2012

Vermont's Best Management Practices for Highways & Wildlife Connectivity

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Preface

We anticipate this manual will be used for transportation planning, operations and maintenance, and monitoring and research related to wildlife, ecological systems with respect to transportation systems. Best Management Practices (BMPs) described in this guide should be included in the evaluation, design, construction, operations, maintenance, and monitoring of transportation projects and facilities. The manual is organized into 3 main sections: 1) planning, 2) design and construction, and 3) operations, maintenance, and monitoring. The sections show steps, procedures, and examples of how to address various issues dealing with ecosystems, wildlife, and transportation. Think of this manual as a step by step process or checklist of how to plan and manage roadways for increased wildlife connectivity. The practices included here could become part of the regulatory – best management practices of planning, daily operations, construction, and research phases of transportation.

Manual Preparation

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A. Executive Summary

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A. Executive Summary

This Manual provides guidance to planning, project design and construction, and operations and maintenance on ways that wildlife interactions with the highway transportation system can be improved. The Best Management Practices (BMPs) described are derived from the scientific and technical literature and are the ones most likely to be effective in Vermont, especially in combination with planned improvements for flood resiliency. The guidance is intended to solve identified problems with wildlife movement and connectivity using proven and testable methods. Implementing these BMPs won't solve all transportation impacts to wildlife, but it will help improve conditions for both wildlife populations and driver-safety.

The Problem

Wildlife need to move. Ecosystems need interactions to be resilient. Transportation needs to consider not just the wildlife in the vehicle collisions, but the entire, interacting ecosystems bisected by roads and highways.

The Solution

Best management practices are the combination of management behaviors and infrastructure solutions. For transportation systems, there is a wide range of viable solutions for reducing wildlife impacts. These include traffic calming, signs, wildlife under-crossings and over-crossings, driver education, and fencing to control access to the right-of-way. Different management actions can be implemented at different phases in planning and operations. For example, it is less expensive to plan in advance for wildlife passage than retrofit existing highways with new structures, including for flood resiliency, so planning new projects can incorporate structural modifications to facilitate wildlife passage. Existing infrastructure may pose a barrier or an opportunity for wildlife passage (e.g., culverts), depending on how they are maintained and whether or not they have features that enable passage. Existing infrastructure may pose barriers to wildlife movement, but can be retrofit to create opportunities for wildlