party governmental review and decision-making through greater information transparency, improved process efficiency and a focus on outcome and solutions. Many regulatory improvement initiatives spearheaded by Scott over the course of his career are now central to Washington State's core regulatory business.

Scott led the initiative to develop and implement Washington's first multi-agency permitting team for transportation — the MAP Team. The MAP Team is co-located in a single facility and includes the Washington State Departments of Transportation (WSDOT), Ecology and Fish and Wildlife; the federal U.S. Army Corps of Engineers; and the local King County Department of Development and Environmental Services. Together these agencies work with WSDOT (the applicant) on priority state transportation projects to expedite and streamline permitting review and decision-making.

For the Monitoring Inventory Portal Project with the Washington State Puget Sound Partnership, Scott co-led a Web development effort to document ecosystem-based monitoring projects and programs of interest to Puget Sound clean up and recovery. Key objectives behind the effort were to compile a comprehensive catalogue of monitoring metadata from federal, state and local governments, tribes, nonprofit organizations and academic institutions; and enable user-friendly access to the metadata via a Web-enabled monitoring inventory portal.

Scott Hitchcock, Senior Systems Architect, ICF Jones & Stokes, designs and implements user-friendly and intuitive electronic tools such as permit streamlining applications, document management systems, GIS mapping tools, calendars and messaging interfaces. He also customizes databases and Web-based tools for specific user groups including project teams, stakeholders and the public. Scott's skills include project management; business process analysis; requirements specification; data scheme design and implementation; and interfaces for data-enabled Web sites developed with HTML, DHTML, PHP, ASP.NET, ASP, VBScript and JavaScript. Scott develops business tier components using the Model-View-Controller (i.e., Model 2) paradigm in C#. Scott uses MSSQL2000/2005 Server, MS-Access and MySQL for database solutions. Additionally, he has experience configuring and managing Internet servers using IIS or Apache running on Windows NT/2000/2003 and Linux servers.

Web-Based Environmental Permitting — Scott led the design and development process for Web-based applications that allow public review of permit process and procedures for agencies, including Washington State Office of Regulatory Assistance. Scott developed an On-line Permit Application and Review System named Epermitting.org for the State of Washington. Scott co-lead development of a Geo-Locator Service for the Washington State's Office of Regulatory Assistance. The Geo-Locator Service will include a map interface used to select locations. This will be integrated in to Web-based input forms in Epermitting.org (and other State applications) to better identify project locations and boundaries.

Database Development — Scott has designed and implemented MS Access databases for Caltrans, including a grant-tracking database used for tracking Caltrans grant recipients. This database included features that allowed users to report on the number of grants received, the total amount awarded by fiscal year and various milestone reports for tracking the progress of a grant application. Scott also designed and implemented an MS Access contacts database for Caltrans District 3 (2004) to create mailing lists and track communications with key contacts throughout the district.

Content Management Systems (CMS) — Scott has experience with various Content Management Systems that have been deployed on both the Linux and the Microsoft platforms. Most recently, Scott has worked with the Rainbow Open Source CMS to create highly customized CMS solutions that are designed to improve efficiency in permitting processes. Scott has also used CMS in a more traditional sense to deploy public outreach Web sites that can be updated easily by non-programmers.

Assessing Mitigation Measures to Reduce Moose-Vehicle Collisions: A Modeling Approach

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Abstract

Over 200 moose-vehicle collisions occurred yearly in Québec between 1990 and 2002, including about fifty in the Laurentides Wildlife Reserve situated between Québec City and Saguenay. In this northern area where 100 metric tons of road salt per kilometer are used in winter, one of the main causes of these collisions is the presence of roadside salt pools in spring and summer attracting moose to the road. Sodium is an essential nutrient in the moose's diet and moose can either get it by eating aquatic plants all day or by a quick drink from roadside salt pools. A previous agent-based model (Grosman et al., in press) investigated whether removal of these roadside salt pools and the construction of compensatory salt pools 100m to 1,500m away from the road shoulder, would reduce moose-vehicle collisions. It demonstrated a significant reduction (49%) in moose road crossings with 100% salt pool removal with no compensation salt pools and 18% reduction with 100% salt pool removal with compensation salt pools. The new model (Grosman et al., in review) added road avoidance behaviour and salt-pool spatial memory to the previous model to determine if these moose behaviours would influence road crossings frequency. The mitigation measures being assessed were the removal of roadside salt pools and the construction of compensatory salt pools. Moose road crossings were used as a proxy measure for moose-vehicle collisions. There was a significant reduction in road crossings when the roadside salt pools were either completely or 2/3 removed, with and/or without salt pool displacement. With 100% salt pool removal, the reduction was greater (70%) without compensatory salt pools than with them (49%). With 2/3 salt pool removal, the reduction was about the same with and without compensatory salt pools (12 to 16%). These results from 100% salt pool removal scenarios without and with compensatory salt pools represent an absolute increased reduction in road crossings from the previous model of 21% and 32%, respectively. The road avoidance behaviour was the main cause of this increased reduction whereas the spatial memory of 1/3 of the roadside salt pools in scenarios #4 and #5 with 2/3 salt pool removal lessened the effect of the road avoidance factor, leading to rather small reductions, similar to the Grosman et al. (in press) model. This agent-based model was effective in modelling moose behaviour with salt pools and roads. It was essential that correct moose behaviour was available in the published literature, including road avoidance and salt-pool memory, and that the GPS telemetry data was used to calibrate and validate the model.

Acknowledgements

This study was funded by the Ministère des Transports du Québec, the Ministère des Ressources naturelles et de la Faune du Québec, and the Université du Québec à Rimouski. The first author was supported with funding from the Université du Québec à Rimouski and the Ministère des Ressources naturelles et de la Faune.

Biographical Sketches

Paul Grosman, after 31 years of work in the business computer applications field, has returned to university and obtained a B. Sc. (Honours) in Environmental Science from Concordia University. He is now a M. Sc candidate in Geography, Urban & Environmental Studies at the same institution.

Dr. Jochen A. G. Jaeger received his PhD from the Department of Environmental Sciences at the ETH Zurich, Switzerland, and worked at Carleton University, Ottawa, and ETH Zurich. He joined Concordia University in 2007 as an Assistant Professor. His research is in landscape ecology, road ecology, urban sprawl, ecological modelling, and environmental impact assessment.

Dr. Pascale M. Biron is a fluvial geomorphologist who has joined Concordia University in 1998. Her research involves stream restoration for fish habitat, sustainable management of agricultural streams, GIS, three-dimensional computational fluid dynamics and river management.

Dr. Christian Dussault obtained his doctorate at Laval University where he studied the ecology of the moose and worked on a study of the impact of forest cuts on terrestrial fauna for the Québec government. He is a biologist with the Québec Ministry of Natural Resources and Wildlife.

Dr. Jean-Pierre Ouellet is a professor in biology at University of Québec at Rimouski and director of the BIONORD Research Group. He is a member of the Center of Nordic Studies. He has a Ph.D. in zoology from the University of Alberta. He is a specialist in the *cervidae* family (white-tailed deer, moose, and caribou) and in their habitat. He was recently appointed Vice-Rector of Academic Affairs and Research at UQAR.

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SPATIOTEMPORAL DISTRIBUTIONS OF WILDLIFE-VEHICLE COLLISIONS AND THEIR APPLICATION FOR MITIGATION PLANNING

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Abstract

Wildlife-vehicle collisions (WVCs) pose a serious safety and wildlife management concern especially in regions where wildlife numbers are increasing concurrent with road densities and traffic volumes. In some regions WVCs and landscape fragmentation caused by roads pose a serious threat to the long-term population persistence of wildlife populations especially those designated as species-at-risk by regional government committees. For example, 7 of the 8 turtle species in southern Ontario are designated as species at risk by the Committee on the Status of Endangered Wildlife in Canada, and impacts of roads have been listed as one of the many threats for 5 of these species. Previous research has shown that WVCs are spatially and temporally clustered, and these clusters are correlated with the characteristics of the landscape, e.g. habitat and road, e.g. traffic volume. However much of the research has concentrated on mapping and evaluating spatial distributions of WVCs for a specific period of time in one-dimension along a road.

This poster highlights the development of algorithms that show the spatial and temporal distribution of WVCs along roads independently. The algorithms then combine space and time to show a two-dimensional, dynamic spatio-temporal distribution of WVCs along roads. The algorithms use the density kernel function to explore spatial and temporal clustering and the Ripley's K function to determine if clustering is significantly different from a random distribution. The poster highlights the application of these algorithms to three different WVC data sets: moose-vehicle collisions on four roads in northern Vermont, turtle-vehicle collisions in northern New York State, and white-tailed deer collisions on Highway 93 in Montana. User-friendly graphical space-time output is displayed for all three cases. Major results show that in some cases hotspots are not static along the road and change spatially through time.

These spatiotemporal algorithms provide novel and innovative tools to determine the dynamic patterns of WVCs along roads, and can be applied to any data set, e.g. vehicle crash data that contain spatial and temporal coordinates. High resolution, long-term, accurate, and consistent WVC data collection will provide a more rigorous, multi-scaled approach to ascertain spatio-temporal distributions. These types of exploratory analyses are especially applicable to display changing WVC patterns through time due to the quickened pace of changing habitat mosaics surrounding roads, possibly as a result of climate change and or human development.

It is recommended that these types of analyses be used as a first step to understanding the processes associated with WVCs. Results such as the scale and duration of WVC hotspots can assist transportation and environmental planners in determining appropriate mitigation strategies required on new and old roads. For example, mitigation strategies that incorporate less permanent-movable strategies, such as enforced speed reductions may be more cost-effective than more permanent structures, such as underpasses and overpasses in regions where collision hotspots are dynamic through known periods of time and space.

Acknowledgements

The algorithms were developed as part of the author's MSc. research at the State University of New York, Environmental Sciences and Forestry. Special thanks to the Department of Environmental Resource Engineering for the teaching scholarship that funded the research. Dr. Giorgos Mountrakis was instrumental in developing the algorithms. WVC data sets were obtained from transportation planners and researchers with the Vermont Department of Transportation, Chris Slesar and John Austin, Montana Department of Transportation, Pat Basting and Dr. Patty Cramer and Clarkson University, Dr. Tom Langen.

Biographical Sketch

Kari Gunson holds a BSc. in Zoology and Ecology from the University of Calgary, MSc. in Conservation Biology from the University of Cape Town, and another MSc. in Geospatial Technologies from the State University of New York. She has eleven years experience in road ecology focusing mainly on the interactions of roads and wildlife, and has co-authored eight peer-reviewed articles in this area of research. She worked six years as a research associate on the Banff Crossings Project in Banff National Park and she has currently started an environmental consulting company (www.eco-kare.com) based in Toronto, Ontario specializing in bridging the gap between road ecology science and on the ground road-construction projects.

UNDERSTANDING AND COMMUNICATING THE INDIRECT EFFECTS OF TRANSPORTATION ON LAND USE

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Introduction

Despite a relatively extensive body of research on the indirect effects of transportation infrastructure on land use, the political and public discourse about such effects is typically mired in highly charged disagreements and competing ideologies. In part, this is because some often cited studies have drawn overly simplified conclusions (e.g., "the amount of induced demand is determined by the number of new lane miles") or they are based on a certain ideology (e.g., "highways don't cause sprawl; permissive land use regulation causes sprawl"). Such conclusions tend to obscure critical analysis and lead to a hardening of positions and unproductive public debate.

At the same time, there have been a variety of rigorous studies that provide valuable insights on the nexus between transportation and land use. These studies rarely seem to gain ground in the public discussion. This may be in part because these studies are complex or heavily conditioned such that the findings aren't readily accessible to the public or are difficult to apply to specific projects.

Growing concern about climate change has further increased the public's interest in the effects of induced growth, which further compels transportation agencies to find a clear and relatively straightforward approach for evaluating, understanding, explaining, and addressing the potentially complicated nexus between transportation and indirect land use effects.

Methodology

The purpose of this analysis was to (1) identify specific factors that influence how transportation projects indirectly affect land use, and (2) to apply these factors to illustrate how they can be used for evaluating and communicating the indirect effects of transportation infrastructure on land use. The core of the methodology is a synthesis and analysis of numerous studies in order to identify the key determinants of indirect land use effects. These determinants form an analytical framework for evaluating induced growth from transportation proposals. This framework also facilitates conveying analysis and findings so that they will be accessible to the public and decision makers.

Results

The review and synthesis of existing research and case studies revealed ten key variables that have the greatest influence on how transportation investments influence travel and land use patterns. The metrics address changes to access and mobility, traffic and transit performance, existing land uses, land use regulations, real estate market characteristics, and public perceptions.

Discussion and Conclusion

The ten variables distilled through the synthesis of existing research help to explain why certain roadway projects increase automobile use and sprawl while others do not, or why certain transit projects increase development density, while others do not. They provide an effective template for communicating land use effects to the public and decision-makers, and they suggest prescriptive guidance on planning and designing transportation projects that have desired land use effects.

The identified factors are a mixture of quantitative and qualitative metrics. They are not weighted or prioritized in terms of each factor's relative influence on induced growth. Some existing studies have suggested a weighting, but there is limited consistency in that regard. Additional research on this topic could inform a weighting system that would increase the acuity and utility of this methodology as an analytical tool.

CHANGING INDECISION INTO ACTION: A CASE STUDY ON SUCCESSFUL INTERAGENCY COOPERATION TO BENEFIT THE NATURAL ENVIRONMENT – I-295/I-76/NJ RT. 42 DIRECT CONNECTION, CAMDEN COUNTY, NJ

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Abstract

When the New Jersey Department of Transportation (NJDOT) embarked on the redesign of a major interchange, the NJDOT and its consultant, Dewberry, recognized that the project would face significant hurdles including potential impacts to fragile wetlands and a sensitive stream, to valuable cultural resources, and to the community. Approvals and/or permits would be required from a lengthy list of agencies. Permitting and environmental documentation would include wetlands delineation, mitigation planning and permitting; soil erosion plans; land use regulation and planning; waterfront development permitting; flood hazard areas; stormwater management; riparian rights, deeds, title; and reforestation plans pursuant a No Net Loss Reforestation Act.

After studying streamlining processes implemented elsewhere, Dewberry and the NJDOT developed a streamlining process to move the project through regulatory review and permitting. The formal streamlining program tightened time frames and committed decision makers to progress. Dewberry and the NJDOT worked with agencies to select the appropriate methodology, verify field data, review results, and make decisions as the work progressed. Consensus points were built into the process and all parties were required to refrain from re-opening the issues agreed-upon, unless new and significant data were generated. In addition to maximizing interagency coordination, the process merges National Environmental Protection Act (NEPA) efforts with US Army Corps of Engineers (USACE) Section 404 Permitting using one Environmental Impact Statement (EIS) thus, saving time and money.

It worked! The regulators (including the USACE, US Environmental Protection Agency, New Jersey Department of Environmental Protection) applauded the program and expressed the desire to implement this process on similar future transportation projects. The Delaware Valley Regional Planning Commission Executive Director summarizes the effectiveness eloquently, “This project charted new territory in the New Jersey portion of our region, and possibly the state, by bringing together planners, engineers, resource and permit agency reps early and often as a means of producing an environmental document and a preferred alternative in a fully collaborative effort. The viewpoints of various disciplines were sought much earlier in the process than is typical. This streamlining of the process in no way diminished the consideration of natural and human resources. Nor did it allow engineering considerations to advance in a vacuum. On the contrary, the early consideration of all of these perspectives has led to a very balanced consideration of all resources and means of addressing the purpose and need of this improvement project.”

As environmental professionals, we can bring value (time, cost, wise solutions) to the transportation process. This is a realistic program that any region can implement to prevent red tape, indecision and re-work from affecting a transportation project’s cost and schedule while embracing ideology that will minimize impact to natural resources. The process eliminates duplication of effort; the USACE adopted the conceptual Section 404 permit application early, during the NEPA phase.

Regulators welcome change when appropriate. As transportation planners, engineers and environmental professionals we need to take brave steps to promote streamlining during a project’s earliest conversations, to outline a formal program, and to hold decision makers to that program.

Acknowledgements

One of the difficulties faced by similar projects is the turnover of agency representatives. When agency representatives change, new personnel come on board without an understanding of the issues from all the stakeholders who have already shared their views. On the I-295/I-76/Rt. 42 Interchange, agency representatives did change over time but their replacements joined the team with the same commitment to project success; the spirit and mission of the agency coordination efforts endured. We wish to acknowledge all those who made this process a success including:

- Jeanette Mar and Lourdes Casteneda, Federal Highway Administration
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- Nicholas Caiazza, NJ Transit (formerly New Jersey Department of Transportation)
- Ken Koschek and Thomas Micai, New Jersey Department of Environmental Protection
- Sam Reynolds and Michael Hayduk, US Army Corps of Engineers
- Grace Musumeci, US Environmental Protection Agency
- David Carlson, FHWA (formerly US Environmental Protection Agency)

Biographical Sketches

Bruce Hawkinson graduated from Rutgers University with a BS degree in Wildlife Biology. He has worked for NJDOT for 29 years.

Jo Ann Asadpour graduated from Mary Washington College with a BS degree in Environmental Earth Science. She has worked at NJDOT for 23 years.

Ileana Ivanciu has over 25 years of experience in the design and implementation of environmental studies conducted as part of transportation project development and construction. She has extensive experience with environmentally-sensitive projects and the incorporation of stakeholder input during concept development and alternatives analysis. She has managed contracts for transportation agencies with a cumulative contract value of over $50M and has been responsible for overseeing the environmental and permitting process for projects with cumulative construction value of well over $1.5B. Ivanciu, a registered Professional Geologist, has Master's and Bachelor's degrees in Geology and Geophysics from the University of Bucharest.

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DEVELOPING A MODEL FOR IDENTIFYING POSSIBLE ROAD KILL LOCATIONS ON HIGHWAY USING INDICATOR SPECIES AND LIMITED WILDLIFE DATA

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Abstract

Wildlife mortality due to vehicular collision is one of the most important threats of road development and operation. Though research has been conducted on factors affecting road kill, the identification of mortality locations as a key to developing mitigation measures such as wildlife crossings has largely been ignored. Studies conducted to identify the locations of wildlife crossings need extensive wildlife datasets and collection of such data is not always possible. Road development is a continuously growing process worldwide. Hence it is important to develop and validate a model which can identify possible mortality locations for wildlife using limited wildlife data. The A73 highway in The Netherlands was selected to develop a model using badger *(Meles meles)* and roe deer *(Capreolus capreolus)* as indicator species. Data on wildlife mortality and location of mitigation measures such as wildlife overpass/underpass was used for validation.

Impedance is the resistance offered by different land use and landcover types to animal movements. The first step to identify relative mortality along the A73 was the creation of an impedance map for the two species, based on analysis of expert knowledge. The impedance map was rasterised and circular buffers of 250 meter radius were developed. Using zonal statistics the circular buffers were divided into four categories – no, low, medium and high impedance. Secondly, a traversability equation from Jaarsma *et al* (2006) was used to estimate the probability of road kill for the indicator species. The A73 highway was divided into mortality threat zones of low, medium and high probability. Overlay analysis of the impedance map and the mortality threat map was performed using two scenarios.

The impedance model showed high impedance values for human settlements and industrial areas while the A73 highway posed medium impedance for both species. The predicted mortality of the indicator species increased with increasing traffic intensity. High probability of road kill was estimated in four continuous lanes of roads while relatively low probability was estimated if four lanes were divided in 2x2 lanes by a strip of grass or shrubland. In case of badger *(Meles meles)* scenario 2 identified 77 high mortality circular buffers. Likewise for roe deer *(Capreolus capreolus),* scenario 2 identified 71 high mortality circular buffers. Validation showed that scenario 2 predicted results better than scenario 1. The recent developed model is able to predict relative wildlife mortality locations using only species presence data. Validation of the model has shown satisfactory results. Therefore the model has a potential for its use to prioritize locations for construction of wildlife overpasses or underpasses in situations with limited data availability. Using the output from the current model, a separate functional model has been developed in STELLA to estimate animal mortality. Future focus should be on applying and validating the model in different locations for different species.

Acknowledgements

I would like to thank Zoodiervereniging Vzz, Society for the study and conservation of mammals for providing me badger and roe deer presence and mortality data. I would also like to thank GEM program of Erasmus Mundus scholarship program including University of Southampton (UK), Lund University (Sweden), Warsaw University (Poland) and ITC (The Netherlands) for the help and knowledge they offered.

Biographical Sketches

Parag Khatavkar is an ecologist with 2 years of experience in conservation, GIS and Environmental Impact Assessment. He has recently finished his second Master's in Environmental Modelling and has keen interest in studying the impacts of road on flora on fauna to develop appropriate mitigation measures

Andre Kooiman is lecturer geographic information management and course coordinator of the Erasmus Mundus MSc course on Geo-information and Earth Observation for Environmental Modelling and Management, in ITC, Enschede, the Netherlands. He is responsible for education, research and consulting on geo-information management. He worked for over twenty years in advisory and management positions related to geographic information science for environmental planning and management in The Netherlands, Africa and Southeast Asia.

Joan Looijen is an ecologist, with more than 20 years experience in teaching, training and research in the field of Environmental Impact Assessment and Strategic Environmental Assessment using spatial decision support tools.

Sukhad Keshkamat, an engineer with over 12 years work experience in highway & bridge development, is now a doctoral researcher working in the transdisciplinary field of integrated spatial assessment at ITC. His particular research interests lie in the impact-based route planning of geographically large-scale highway corridors.

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TDOT's Early Environmental Screening Process (EES)

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Abstract

A variety of environmental factors can negatively affect a road project between conception and construction. When these factors arise late in the project development process, both project scheduling and budgeting can be severely impacted. The Early Environmental Screening Process (EES) was developed to avoid potential pitfalls by identifying environmental challenges at the beginning of a project's development using GIS technology. The EES process is employed during the initial development stages even before the NEPA process begins, typically when only a transportation need has been identified. One of the primary goals of the EES is to prevent environmental concerns from being an afterthought only addressed after engineering concerns have been satisfied.

Representatives from multiple environmental disciplines within TDOT compiled a list of potential problems from their respective disciplines that derail projects. These representatives then created distance buffers that could be used in a GIS environment to aid project planners in determining how close a given environmental feature could be to a project before it was affected. In addition to the distance buffers, impact weights were also assigned ranging from no effect to substantial effect for each of the categories below:

- Community Impact Group– Cemeteries, Institutions, Sensitive community populations
- Historic Architecture & Archaeology Group– National Register sites, cemetery sites, cemetery properties
- Ecology Group– Rare and protected species (bat, terrestrial, and aquatic species), TDEC Conservation Sites, TDEC Scenic Waterways, large wetland impacts
- Hazardous Substances & Geology Group – Superfund sites, caves, pyritic rock
- Railroads & Public Lands Group – Railroads, Tennessee Natural Areas Program, Wildlife Management Areas, other public lands (recreational, nature, federal, state)

Using these instructions, planners are able to make informed decisions regarding the relationship of environmental features and road projects without becoming experts in each given field and ensuring that projects are getting some level of environmental input even at the very earliest stages of development.

As would be expected, multiple challenges presented themselves during the development of the EES process. The first issue was that of GIS data availability. Once each technical discipline had compiled their list of potential project de-railers, the list had to be cross checked with currently available GIS data to make sure the data was valid or if the data even existed at all. It quickly became apparent as well that not all environmental factors should be treated equally, and therefore a scoring system would have to be developed. Questions also arose concerning how current decisions would be scrutinized in the future as data sets evolved over time. How could we ensure the decisions we made today would still be defensible tomorrow when spatial data sets are dynamic by definition and typically are discarded as soon as they are updated?

Through a lot of hard work and cooperation between multiple divisions within TDOT, the EES process is now being implemented. The process will now become an integral part of the overall Tennessee Environmental Streamlining Agreement (TESA) which ensures an open exchange of information between TDOT and various regulatory and commenting agencies throughout the life of a project. EES better allows TDOT to choose transportation routes that are environmentally sensitive, purpose driven, and economically feasible.

DEVELOPING A STATE WILDLIFE ROADKILL IDENTIFICATION GUIDE

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Abstract

Developing a guide to improve forensic data collection when monitoring wildlife mortality on state roads and highways.

Transportation agencies are making increasingly larger and more comprehensive infrastructure investments to protect wildlife as part of their planning and design processes. Concurrently, the understanding of the behavioral characteristics and habitat requirements of specific species of wildlife is growing. With this increased knowledge base, state transportation agencies have the opportunity to maximize the effectiveness of their wildlife protection investments by designing infrastructure for specific species of state interest. State transportation agency decisions to support the wildlife protection investments are often based, in part, on historic roadkilled wildlife data collected by state natural resource and/or transportation agency staff or contractors. Spatial and temporal information, as well as species identification are the three fundamental components necessary for reliable roadkilled wildlife reporting. While accurate spatial information can be obtained from GPS devices and physical marking systems; and accurate temporal information can be obtained from time measuring devices; accurate species identification is largely dependent on the personal knowledge of those handling roadkilled wildlife and completing roadkill reports. One information shortfall in the data collected by state transportation agencies appears to be the lack of consistently accurate species identification. If roadkilled species are inaccurately identified, then the value of the data of wildlife mortality reporting systems for species-specific wildlife protection initiatives may be severely compromised. The major factor limiting accurate species identification by transportation agencies appears to be the lack of wildlife forensics training for their staff and contractors. In 2008, the first wildlife roadkill identification guide developed by a transportation agency in North America was published by the British Columbia Ministry of Transportation and Infrastructure (BCMoT). The guide provides a practical tool to help address the issue of random and systematic species reporting inaccuracies found in the BCMoT Wildlife Accident Reporting System (WARS) database. The process and issues of developing the BCMoT guide are examined, and suggestions and recommendations for producing similar guides for other transportation agencies are provided.

An electronic copy of this poster is included in the Appendices of the Proceedings.

FHWA 2009 Environmental Excellence Awards

ICOET was pleased to once again host the Federal Highway Administration's Environmental Excellence Awards ceremony. The biennial awards program recognizes organizations, projects, and individuals who forge creative solutions and innovations for balancing the needs of a safe and efficient transportation network with environmental sensitivity. This year 13 winners in 12 categories were selected to receive the 2009 awards. Judges for the program also selected one project for special recognition, and two projects for honorable mention, from 98 entries submitted.

Following opening remarks by Tom Sorel, Commissioner for the Minnesota Department of Transportation, FHWA Deputy Administrator Greg Nadeau and FHWA Minnesota Division Administrator Derrell Turner presented the awards during a luncheon ceremony, with assistance from Carol Adkins and Patricia Cazenas of FHWA's Office of Project Development and Environmental Review. For more information on the 2009 awards program and winners, please refer to FHWA's Environmental Excellence Awards Web site at www.fhwa.dot.gov/environment/eea2009.

Excellence in Air Quality Improvement and Global Climate Change

California Regional Blueprint Project, California Department of Transportation (Caltrans)
Caltrans, in coordination with the Governor's Office of Planning and Research and the California Department of Housing and Community Development, oversees the California Regional Blueprint Program to encourage sustainable growth on a regional scale. The program provides funds for voluntary regional sustainable growth-planning efforts that emphasize transportation and scenario-planning activities. Participating Metropolitan Planning Organizations (MPOs) and Regional Transportation Planning Agencies (RTPAs) engage in visualization and scenario planning with extensive public participation. Regional agencies then use this planning process to create and implement a Regional Blueprint Plan, which integrates transportation, environment, housing, and other key regional issues into a preferred-growth scenario. The outcome-based goals of each Regional Blueprint planning process include reducing emissions of greenhouse gases from mobile sources, integrating environmental concerns into regional planning, linking transportation and housing needs at a regional level, building interagency partnerships, and creating proactive public involvement. The Regional Blueprint Program is an innovative policy solution to encouraging sustainable growth and combating global climate change.

Excellence in America's Byways

Minnesota's North Shore Scenic Byway, Minnesota Department of Transportation
Minnesota's North Shore Scenic Byway strategic master planning process enhances the ecological and cultural sustainability of the North Shore. Planning and maintaining the 154-mile North Shore Scenic Byway requires the integration of varying landscapes, national and State forests and parks, towns, communities, and harbors. To ensure that the byway responds to local needs, the North Shore Scenic Drive Council consults with a broad range of stakeholders and public agencies, and then updates the Long-Range Strategic Plan every three years. This plan integrates infrastructure with the surrounding landscape by balancing needs for mobility and safety with environmental, community, cultural, and scenic objectives. Examples of the Council's commitment to the improvement of the byway include the implementation of traffic calming measures within town centers, the replacement of unsafe highway sections, and the construction of bridges that incorporate bicycle and pedestrian paths. The partner agencies' creative efforts ensure that the byway allows all of its users to experience the unique scenic and cultural features of Minnesota's North Shore.

Excellence in Context Sensitive Solutions

Glenville Wetland Mitigation Bank / Fox Point State Park, Delaware Department of Transportation (DelDOT)
DelDOT and the Delaware Department of Natural Resources and Environmental Control (DNREC) joined forces with New Castle County and multiple Federal agencies led by FHWA to implement context sensitive solutions in response to the Glenville flood of 2003. Tropical Storm Henri and Hurricane Isabel flooded the community of Glenville, which lay in the 100-year floodplain of the Red Clay Creek. DelDOT, because of its knowledge, experience, and resource power, was chosen to lead the relocation effort for the residents living in the 145 homes affected by the flood. The project team found a creative and context-sensitive way to address the former location of these homes: the 57-acre area became the Glenville Wetland Mitigation Bank, created in conjunction with the U.S. Army Corps of Engineers and the Environmental Protection Agency. The mitigation bank consists of 46 acres of new and restored wetlands and habitat

with a buffer area for the 30 residences that remain. After excavating over 300,000 cubic yards of soil to create this wetland bank, DelDOT and DNREC reused the soil to cap a brownfield site and create an expanded 55-acre Fox Point State Park along the Delaware River. The Federal, State, and local partnership produced context-sensitive strategies and saved approximately $3 million in Delaware tax dollars while providing a mitigation bank, flood mitigation, a functioning new park, and a revitalized housing community.

Excellence in Cultural and Historical Resources

Minnesota Historic Bridge Management Program, Minnesota Department of Transportation (Mn/DOT)

The Minnesota Historic Bridge Management Program demonstrates Mn/DOT's commitment to excellence in cultural and historical resource preservation. The program began over 25 years ago with the completion of historical contexts to guide the evaluation of bridges in the State and the subsequent evaluation and identification of 250 bridges with historical significance, 33 of which were owned by the State. Mn/DOT worked closely with the Minnesota SHPO to identify candidates for long-term preservation and to develop individual management plans for the 24 selected structures. Mn/DOT also provided local transportation agencies with generalized historic bridge management that could help guide preservation and restoration of the over 200 locally owned historic bridges. The Minnesota SHPO recognized Mn/DOT's extensive effort and agreed to streamline the environmental review process for all nonhistoric bridges, thereby decreasing the cost and delays for 5,000 potential bridge improvement projects. The Minnesota Historic Bridge Management Program promotes a deeper commitment to the preservation of the State's distinguished engineering heritage while expediting the environmental review process.

Excellence in Ecosystems, Habitat, and Wildlife (2 Winners)

Innovative Top-down Construction Used on Washington Bypass Project, North Carolina Department of Transportation (NCDOT)

The project design-build team used an innovative gantry design to construct a 2.8-mile bridge with minimal disturbance to the surrounding environmentally sensitive wetland ecosystem. The NCDOT Washington Bypass Project consists of a 6.8-mile bypass route around the city of Washington, North Carolina, on US 17. The team came up with the world's first erection gantry to construct the bridge from the top down. Using gantries to drive the piles that support the bridge minimizes the construction footprint and limits disturbance to the area immediately around the bridge. Compared with traditional wetland construction that makes extensive use of access trestles, barges or tugboats, and cranes, the new erection gantry method holds great promise for minimizing construction damage to environmentally sensitive areas in the future.

Oregon Department of Transportation (ODOT) Vernal Pool Mitigation and Conservation Bank

ODOT created the first conservation bank in the State of Oregon, the Vernal Pool Mitigation and Conservation Bank, in the Rogue Valley. Vernal pools are unique environments that fill with water during rainy seasons of the year and dry out during others. ODOT enlisted the U.S. Fish and Wildlife Service (USFWS) and State and local resource agencies to find a vernal pool preservation site that would contribute to the conservation of rare species and habitats. The agencies unanimously chose an 80.23-acre site located directly adjacent to The Nature Conservancy's Whetstone Savanna Preserve. Together, the mitigation bank and the preserve will provide 160 acres of contiguous high-functioning vernal pool habitat. The complex will be protected by The Nature Conservancy to sustain wetland functions and values. Habitat will be provided for large-flowered woolly meadowfoam and Cook's lomatium, two endangered plant species, as well as the threatened vernal pool fairy shrimp. In addition to addressing species issues, the bank is available to compensate for impacts to wetlands. ODOT's collaboration with resource agencies and the Conservancy exemplifies a carefully researched mitigation project that preserves wildlife habitat in a unique and sensitive ecosystem.

Excellence in Environmental Research

Quieter Pavement Research: Development of Technology for Measurement of Tire / Pavement Noise Using the On-Board Sound Intensity Method, California Department of Transportation (Caltrans)

Caltrans' Division of Environmental Analysis adapted a little-known General Motors (GM) measurement methodology to precisely quantify tire/pavement acoustics. The new methodology, On-Board Sound Intensity (OBSI), is based on acoustic work done on test tracks in the 1970s by GM. The dominant noise source on light vehicles operating at freeway speed is tire/pavement noise. The noise levels on different pavements can vary widely depending on material type and surface texture. It was this tire/pavement noise phenomenon that led Caltrans to develop OBSI. The Caltrans-modified approach uses one standard tire to evaluate many different pavements with traffic on active freeways in real time. The unique aspect of this procedure allows pavement noise to be separated from other noise generators on a moving vehicle. This work has demonstrated that lowering pavement noise levels also lowers community noise adjacent to highways. Development of quieter pavement is another potential tool that transportation departments may use to lower overall traffic noise levels in the community. A better understanding of tire/pavement acoustics will improve noise-modeling calculations and noise-mitigating design features. This Caltrans-/GM-developed process is now being adopted as a measurement standard by the American Association of State Highway and Transportation Officials (AASHTO), ASTM International (formerly the American Society for Testing and Materials), and SAE International (the Society of Automotive Engineers International).

Excellence in Environmental Streamlining

11th Street Bridges Environmental Impact Statement, District of Columbia Department of Transportation (DDOT)
DDOT's 11th Street Bridges project will enhance the mobility of traffic across the Anacostia River. The project will eliminate the need for traffic to cut through neighborhood streets between the Anacostia Freeway and the Southeast Freeway. DDOT adopted an aggressive schedule and committed the necessary resources to advance the project and meet the goal of improving the quality and timeliness of the transportation-delivery process. To develop the project's Draft Environmental Impact Statement (DEIS), DDOT partnered with the public and more than 30 Federal and non-Federal participating agencies to gain early acceptance by all stakeholders. The team identified critical project issues, which improved the scoping phase and addressed stakeholders' concerns early in the DEIS. As a result, the solutions presented in the Final DEIS were representative of stakeholder needs and were environmentally sound. DDOT's collaborative and proactive approach to developing the 11th Street Bridges DEIS resulted in a streamlined project, exceeding the Federal Highway Administration's National Performance Objective.

Excellence in Nonmotorized Transportation

Midtown Greenway & Bridge, Minnesota Department of Transportation
The Midtown Greenway and Bridge project transformed the Midtown railroad corridor into a safe, fast, and barrier-free trail system for commuting and recreation while preserving necessary space for possible future coexistence with a light-rail transit system. Successful completion of the Greenway corridor required innovative design elements to improve mobility, safety, and access for pedestrians, bicyclists, and transit users. During the project planning process, stakeholders wanted to create an aesthetic signature community gateway. The 215-foot cable-stayed bridge was designed for the gateway, which fits within the available right of way and is used by 3,000 bicyclists and pedestrians on a daily basis for commuting and recreation. This much-needed Midtown Greenway Trail and gateway bridge represent a significant and successful local, State, and Federal investment in alternatives that encourage sustainable transportation.

Excellence in Roadside Resource Management and Maintenance

Nebraska Department of Roads (NDOR) Plan for the Roadside Environment
NDOR's Plan for the Roadside Environment promotes the increased use of native plantings and vegetation management to provide a sustainable roadside. The plan emphasizes the use of native plantings adapted specifically to the varying climate zones across the State. It contains sections for each of the six landscape regions across Nebraska. Each individual landscape section contains regional maps and summarizes a variety of ecosystem information for the region, including hydrology, climate, and soil and plant communities, as well as regional-history, land-use, and economic features. The plan is applicable to the entire State and includes landscaping objectives for integration into transportation planning, safety, design, and operation of the system. The informational base benefits NDOR and natural resource agencies concerning the role of the roadside environment and how to achieve good stewardship and maintenance of a unique and sustainable "Nebraska-style" landscape.

Excellence in Wetlands, Watersheds, and Water Quality

Caltrans Statewide Stormwater Management Program, California Department of Transportation
Caltrans' integrated Statewide Stormwater Management Program protects water quality while fulfilling the agency's mission to improve mobility across California. The comprehensive program addresses water quality throughout the project-delivery process for highway improvement projects. The Stormwater Management Program developed best-management practices (BMPs) for all departmental activities, including environmental, design, construction, facility operations, and maintenance. The program implements over 70 BMP types and uses more than nine types of stormwater control devices to prevent pollution and treat stormwater runoff. The program also includes a public education component; Caltrans' statewide Don't Trash California campaign has educated nearly half a billion Californians about trash and its effects on water quality. In partnership and collaboration with State DOTs, Caltrans hosted the first American Association of State Highway and Transportation Officials (AASHTO) Stormwater Conference in June 2008 to bring together State DOT representatives, the Federal Highway Administration, the Environmental Protection Agency, and leading academic researchers to share and advance the knowledge of stormwater runoff management directly related to highways and transportation facilities.

Excellence in Environmental Leadership

Gary Ruggerone, Senior Environmental Planner, District 5, California Department of Transportation
Gary Ruggerone has demonstrated environmental leadership over the course of his 30-year tenure at Caltrans, where he oversees the Environmental Stewardship Branch and leads the Emergency Response Team for Environmental Planning in Caltrans – District 5. Gary's ability to foster cross-agency cooperation and to transmit information from field crews to upper management allows him to efficiently integrate ecological principles into his many transportation projects, a few of which stand out as true advances in environmental planning. In the Elkhorn Slough Early Mitigation Pilot Project, he was instrumental in initiating a watershed approach for an early mitigation process that can be implemented years in advance. He also conceived of and executed two Programmatic Agreements between the Federal Highway Administration and the Ventura Office of the US Fish and Wildlife Service (USFWS) for the California red-legged frog and Smith's blue butterfly, which saved time and money for Caltrans and USFWS staff. This award recognizes Gary's distinguished career as an innovative team and environmental leader.

Judge's Award for Special Recognition

The Oregon Solar Highway Initiative, Oregon Department of Transportation
The Oregon Solar Highway Initiative is a partnership with the private sector that utilizes State and Federal tax credits, depreciation, and utility incentives to finance renewable energy projects located in the highway operating right of way. The first project under the Initiative is a 594-panel, 104-kilowatt, ground-mounted solar array located inside the interchange of Interstate 5 (a federally-designated Corridor of the Future) and Interstate 205 in Tualatin, Oregon. ODOT seeks to demonstrate that solar arrays will complement and not compromise the transportation system, and that they can thus be deployed on highways throughout the nation. The Oregon Solar Highway Initiative reflects the innovation and spirit of partnership that are necessary to develop entrepreneurial and sustainable ways of addressing the nation's transportation and energy needs.

Honorable Mentions for Environmental Excellence (2 Winners)

TRIP to Work Program, South I-25 Urban Corridor Transportation Management Association, Denver, Colorado
The Transit Rider Incentive Program (TRIP) provides affordable public transportation services to employees working in the South I-25 Urban Corridor of Denver, Colorado. The South I-25 Urban Corridor Transportation Management Association, a coalition of local governments and business groups within the South I-25 Corridor, partnered with the Denver Regional Transportation District to discount monthly light-rail, bus, and "Call-n-Ride" passes that provide employees with a low-cost alternative to driving to work.

Walk There!, Metro Regional Government, Portland, Oregon
Portland's Walk There! program, developed by Metro, promotes walking as a healthy transportation option. The Walk There! guidebook highlights 50 walking routes in the Portland metropolitan region and enhances access for people with disabilities by including detailed information about each route's distance, difficulty, terrain, and incline. Metro distributed the guidebook through medical clinics around the region.

Judges for 2009 Awards Program

Catherine Liller, National Transportation Liaison, US Fish and Wildlife Service
Rachel Herbert, Water Permits Division, US Environmental Protection Agency
Jeremiah Dumas, ASLA, GeoSystems Research Institute, Mississippi State University

ICOET 2009 Final Program

Sunday, September 13

3:00 PM – 7:00 PM **Conference Registration and Check-in**

5:00 PM – 7:00 PM **ICOET Steering Committee Business Meeting** (St. Louis River Room)

7:00 PM – 8:15 PM **"Division Street" Documentary Film Screening** (Lake Superior Ballroom L)
Moderator: Trisha White, Habitat & Highways Campaign Director, Defenders of Wildlife
Discussion with filmmaker Eric Bendick follows screening

Monday, September 14

7:00 AM – 5:30 PM **Conference Registration and Check-in**

8:30 AM – 9:30 AM **Conference Welcome and Opening Remarks** (Lake Superior Ballroom J)

- Paul Wagner, Washington State DOT, ICOET 2009 Conference Chair
- James Martin, PE, Associate Director, Center for Transportation and the Environment
- Frank Pafko, Environmental Services Director, Minnesota DOT
- Don Ness, Mayor of Duluth

9:30 AM – 10:30 AM **Plenary Session 110: US / International Policy Updates** (Lake Superior Ballroom J)
Moderator: Frank Pafko, Environmental Services Director, Minnesota DOT

- Carol Adkins, Acting Director, Office of Project Development and Environmental Review, FHWA, Washington, DC
- Lars Nilsson, Environmental Director, National Road Administration, Sweden
- Thomas Duffus, Upper Midwest Director, The Conservation Fund, Duluth, MN

10:30 AM – 11:00 AM **Break in Sponsors Hall** (Lake Superior Ballroom O)

11:00 AM – 12:30 PM **Plenary Session 120: Moving Toward Sustainability – Case Studies in Integrating Land Use, Conservation, Transportation, and Community Planning**
(Lake Superior Ballroom J)
Moderator: Debra Nelson, Water and Ecosystems Section Manager, New York State DOT

- Integrating Conservation and Long-Range Transportation Planning Using a Strategic Assessment Framework *(Craig Casper, Pikes Peak Area COG, Colorado Springs, CO, USA)*
- Looking to the Future with Retrofit Options from Lessons Learned *(Bruce Eilerts, Arizona DOT Office of Environmental Services, Phoenix, AZ, USA)*
- Long Point World Biosphere Reserve Causeway Improvement Plan, Port Rowan, Ontario, Canada: Benefits for Wildlife Movement, Species at Risk, Traffic, and Pedestrian Safety *(Geoffrey Gartshore, Ecoplans Limited, Ontario, Canada)*

12:30 PM – 2:00 PM **FHWA Environmental Excellence Awards Luncheon** (Lake Superior Ballroom K)
Remarks: Thomas Sorel, Commissioner, Minnesota DOT
Awards presented by:

- Greg Nadeau, Deputy Administrator, Federal Highway Administration, Washington, DC
- Derrell Turner, Division Administrator, FHWA Minnesota Division
- Carol Adkins, FHWA Office of Project Development and Environmental Review
- Patricia Cazenas, FHWA Office of Project Development and Environmental Review

Monday, September 14

2:00 PM – 3:30 PM **CONCURRENT SESSIONS**

Session 131: Climate Change – Understanding the Impacts and Developing Mitigation Strategies (Lake Superior Ballroom J)
Moderator: Shari Schaftlein, Office of Project Development and Environmental Review, FHWA, Washington, DC

- How will Climate Change affect the Design and Management of the Highways Agency Soft Estate? *(Lucia Collinwood, Parsons Brinckerhoff, Cardiff, Wales)*
- The FHWA Carbon Sequestration Pilot Program: Economics, Environment and Policy *(Stephen Earsom, FHWA, Washington DC, USA)*
- Potential Impacts of Climate Change on Urban Flooding: Implications for Transportation Infrastructure and Travel Disruption *(Heejun Chang, Portland State University, Portland, OR, USA)*
- Washington State Department of Transportation Interim Approach to Project-Level Greenhouse Gas and Climate Change Evaluations For Transportation Projects *(Tim Sexton, Washington State DOT, Seattle, WA, USA)*

Session 132: Citizen Science – Effective Strategies and Stakeholder Involvement (Lake Superior Ballroom L)
Moderator: Susan Hagood, Wildlife Issues Specialist, Humane Society of the United States, Washington, DC

- Road Watch in Pass: Web-based Citizen Involvement in Wildlife Data Collection *(Tracy Lee and Danah Duke, Miistakis Institute for the Rockies, Alberta, Canada)*
- Wildlife Tunnels Under a Busy, Suburban Boston Roadway *(Lydia Rogers, Wildlife Passages Task Force, Concord, MA, USA)*
- Motorists as Citizen Scientists: The Benefits of a Wildlife Reporting Website *(Angela Kociolek, Western Transportation Institute at Montana State University, Bozeman, MT, USA)*
- Can Citizen Science Represent Wildlife Activity Along Highways? Validating a Monitoring Program *(Kylie Paul, University of Montana, Missoula, MT, USA)*

3:30 PM – 4:00 PM **Break in Sponsors Hall** (Lake Superior Ballroom O)

4:00 PM – 5:30 PM **CONCURRENT SESSIONS**

Session 141: Adapting Agency Relationships in a Changing Regulatory Environment (Lake Superior Ballroom J)
Moderator: Derrell Turner, Administrator, FHWA Minnesota Division

- Interagency Partnering for the Development of Stream Crossing Standards in New York State *(Brandon Greco and Debra Nelson, New York State DOT, Albany, NY, USA)*
- Endangered Species Act Section 7 Consultation and the US Fish And Wildlife Service's Information, Planning, and Consultation (IPaC) System *(Michael Horton, US Fish and Wildlife Service, Arlington, VA, USA)*
- Intercounty Connector (ICC): Environmental Compliance Management Using Integrated Technologies to Provide Context Sensitive Solutions *(Holly Shipley, KCI Technologies, Inc., Sparks, MD, USA)*

Monday, September 14

4:00 PM – 5:30 PM **CONCURRENT SESSIONS**

Session 142: Technical Tools for Integrating Ecological Considerations in Planning and Construction (French River Room)
Moderator: Cameron Bump, Transportation Liaison, Wisconsin Department of Natural Resources

- Traffic Volume as a Primary Road Characteristic Impacting Wildlife: A Model for Land Use and Transportation Planning *(Barbara Charry, Maine Audubon, Falmouth, ME, USA)*
- Integrating Environmental Concerns with the Planning and Construction of the South Extension of Interstate 355 into Will County, Illinois *(Angela LaPorte and Brian Smith, AECOM, Chicago, IL, USA)*
- Ecological Effects of Road Construction on Regional Ecosystem *(Shyh-Chyang Lin, National Kinmen Institute of Technology, Kinmen, Taiwan)*
- Incorporating Road-Mortality Hotspot Modeling and Connectivity Analyses into Road Mitigation Planning in Ontario, Canada *(Kari Gunson, Ontario Road Ecology Group, Ontario, Canada)*

Session 143: Advance Mitigation and Mitigation Banking Programs
(Lake Superior Ballroom L)
Moderator: Sarma Straumanis, Wetland Program Coordinator, Minnesota DOT

- Use of Habitat Credit Trading as a Mitigation Tool for Transportation Projects: A FHWA Pilot Project in Arkansas *(Andrew Peck, Department of Environmental Sciences, Arkansas State University, AR, USA)*
- Regional Advance Mitigation Planning: A Pilot Study Integrating Multi-agency Mitigation Needs and Actions Within a Comprehensive Ecological Framework *(Patrick Huber, University of California, Davis, CA, USA)*
- Status of Mitigation Banking for Transportation in the Upper Midwest *(Thomas Mings, US Army Corps of Engineers, St. Paul, MN, USA)*

5:30 PM **Monday Sessions Adjourn**

US Fish and Wildlife Service Transportation Biologists Peer Exchange Meeting
(St. Louis River Room)

6:00 PM – 8:00 PM **Welcome Reception and Cash Bar at Great Lakes Aquarium**
Thanks to our Silver co-sponsor ARCADIS!

Tuesday, September 15

7:30 AM – 5:30 PM **Conference Registration and Check-in**

8:30 AM – 10:00 AM **CONCURRENT SESSIONS**

Session 211: Integrating Ecology and Transportation Planning at the Landscape Scale
(Lake Superior Ballroom J)
Moderator: Mary Gray, Environmental Protection Specialist, FHWA, Olympia, WA

- California Essential Habitat Connectivity Planning *(Amy Pettler, Caltrans, Sacramento, CA, USA)*
- Establishing the Legacy Nature Preserve through Collaborative Planning and Adaptive Management *(Michael Perkins, HDR, Inc., Salt Lake City, UT, USA)*
- Nebraska Department of Road's Plan for the Roadside Environment *(Arthur Thompson, Nebraska Department of Roads, Lincoln, NE, USA)*
- Similar Impacts, Similar Solutions? The Effects of Transport Infrastructure on Outdoor Recreation and Wildlife *(Jan Olof Helldin, Swedish Biodiversity Centre, SLU, Uppsala, Sweden)*

Tuesday, September 15

8:30 AM – 10:00 AM **CONCURRENT SESSIONS**

Session 212: Ecological Considerations for Planning and Designing Bridges
(French River Room)
Moderator: Peter Leete, Hydrologist, Minnesota Department of Natural Resources

- Road Infrastructure and Stream Habitat Connectivity: Research Tools to Aid Management and Conservation Plans in a Changing Environment *(Keith Nislow, US Forest Service Northern Research Station, Amherst, MA, USA)*
- MassHighway Guidance Handbook: Design of Bridges and Culverts for Wildlife Passage *(David Nyman, Comprehensive Environmental Inc., Milford, MA, USA)*
- Do Bridges Affect Migrating Juvenile Salmon: Tracking Juvenile Salmon and Predator Fish Movements and Habitat Use Near the SR 520 Bridge in Lake Washington *(Philip Bloch, Washington State DOT, Seattle, WA, USA)*
- Are Non-Wildlife Underpasses Effective Passages for Wildlife? *(Andreas Seiler, Swedish University of Agricultural Sciences, Uppsala, Sweden)*

Session 213: Wildlife Habitat Connectivity – Innovative Tools and Techniques
(Lake Superior Ballroom L)
Moderator: Hans Bekker, Senior Ecologist, Rijkswaterstaat Centre for Traffic and Navigation, Zuid-Holland, The Netherlands

- Are We There Yet? A Case for Spatially Explicit Linkage Modeling for Integrative Conservation Planning *(Julia Kintsch, ECO-resolutions, LLC, Denver, CO, USA)*
- Monitoring Wildlife Overpass Use by Amphibians – Do Artificially Maintained Humid Conditions Enhance Crossing Rates? *(Edgar Van der Grift, Alterra Wageningen UR, Gelderland, The Netherlands)*
- New Concepts in Wildlife Habitat Linkage Assessments To Focus Mitigation Measures and Reduce Wildlife Crossing Costs *(Bill Ruediger, Wildlife Consulting Resources, Missoula, MT, USA)*
- Washington's Habitat Connectivity Highway Retrofit Initiative *(Kelly McAllister, Washington State DOT, Olympia, WA, USA)*

10:00 AM – 10:30 AM **Break in Sponsors Hall** (Lake Superior Ballroom O)

10:30 AM – 12 NOON **CONCURRENT SESSIONS**

Session 221: Wildlife Habitat Connectivity – Planning and Design
(Lake Superior Ballroom J)
Moderator: Jennie Ross, Environmental Assessment Unit Chief, Minnesota DOT

- Idaho Statewide Wildlife / Transportation Database *(Brent Inghram, FHWA Idaho Division, Boise, ID, and Gregg Servheen, Idaho Department of Fish and Game, Boise, ID, USA)*
- Judd Road Connector: Lessons Learned in Ecological Mitigation – Wildlife Crossings, Habitat Preservation, Wetlands and More *(Ed Frantz, New York State DOT, Utica, NY, USA)*
- Avian Protection Plan for the Nebraska Department of Roads *(Eric Zach, Nebraska Department of Roads, Lincoln, NE, and Dionne Gioia, US Dept of Agriculture APHIS Wildlife Services, Union, NE, USA)*
- How Do Major Roads Affect Barn Owls? Distribution, Space Use, Food Source and Mortality *(Joana Sousa, Centro Biologia Ambiental, Lisboa, Portugal)*

Tuesday, September 15

10:30 AM – 12 NOON **CONCURRENT SESSIONS**

Session 222: Wetland Mitigation and Ecological Considerations for Stormwater Management (French River Room)
Moderator: Wesley Saunders-Pearce, MS4 Specialist, Minnesota DOT

- Wetland Mitigation in Abandoned Gravel Pits – Creating Fresh Meadow and Shrub Swamp *(Kurt Johnson, University of Minnesota Natural Resources Research Institute, Duluth, MN, USA)*
- Regenerative Stormwater Conveyance (RSC) as an Integrated Approach to Sustainable Stormwater Planning on Linear Projects *(Joe Berg, Biohabitats, Inc., Baltimore MD, USA)*
- Oregon DOT Stormwater Treatment and Management Program: A Framework for Adapting to Changing Pollutants, Regulations, and Practices *(Zak Toledo, HDR, Inc., Salem, OR, USA)*

Session 223: Wildlife-Vehicle Collisions – Data Collection, Monitoring and Modeling (Lake Superior Ballroom L)
Moderator: Cheryl Martin, Environmental Engineer, FHWA Minnesota Division

- Arboreal Mammals Use an Aerial Rope Bridge to Cross a Major Highway *(Rodney van der Ree, Australian Research Centre for Urban Ecology, Victoria, Australia)*
- Using Global Positioning System Technology to Determine Wildlife Crossing Structure Placement and Evaluating Their Success in Arizona *(Jeffrey Gagnon, Arizona Game and Fish Department, Phoenix, AZ, USA)*
- Bozeman Pass Wildlife Pre-and Post-Fence Monitoring Project *(April Craighead, Craighead Environmental Research Institute, Bozeman, MT, USA)*
- Predictive Models of Herpetofauna Road Mortality Hotspots in Extensive Road Networks: Three Approaches and a General Procedure for Creating Hotspot Models *(Tom Langen, Clarkson University, Potsdam, NY, USA)*

12 NOON – 1:30 PM **Keynote Speaker Luncheon** (Lake Superior Ballroom K)

- Rick Ridgeway, Vice President of Environmental Initiatives, Patagonia, Inc.

Thanks to our Bronze co-sponsors Connectivity for Wildlife LLC, ElectroBraid Fence, and Great Lakes Maritime Research Institute!

1:30 PM – 3:00 PM **CONCURRENT SESSIONS**

Session 231: Mitigating Highway Impacts on Ecosystems (Lake Superior Ballroom J)
Moderator: David Weirens, Land and Water Section Manager, Minnesota Board of Water and Soil Resources

- Evaluation of a Rapid Assessment Protocol to Assess Road-Stream Crossings for Aquatic Organism Passage *(Scott Jackson, UMass Department of Natural Resources Conservation, Amherst, MA, USA)*
- Where the River Meets the Road: How Washington State is Providing Habitat while Protecting Highways *(Paul J. Wagner, Washington State DOT, Olympia, WA, USA)*
- Effective Mitigation: The Cumulative Impact of Climate Change on Transportation Network and its Implications on Aquatic Biodiversity of Ganges Headwaters, Garhwal Himalayas *(Ramesh C. Sharma, Departmental of Environmental Sciences, H.N.B.Garhwal University, Uttarakhand, India)*
- Adapting Relationships for Agencies and Institutions: The I-90 Snoqualmie Pass East Project's Collaborative Approach to Identifying a Preferred Alternative and Mitigation Strategy *(Jason Smith, Washington State DOT, Yakima, WA, USA)*

Tuesday, September 15

1:30 PM – 3:00 PM **CONCURRENT SESSIONS**

Session 232: Improving Data Collection and Monitoring Methods (French River Room)
Moderator: Leonard Sielecki, Environmental Management Section, University of Victoria, British Columbia, Canada

- Reducing Road-Based Habitat Fragmentation: An Eastern Box Turtle (Terrapene c. carolina) Case Study *(Susan Hagood, The Humane Society of the US, Washington DC, USA)*
- Re-evaluating the Needs for Animal Passages in Israel: Towards a Long-term Monitoring Scheme *(Tamar Achiron-Frumkin, Ecological and Environmental Advisors, Israel)*
- Restoring Ecological Networks Across Transport Corridors in Bulgaria *(Edgar Van der Grift and Vanya Simeonova, Alterra Wageningen UR, Gelderland, The Netherlands)*
- Development and Utilization of a Regional Invasive Plant Species Database at the New York State Department of Transportation *(Christine Colley, New York State DOT, Buffalo, NY, USA)*

Session 233: Wildlife-Vehicle Collisions – Effective Mitigation Strategies
(Lake Superior Ballroom L)
Moderator: Sandra Jacobson, Wildlife Biologist, US Forest Service, Pacific Southwest Research Station, Bend, OR

- Using Specialized Tunnels to Reduce Highway Mortality of Amphibians *(Cyndi Smith and Katie Pagnucco, Parks Canada – Waterton Lakes National Park, Alberta, Canada)*
- A Quantitative Comparison of the Reliability of Animal Detections Systems and Recommended Requirements for System Reliability *(Marcel Huijser, Western Transportation Institute at Montana State University, Bozeman, MT, USA)*
- Evaluation of an Animal-Activated Highway Crosswalk Integrated with Retrofit Fencing Applications *(Norris Dodd, AZTEC Engineering, Phoenix, AZ, USA)*
- Effectiveness of Mitigation Measures to Reduce Road Mortality in the Netherlands: Badger Meles meles *(Hans Bekker, Rijkswaterstaat Centre for Traffic and Navigation, Zuid-Holland, The Netherlands)*

3:00 PM – 3:30 PM **Break in Posters Hall** (Edmund Fitzgerald Exhibit Hall)

3:30 PM – 5:30 PM **Session 240: Poster Presentations** (Edmund Fitzgerald Exhibit Hall)
50 posters showcasing innovative projects, applications, and research in progress will be on display. Authors representing 10 countries will be available to discuss their work.

5:30 PM **Tuesday Sessions Adjourn**

5:00 PM **CONCURRENT BUSINESS MEETINGS**

Deer-Vehicle Crash Information and Research Center Technical Advisory Committee
(Gooseberry Falls Room 1)

FHWA Transportation Liaison Peer Exchange Workshop (Gooseberry Falls Room 3)

TransWild Alliance Meeting hosted by Defenders of Wildlife
(Comfort Suites Conference Room)

7:00 PM **TRB ADC30 Committee on Ecology and Transportation** (St. Louis River Room)

TRB AFB40 Committee on Landscape and Environmental Design (Split Rock Room 1)

Wednesday, September 16

7:30 AM – 5:00 PM **Conference Registration and Check-in**

8:00 AM – 9:00 AM **Plenary Session 310: Field Trips Overview by Minnesota DOT**
(Lake Superior Ballroom J)
Moderator: Frank Pafko, Environmental Services Director, Minnesota DOT
- Dwayne Stenlund, Erosion Control Specialist, Minnesota DOT
- Scott Bradley, Director of Context Sensitive Solutions, Minnesota DOT
- Paul Sundberg, Manager, Gooseberry Falls State Park, Minnesota Department of Natural Resources

9:00 AM – 9:30 AM **Break / Pick up Box Lunches in Sponsors Hall** (Lake Superior Ballroom O)

9:30 AM – 4:00 PM **FIELD TRIPS** (Atrium Lobby – buses depart promptly at 9:30 AM)
- Trip 1: North Shore National Scenic Byway
- Trip 2: Aquatic Habitat Reconstruction Tour

6:00 PM – 9:00 PM **Dinner and Cash Bar at Grandma's Sports Garden**
Thanks to our Gold co-sponsor HDR Engineering, Inc.!

Thursday, September 17

7:30 AM – 10:30 PM **Conference Registration and Check-in**

8:30 AM – 10:00 AM **CONCURRENT SESSIONS**

Session 411: The Economics of Mitigation and Cost-Effective Strategies
(Lake Superior Ballroom J)
Moderator: Tom Mings, Senior Ecologist, US Army Corps of Engineers
- Cost Justification and Examples of Cost-Benefit Analyses of Mitigation Measures Aimed at Reducing Collisions with Large Ungulates in the United States and Canada *(Marcel Huijser, Western Transportation Institute at Montana State University, Bozeman, MT, USA)*
- An Analysis of the Efficacy and Comparative Costs of Using Flow Devices to Resolve Conflicts with North American Beavers Along Roadways in the Coastal Plain of Virginia *(Stephanie Boyles, Christopher Newport University, Portsmouth, VA, USA)*
- Prioritizing Road Crossing Improvement to Restore Stream Connectivity for Stream-Resident Fish *(Matthew Diebel, University of Wisconsin, Madison, WI, USA)*

Session 412: Wildlife Crossings – Location and Design (Lake Superior Ballroom L)
Moderator: Scott Bradley, Director of Context Sensitive Solutions, Minnesota DOT
- Multi-Scale Habitat-Resistance Models for Predicting Road Mortality "Hotspots" for Reptiles and Amphibians *(David Patrick, Paul Smith's College, Paul Smiths, NY and Viorel Popescu, University of Maine, Orono, ME, USA)*
- Integrating Ecosystem Needs with Transportation Facility Design: Design Engineering Challenges of the I-90 Snoqualmie Pass East Project *(Randall Giles, Washington State DOT, Yakima, WA, USA)*
- A Summary of the Wildlife Linkage and Highway Safety Assessment: A Prioritization and Planning Tool For Western Montana *(Elizabeth Williamson and Dylan Taylor, American Wildlands, Bozeman, MT, USA)*
- Using Noninvasive Genetic Sampling Methods to Assess the Value of Wildlife Crossings for Black and Grizzly Bear Populations in Banff National Park, Alberta, Canada *(Michael Sawaya, Montana State University, Bozeman, MT, USA)*

10:00 AM – 10:30 AM **Break in Sponsors Hall** (Lake Superior Ballroom O)

Thursday, September 17

10:30 AM – 12 NOON **CONCURRENT SESSIONS**

Session 421: Integrating Ecological Considerations into Construction, Operations, and Maintenance (Lake Superior Ballroom L)
Moderator: Carmelita Nelson, Roadsides for Wildlife Program Manager, Minnesota Department of Natural Resources

- The Ecological Implications of Cured-in-Place Pipe Rehabilitation Technology *(Bridget Donaldson, Virginia Transportation Research Council, Charlottesville, VA, USA)*
- Managing an Unpredicted and Unexpected Large Scale Amphibian Migration: Applying Hungarian Experience and Knowledge to Protect Western Toads on a British Columbia Highway *(Leonard Sielecki, University of Victoria, British Columbia, Canada)*
- Down the Drain: How to Avoid Trapping Amphibians in Road and Sewer Drainage Systems – Designing Fauna Friendly Drainage Systems and Other Protective Measures *(Bruno Schelbert, Departement Construction, Traffic and Environment, Aarau, Switzerland)*
- "Sustainable Highway Construction" is NOT an Oxymoron *(Gary Demich, H.W. Lochner, Inc., Chicago, IL, USA)*

Session 422: FHWA's Eco-Logical Program – Case Studies (Lake Superior Ballroom J)
Moderator: Carol Adkins, Acting Director, Office of Project Development and Environmental Review, FHWA, Washington, DC

- Eco-Logical: An Ecosystem Approach to Developing Transportation Infrastructure Projects in a Changing Environment *(Bethaney Bacher-Gresock, FHWA, Washington DC and Julianne Schwarzer, Volpe National Transportation Systems Center, Cambridge, MA, USA)*
- MARC's Eco-Logical Project: A Regional Approach to Linking Environmental and Transportation Planning *(Lisa Pool and Tom Jacobs, Mid-America Regional Council, Kansas City, MO, USA)*
- Developing and Piloting an Eco-Logical Approach to Transportation Project Delivery in Montana *(Deborah Wambach, Montana DOT, and Scott Jackson, US Fish and Wildlife Service, Helena, MT, USA)*
- Texas Ecological Assessment Protocol (TEAP): Eco-Logical information for Transportation Planning *(Sharon Osowski, US Environmental Protection Agency, Dallas, TX, USA)*

12 NOON – 12:30 PM **Conference Wrap-up and Closing Remarks** (Lake Superior Ballroom J)

- Paul Wagner, Washington State DOT, ICOET 2009 Conference Chair

12:30 PM **Conference Adjourns**

FHWA Transportation Liaison Peer Exchange Workshop (St. Louis River Room)

2:00 PM **USDA Forest Service Coordination Meeting** (Split Rock Room 1)

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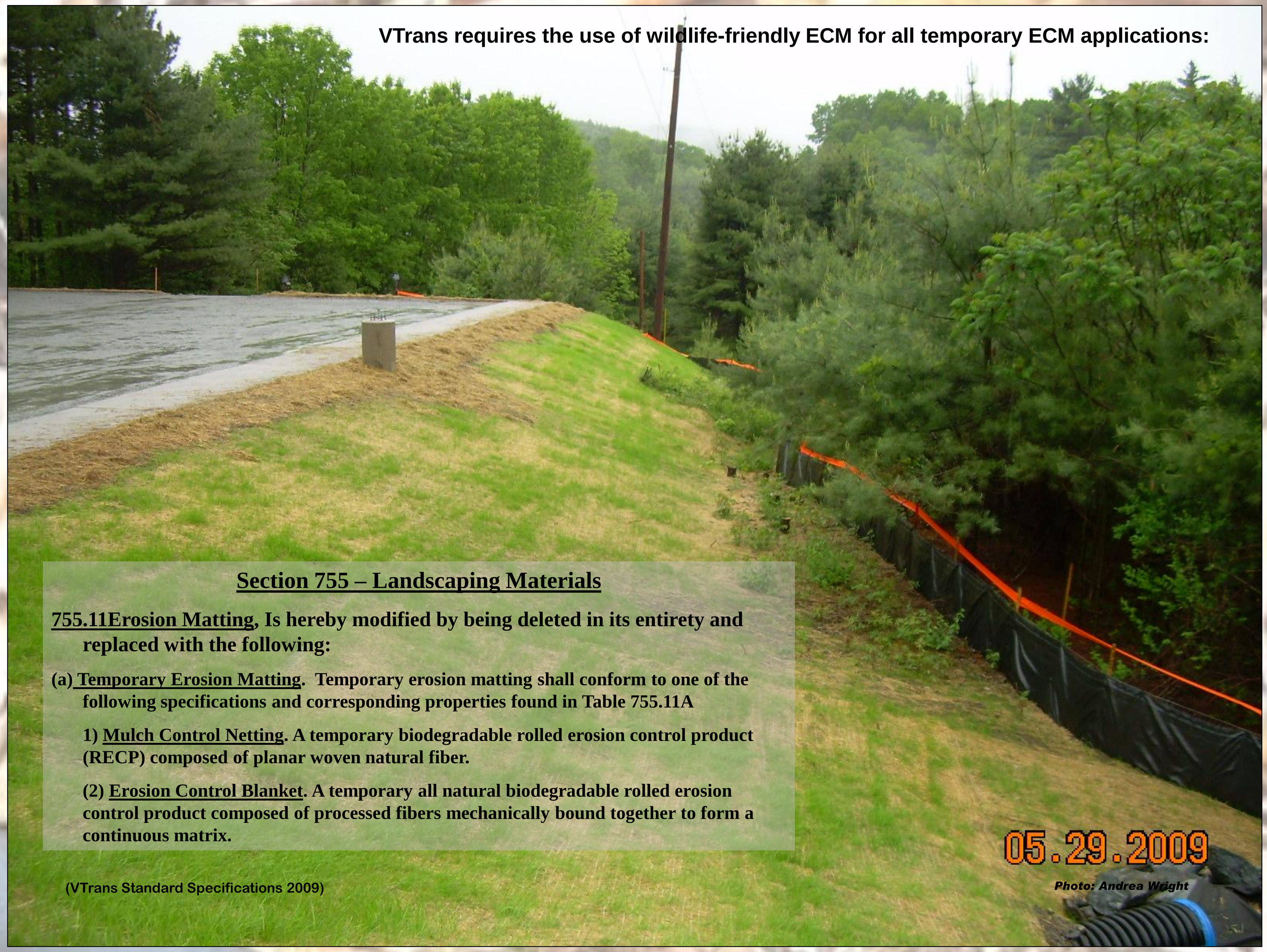
Introduction

In response to incidents of wildlife entanglement in erosion control matting (ECM), the Vermont Agency of Transportation (VTrans) and the Vermont Agency of Natural Resources (VANR) proposed a sweeping change in the type of erosion control matting used on construction projects in Vermont. An ad-hoc work group set out to develop an interagency approach to what has been identified as a perennial problem inherent to ECM containing plastic mesh netting (Stuart et al. 2001; Barton and Kinkead 2005; Walley et. al. 2005). Rather than respond on a project-by-project basis, VTrans elected to eliminate the use of polymer-based matting as a temporary erosion control method on all construction and maintenance projects. Following the VTrans change, the VANR updated the Vermont Standards and Specifications for Erosion Prevention and Sediment Control to require loosely woven natural fiber ECM to reduce potential wildlife entanglement.



Erosion Control Matting (ECM) and Wildlife

Temporary Erosion Control Matting (ECM) is a vital component of many environmentally responsible construction projects. ECM prevents exposed soil from eroding off of a project site while the vegetation is being established. It is generally used on slopes, installed within 48 hours of grading, and is expected to decompose within two years. However, the environmental protection provided by certain erosion control products has an unintended consequence.

The vast majority of temporary ECM used in Vermont prior to 2009 contained a plastic monofilament mesh – made of the same material as fishing line. This material presents some risks to wildlife. ECM with plastic mesh often entangles wildlife, including mammals, birds, fish, reptiles, and amphibians (Stuart et al. 2001; Barton and Kinkead 2005; Walley et. al. 2005). Wildlife Entanglement can quickly become a considerable regulatory problem if Threatened or Endangered Species are harmed.

Moreover, the plastic mesh in temporary ECM has been found intact on project sites up to 8 years after installation (Walley et. al. 2005). Because this product is photodegradable (rather than biodegradable), once the vegetation has been established on a project site, the monofilament is no longer exposed to the sun, and therefore does not disintegrate as designed. Large portions of this material remain in the ground for years, or can even break away and get transported to a new location by water or wind – similar to "ghost nets" lost from commercial fishing boats.

It is widely believed that snakes suffer the highest rate of mortality as a result of entanglement with ECM containing monofilament mesh. Snakes are unable to move backwards. Once a snake becomes stuck in the plastic mesh, it becomes hopelessly entangled as it tries to free itself. A typical escape behavior for snakes is to thrash and twist, which compounds the entanglement and causes deep cuts. Snakes trapped in netting often die of their injuries, or from prolonged exposure to the elements.

Loosely woven natural fiber ECM does not pose the same risk to wildlife, and has been used successfully in areas where Threatened or Endangered snakes are present. Additionally, it is biodegradable and will not remain on the landscape long after the vegetation has been established on a project site.

Setting the Standard for ECM in Vermont

In October of 2007, a concerned landowner contacted the Vermont Agency of Natural Resources (VANR) Non-Game and Natural Heritage Program (NGNHP) and the Vermont Agency of Transportation (VTrans) to report that nearly 50 Northern Watersnakes (*Nerodia sipedon)* (a Vermont Species of Greatest Conservation Need) were entangled in erosion control matting (ECM) on a local road project.

VTrans convened an ad-hoc interagency work-group to address the problem of wildlife entanglement in ECM. The group included representatives from the VANR NGNHP, VANR Stormwater Section, and VTrans Construction, Operations, and Program Development Divisions. The group quickly reached the consensus that it was neither practical nor desirable to review every project for potential impacts to wildlife from ECM. To achieve a more comprehensive long-term solution, an Environmental Engineer from VTrans Construction examined the feasibility of replacing *all* temporary erosion control products containing plastic mesh with loosely woven natural fiber. Wildlife-friendly ECM can do everything that monofilament matting can do on project sites that require temporary ECM – except entangle wildlife!

In the winter of 2008 VTrans re-wrote its standard specifications requiring contractors to use biodegradable natural-fiber erosion control matting on VTrans construction projects. Shortly after the re-write of the standard specification, VTrans Operations Division mandated the use of natural fiber products for temporary erosion control on routine maintenance projects. VTrans' proactive action on this issue helped chart the course for ANR to similarly rewrite the Vermont Standards and Specifications for erosion control that apply to all public and private jurisdictional construction sites in Vermont – thus achieving the sweeping change envisioned by the interagency work-group.

Multiple agencies and divisions within Vermont State Government voluntarily collaborated to solve a clear environmental challenge. Despite the different mission statements among this diverse work-group, a common vision was found, and within a few months this vision changed how we do business on construction sites in Vermont. It is anticipated that this change will result in a dramatic decrease in wildlife mortality caused by entanglement in ECM – providing an obvious stewardship benefit as well as a regulatory precaution.

Will it Cost More?

Biodegradable natural fiber ECM is slightly more expensive than ECM containing monofilament mesh. However, when the cost increase of natural fiber matting was calculated into the budget of a typical project for the sake of comparison, the increase on a $2 million project was approximately $2,500, or 0.125% of the project budget. VTrans management felt that the environmental benefits of natural fiber matting far outweighed the cost, and the VTrans Specification Committee approved the change to natural fiber matting.

VTrans Construction Environmental Engineer removing snake from monofilament ECM.


"Recycled" natural fiber ECM from the Bennington Bypass.

"The Vermont Agency of Transportation (VTrans) researched herp-friendly alternatives, and facilitated a discussion amongst highway engineers and environmental regulators that resulted in the revision of both the highway design standards, and our regulatory standards to exclude the welded-materials. VTrans' leadership on the issue affected a large number of projects in a very short period. Not only are all regulated projects, and all VTrans projects now designed with the herp-friendly alternative, EPSC (erosion prevention and sediment control) suppliers quickly switched to the alternative in order to keep up with the substantial market sector associated with highway construction projects."

- Padraic Monks, Stormwater Program Manager - Vermont Agency of Natural Resources

Acknowledgements

Mark Backus, Bristol VT; Steve Parren, VANR NGNHP; Padraic Monks, VANR Stormwater Program; William Farley P.E., Andrea Wright P.E., VTrans Construction; Gil Newbury, Craig Digiammarino, VTrans Operations; Jonathan Armstrong P.E., John Lepore, Glenn Gingras, Jeff Ramsey, VTrans Environmental; James S Andrews, Vermont Reptile and Amphibian Atlas Project.

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Fragmentation of China's Landscape by Roads and Urban Areas

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Issue: The challenge of maintaining biodiversity and ecological sustainability while accommodating an increasing population's search for economic security is perhaps nowhere as daunting as in China. a multiple natural degradation calls for improving government-driven management of environmental resources. China's major paved road-ways (national roads, provincial roads, and county roads), railways and urban development are rapidly expanding. A likely consequence of this fast-paced growth is landscape fragmentation and disruption of ecological flows. In order to provide information to planners for use in landscape conservation, there is a need to quantify the magnitude of fragmentation for road planning.

Method & Data: We used a modification of *Meff* that incorporates a "cross boundary calculation" (*Moser et al, 2007)* for the first evaluation of China's fragmentation status due to the paved roads. The province and country boundaries were downloaded from website of Environmental and Ecological Science Data Center for West China. The paved roads layers and railways were produced by digitizing hard copy map of China's national, provincial, and county roads at a 1:1,000,000 scale by using *ArcMap* module and *Raster to Vector*. Land use and land cover raster data were provided by the China Academy of Science at a 1 km2 grid cell size. We excluded most small islands from the current map due to little information available there. We used the effective-mesh-size (Meff) method to provide the first evaluation of the degree of landscape division in China caused by transportation networks. The effective mesh size tool provides one metric, we used *FRAGSTATS* (**McGarigal, 2002**) to measure a number of other indicators: total area and number of patches per patch size class and area-weighted mean shape index for 26 counties in China and 5 counties in California, both are farming areas.

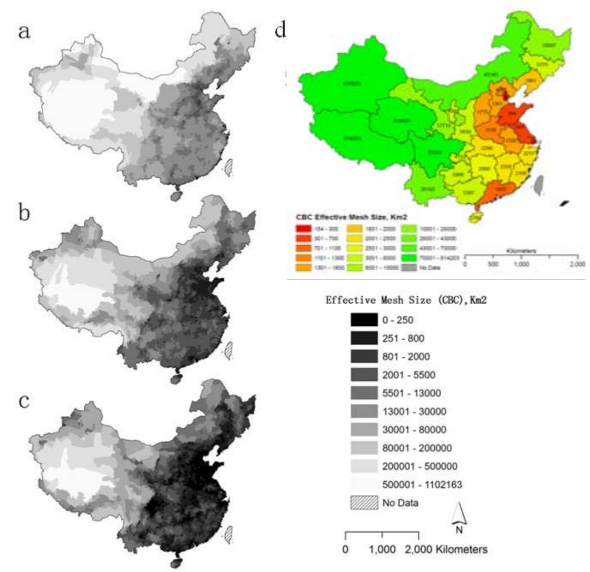


Figure 1 *China's fragmentation spatial distribution based on 3 fragmenting geometries: a) Fg1, b) Fg2, c) Fg3, the reporting unit is the county in each of the provinces. d) Province-level fragmentation.*

We found that fragmentation by major transportation systems and urban areas in China has a spatial distribution pattern, from the least-impacted west to the most impacted south and east of China with 4 tiers based on the provincial Meff. Paved roads, railroads and existing urban areas seriously affect the ecological connectivity in almost all eastern provinces and counties. Several eastern-Chinese provinces have among the most severe landscape fragmentation in the world while others are comparable to less-developed areas in Europe and California. For the province reporting units, FG3 *Meff* size varied between 30 km2 and 304,491 km2. In contrast, of 10 European countries, none has a larger paved road *Meff* than Sweden (7156 km2), while Belgium (150 km2) and the Netherlands (299 km2) are the most fragmented (***Figure 2***). Five Chinese provinces are more fragmented than any measured European Country, while eight western and northern provinces are less fragmented than the least fragmented European country. As pointed out earlier, because of the effect of reporting unit size on apparent *Meff*, these comparisons may have restricted utility (refer to ***Figure2***).

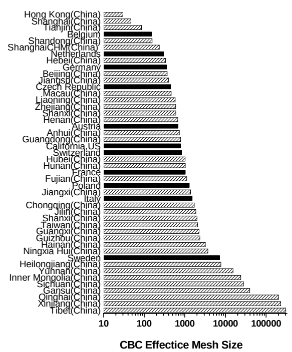


Figure 2. *Comparison between paved-road Meff for the 34 Chinese provinces, the state of California, and countries in Europe.*

We also provide a detailed analysis of fragmentation of similar-sized agricultural zones in eastern China and California's Central Valley (~23,000 km2). The California region has many more small landscape patches delineated by paved roads than the comparable region in China, but has more area in large Montana patches. China has fewer landscape patches overall, with the majority of the landscape patch area in mid-sized patches (20-1000 km2). California's landscape division by paved roads has a strong size distribution signature based on 640 acre sections (1 square mile) and their base-2 division products (e.g., 40 acres). In comparison, China has no obvious land division signature. We recommend that Chinese planners examine new decisions about further road development in the context of existing land-division patterns (Please refer to the right side **figure3**).

China's eastern landscape is heavily fragmented by paved roads, among the most fragmented regions in the world, while the western regions (e.g. Tibet and Inner Mongolia) are much less fragmented by paved roads. Many of the less fragmented areas are found in mountainous and arid and semi-arid regions of this country, while greater fragmentation was found in eastern and central agricultural and urban areas. Detailed landscape analysis of one agricultural region in China revealed that fragmentation by paved roads may not be as severe as in a comparable area in California.

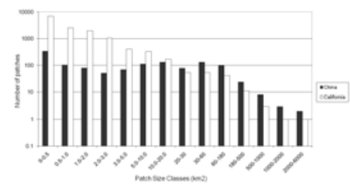


Figure 3a The frequency distribution of patches by size class for China and California agricultural areas.

In the Chinese study area, the largest proportion of patches (28% of 1228) were in the smallest size class (0 to 0.5 km2), with a fairly flat distribution of number of patches from 0.5 km2 to 180 km2 (**Fig. 3a**). There was a rapid decline in number of patches greater than 180 km2, and only two patches greater than 2000 km2. The majority of patch area was in the 50 to 6,000 km2 size classes, with a peak in the 60 to 180 km2 size class (**Figure 3b**). The area-weighted mean shape index that indicates how convoluted patches are, increased steadily with size class, from 1.4 (1 to 2 km2) to 4.9 (2000 to 6000 km2).

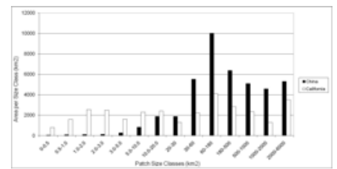
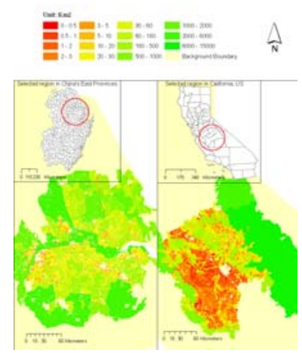


Figure 3b The distribution of patch area by patch size class for Chir



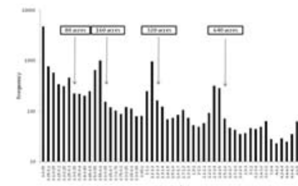


Figure 3c Frequency of landscape patches across patch-size classes in California compared to 640, 320, 160, and 80 acres. The y-axis is log scale. Arrows indicate approximate locations of these standard values, which may be slightly greater than the evident peaks because roads were buffered, removing parts of the intervening patch.

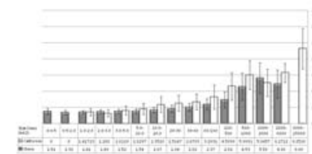


Figure 3d. Area-weighted Mean Shape Index in patch size classes for China and California. The bars indicate the mean shape index and the error bars indicate one standard deviation. Bars are absent from patch size classes <1 km2 because the sheer number of patches made calculation of the shape index prohibitive. No bar is present for China in the 6000-10000 km2 size class because no patches were that large.

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A Conceptual Framework for Assessing Barrier Effects to Wildlife Populations Using Species Group Responses to Traffic Volume

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Introduction

While studies indicate that traffic volume can be a useful tool for predicting impacts to wildlife populations, investigators have been hampered in their ability to use traffic volume predictively because responses among wildlife taxa vary widely. This paper proposes a conceptual framework that summarizes four general responses to increasing traffic volume. Understanding the response category of target species in a project development area enables project planners to better determine the likelihood of current or future impacts as well as appropriate mitigation measures. The objectives of this study were to investigate the role of wildlife behavioral responses to highway traffic volume as a predictive tool to determine barrier effects, to organize these responses in a conceptual framework, and to provide an early warning system that recognizes the rate of traffic volume growth as a trigger for mitigation.

Why Use Traffic Volume?

Traffic volume is a particularly useful metric because it is the basic unit of information used by transportation planners. Traffic volume data has been collected continuously since 1945 through the Highway Performance Maintenance System, which provides a generally uniform, consistent, statistically valid, and credible national level database built from State-provided data.

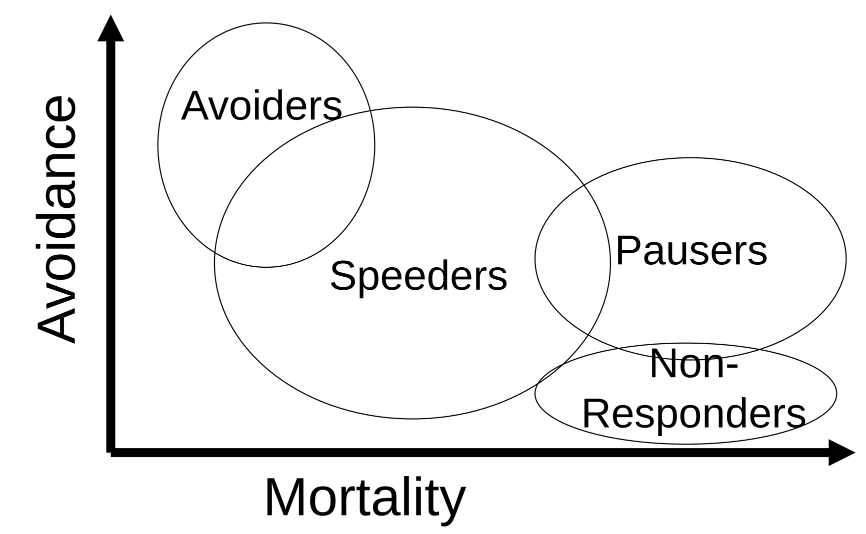
Highways as Barriers

Two highway-related impacts to wildlife are vehicle-caused mortality and movement barriers. Highways can cause barrier effects without mortality because some species will avoid the highway as traffic volume increases (Jaeger et al. 2005). For most terrestrial species, at a threshold volume, highways will become a complete barrier to movement because their probability of successfully crossing is zero due to the risk of mortality, even if a lack of behavioral constraints allows them to continue to attempt crossing. Barriers to animal movement are the focus of this paper.

Traffic volume is a good predictor of adverse effects to wildlife movement (Hels and Buchwald 2001, Trombulak and Frissell 2000). Combined with a framework of behavioral responses to traffic volume by wildlife, quantitative metrics can be better interpreted.

Four General Responses

The four response categories are: **Non-Responders, Pausers, Speeders,** and **Avoiders**. Barrier effects are primarily caused by mortality in the first two types and primarily caused by avoidance behaviors in the second two types. This concept does not apply to species that avoid the surface of the road due to its physical characteristics such as a lack of cover or hostile surface. While not all individuals in a population will react the same way, a high proportion of them will do so based on their sensory capabilities and behavioral responses to danger.

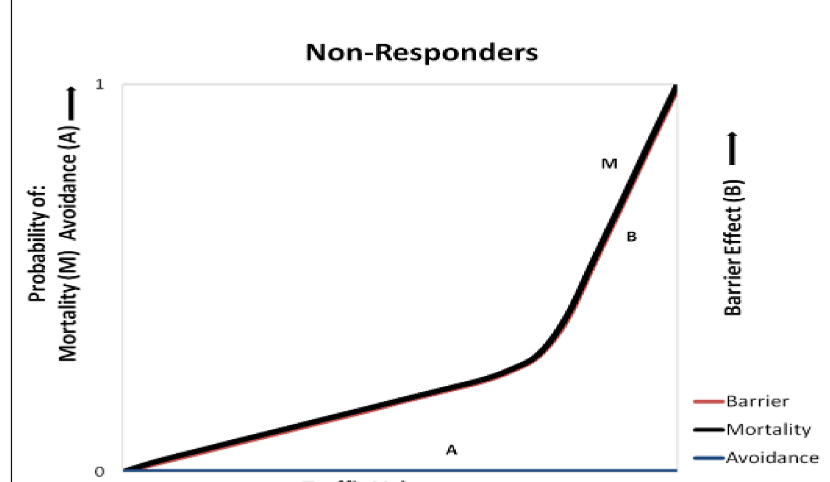


Responses to traffic volume do not fall cleanly along taxonomic lines.

Non-Responders

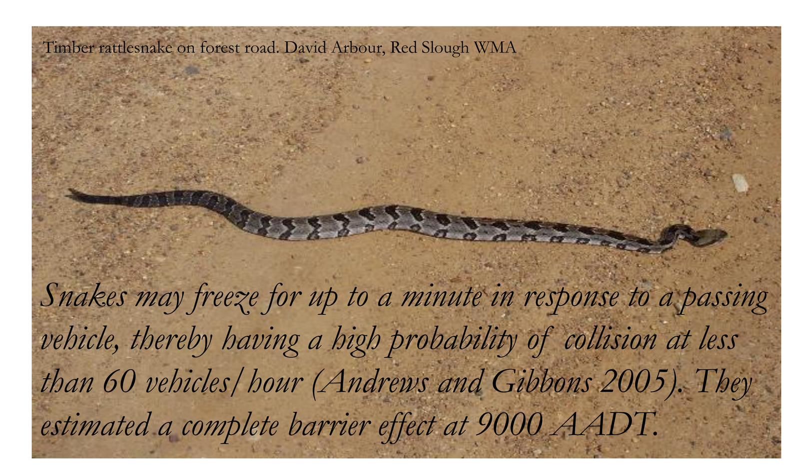
Non-Responders are characterized by a failure to detect or avoid lethal traffic, and continue regardless of traffic volume. This group is exemplified by invertebrates or lower vertebrates such as frogs or some snakes. As traffic volume increases, the probability of successfully crossing approaches zero, thus creating a complete barrier. The shape of the graph essentially follows the traffic flow model (Hels and Buchwald 2001; Van Langevelde and Jaarsma 2005). Non-Responders are at risk of having populations reduced through kill out as well as fragmentation effects.

Non-Responders are as diverse as this Oregon Silverspot Butterfly, endangered partly due to disproportionate vehicle-caused mortality of egg-depositing females, or frogs intent on breeding season movements.

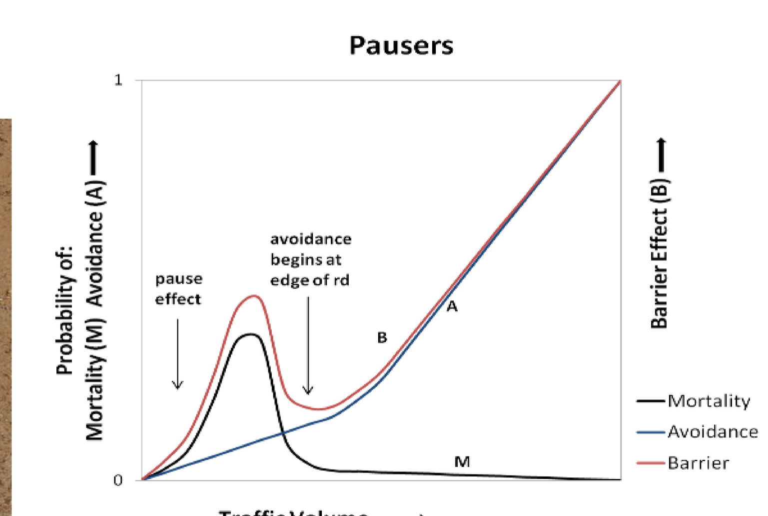


Pausers

Pausers can detect danger as traffic volume increases, but because the response is to stop in the face of danger, their risk of mortality increases with exposure such that the probability of successful crossing is nearly zero as traffic volume increases. Pausers include a variety of taxa in all vertebrate classes that exhibit responses such as crypsis, thanatosis, coiling in snakes, and simply stopping. Pausers are abundantly represented as roadkill, and include such common examples as skunks, porcupines, armadillos, and turtles. Complete barrier effects as traffic volume increases are both the result of high mortality as animals stop in the traffic lane, and can also be the result of avoidance at the edge of the road.

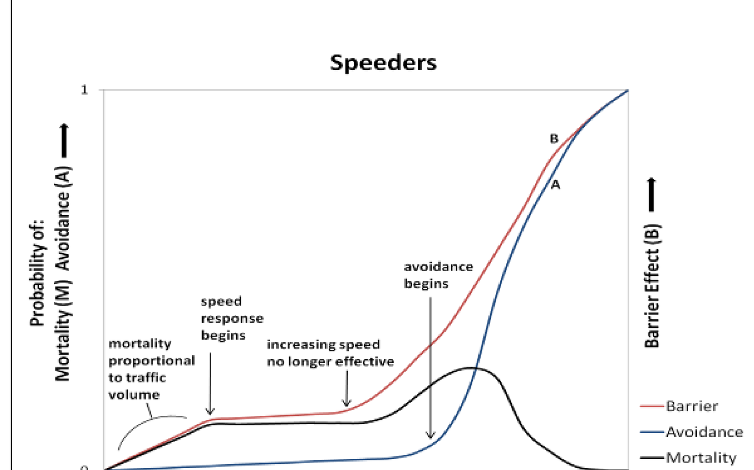


Snakes may freeze for up to a minute in response to a passing vehicle, thereby having a high probability of collision at less than 60 vehicles/hour (Andrews and Gibbons 2005). They estimated a complete barrier effect at 9000 AADT.



Speeders

Speeders flee from perceived danger with increased speed. Speeders can reduce the barrier effects of traffic volume increases by increasing their speed to exploit traffic gaps, but as traffic volume increases and gap distance decreases, the probability of successfully running gaps decreases. Speeders include deer, pronghorn, and rapidly-moving snakes. Barrier effects manifest at higher traffic volume levels than the previous two groups because this group can respond with behavior that reduces mortality risk, but barrier effects do occur both as a result of mortality and ultimately avoidance of the road. Most ungulates would be characterized as speeders, and barrier effects as these more intelligent animals choose to avoid certain death manifest as increased avoidance.

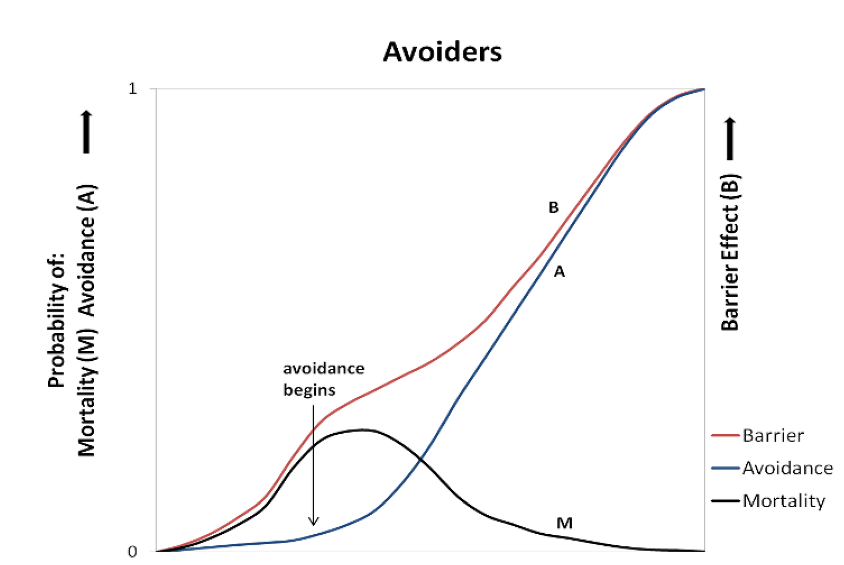


Radio-collared elk studies have shown that the most dangerous day for elk/vehicle collisions on the Tonto NF's highway SR260 is Monday when AADT is 35% lower than on weekends, as elk begin to move again after the weekend avoidance (Dodd et al 2006). Elk have a very high probability of successfully crossing highways because they move rapidly.

Avoiders

Avoiders avoid crossing attempts at fairly low traffic volume. They may modify their temporal behavior to avoid higher traffic volume periods of the day, thus effectively crossing only at lower traffic volume. This group has the lowest mortality rates because they recognize vehicles as dangerous. This group is exemplified by wary and intelligent species such as grizzly bears (*Ursus arctos*) and black bears (*Ursus americanus*). Barrier effects as traffic volume increases occur mostly through avoidance instead of mortality.

Intelligent bears run from danger, but learn to avoid traffic by modifying their activities. When that no longer works, they avoid crossing (Waller et al. 2006).



Implications

Understanding the response of various groups helps to identify and prioritize highway impacts to populations. This conceptual framework suggests that:

1. Some species are far more vulnerable at low traffic volume than others,
2. Vulnerability varies over time from mortality effects to barrier effects,
3. It may be important to mitigate mortality effects on moderate traffic volume highways,
4. Carcass data must be interpreted carefully to avoid interpreting lack of mortality as evidence of lack of a connectivity issue,
5. As traffic volume increases, mortality may be so severe in Non-Responders and Pausers that local populations are wiped out, so decreased evidence of roadkill may signal an advanced problem rather than a lack of problem,
6. As traffic volume increases, safety issues from animal/vehicle collisions may decrease with Speeders and Avoiders, thus reducing the need for DOTs to mitigate collisions, but not solving the natural resource issues,
7. Varying responses by species suggests that highways function as behavioral filters as well as mortality filters, and the rates of both vary with traffic volume.

If empirically confirmed for several species, traffic volume can be useful as an early warning trigger for DOTs and resource managers.
Future research might beneficially illuminate the approximate mortality and avoidance thresholds by species.

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Washington State Department of Transportation

INTERSTATE 90

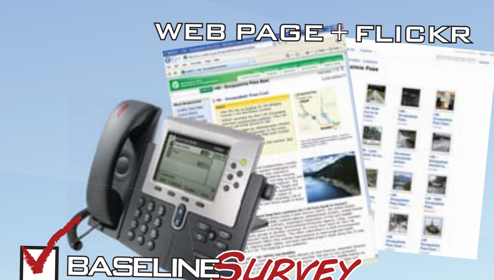
I-90 Snoqualmie Pass East
Hyak to Easton Project

METROPOLITON AGRICULTURAL

Planning for Change

WSDOT's adaptive approach to communicating about the I-90 Snoqualmie Pass East Project with diverse groups

The I-90 Snoqualmie Pass East Project has far-reaching statewide economic, social, and environmental benefits. However, because of its rural location, we did not have a ready made audience to communicate with in the project's backyard. In July 2007, we conducted a baseline survey and found that 84 percent did not know about the project. We developed specific communications strategies which included using reader-friendly writing, reaching audiences directly with our Web site, and presenting the project visually.



WEB & PHONE SURVEY

PRINTED MATERIALS

Throughout the public education process, we developed materials with consistent formats that presented project information in clear, understandable terms. We developed several information portfolios and a children's activity book featuring "Burl the Squirrel." These tools helped WSDOT reach and educate diverse audiences, from children to elected officials.

These innovative communications strategies have been extremely effective, generating hundreds of stories in both print and broadcast media and contributing to over 50 presentations at different fairs, festivals and events across the state in 2008.

Not only do we meet face-to-face with people around the state, we used the web site to host an online open house enabling instant two-way discussions between WSDOT project managers and the public.

OUTREACH TO THE PUBLIC

VISUAL CONCEPTS

Another communication strategy was to present the project visually. Due to the remote location and complexity of the I-90 Project, we determined that design visualization videos were the best way to visually present the project to the public. These 3-D animations of the proposed project helped us and the media explain the complexity of the project to the public.

Developing a State Wildlife Roadkill Identification Guide

Improving forensic data collection when monitoring wildlife mortality on state roads and highways.

Introduction

Globally, transportation agencies are making increasingly larger and more comprehensive infrastructure investments to protect wildlife as part of their planning and design processes. State transportation agency decisions to support the wildlife protection investments are often based on historic roadkilled wildlife data collected by state natural resource and/or transportation agency staff or contractors.

Reliable roadkilled wildlife reporting requires three fundamental components: geographic location, date, and species. Location can be obtained from GPS devices and physical marking systems and date can be obtained from a calendar. However, accurate species identification is dependent on the personal knowledge of those handling roadkilled wildlife and completing roadkill reports.

If roadkilled species are inaccurately identified, then the value of the data of wildlife mortality reporting systems for species-specific wildlife protection initiatives may be severely compromised. The major factor limiting accurate species identification by transportation agencies appears to be the lack of wildlife forensics training for their staff and contractors.

Supporting State Wildlife Protection Investments

As state transportation and natural resource agencies continue to make increasingly larger investments to protect wildlife, there is a greater need for the information used to support and direct these investments to be accurate. If roadkilled wildlife species are inaccurately identified, then any use of the data for state species-specific wildlife collision reduction initiatives may be severely compromised. With improved roadkill reporting, state agencies could avoid the possibility of spending tax dollars developing mitigation for the wrong species of wildlife.

State Wildlife Roadkill Identification Guides

It appears only two wildlife roadkill identification guides have been published by state agencies. In 1995, the first guide was produced by the Dienst Weg-en Waterbouwkunde Rijkswaterstaat (The Road and Hydraulic Engineering Department) in the Netherlands. *"Dieren op en langs de weg" ("Animals on and along the road")* provided comprehensive information on 110 species of amphibians, birds, reptiles, and mammals. The guide was developed to assist department road inspectors reporting wildlife road mortality throughout the Netherlands. In 2008, the first wildlife roadkill identification guide produced by a state agency in North America was published by the British Columbia Ministry of Transportation (BCMoT) in Canada. BCMoT's *"Wildlife Roadkill Identification Guide"* focused on thirteen of the most common large carnivores and ungulates found in British Columbia. The guide was developed to assist the Ministry's private maintenance contractors in identifying wildlife carcasses found on provincial highways as part of their responsibilities for BCMoT's Wildlife Accident Reporting System (WARS).

Fundamentals for Accurate Roadkill Monitoring

There are three essential pieces of information necessary for accurate and reliable reporting of roadkilled wildlife. These are:

1. *Geographic location*
2. *Date*
3. *Species*

Location and date can be determined using a GPS device and a calendar. However, accurate species identification is very dependent on personal knowledge and experience. Where personal knowledge and experience are lacking, identification can be improved with the use of a comprehensive guide.

Roadkill Subculture

Roadkilled wildlife has been the object of ridicule in the public press and popular media for many years. Everything from cookbooks to computer games have been created using roadkilled wildlife.

It is within this social and cultural context that any state guide for identifying roadkilled wildlife is developed. The British Columbia Ministry of Transportation guide was specifically called the *"Wildlife Roadkill Identification Guide"* to avoid any misunderstanding about the purpose of the document. As an official state document, the guide was designed to be completely utilitarian in title and content.

Things to Consider

Species

Most states have many different species of wildlife. Some species of wildlife are common while others are rare and endangered. In addition, some species are more prone to road and highway-related mortality than other species. When developing a wildlife roadkill identification guide, it can be challenging trying to determine if the guide should be limited to a few common species of wildlife, or be comprehensive and include as many species of wildlife as possible.

The basic information required to identify a wild animal can be presented using the following four subjects:

1. ***Appearance and size***
2. ***Life history***
3. ***Abundance and distribution***
4. ***Characteristic features***

Information Sources

There are many good books available for identifying virtually all species of wildlife. Museums throughout the world , like the Smithsonian Institution, publish excellent books on wildlife. The wildlife divisions of state natural resource agencies have invaluable expertise on local species and their geographic distributions.

Photography Sources

Photographs are a key element for any wildlife identification guide. Some of the finest, freely available, collections of wildlife photography have been assembled by state and federal agencies in the United States. The United States National Park Service (USNPS) has one of the best collections of wildlife photographs in the world. The USNPS collection is available without copyright restrictions for state agency use. Wikipedia, and other similar Internet information websites can be good sources of photographs. There are also a number of Internet-based commercial photograph merchants that can provide good quality wildlife photographs.

The assembly of wildlife photography can be problematic if the species involved are rare or endangered. Species rarely sighted are rarely photographed. Consequently, the available stock of photographs of rare and endangered species is very limited. In the absence of photographs, detailed realistic drawings may be substituted.

Public Sensitivities

Photographs of roadkilled wildlife can be extremely graphic. For experienced wildlife biologists, these photographs may be considered as factual representations of the adverse consequences of wildlife-motor vehicle interactions. For the general public, the same photographs may be considered repugnant and disturbing. More seriously, children, who idealize and are endeared to wildlife, can be traumatized by these photographs. State agencies considering producing a roadkill guide must be very aware of public sensitivities.

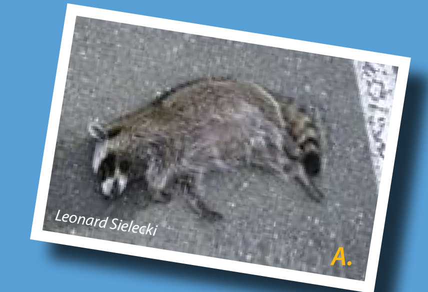
Agency Needs

It is important to understand the needs of agency personnel. An Internet-based guide may be impractical for field staff in remote locations. A large paper document may be unwieldy for use in a truck or car. A guide produced with plastic laminated pages and sized to fit in a glove compartment or coat pocket has the greatest potential to be accepted and used by field staff. When the Dienst Weg-en Waterbouwkunde Rijkswaterstaat (The Road and Hydraulic Engineering Department) in the Netherlands developed its guide "Dieren op en langs de weg" ("Animals on and along the road"), the guide was specifically designed to fit in the pockets of the uniforms of its road inspectors .

Carcass Handling Advisories

Examining the carcasses of dead wildlife has inherent health risks. Whether it be infection or injury as a result of inadequate personal protection, the consequences can be dire, ranging from serious long-term health problems to death. It is essential to include an advisory so that personnel who deal with dead wildlife know how to protect themselves.

Roadkill Quiz



Quiz answers: A. raccoon B. squirrel C. skunk D. fox E. opossum F. moose

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'Adapting to Change' is the timely theme of our 2009 conference program. Now more than ever, our transportation systems and ecosystems need to be addressed in the contexts of global climate change, shifts in funding and priorities, and evolving environmental and transportation policies. The interaction between transportation infrastructure and natural systems requires increasingly interdisciplinary, integrated approaches to planning, building, maintaining and monitoring. ICOET 2009 focuses on the challenges faced, and solutions found, as we adapt to emerging changes in ecology and transportation.

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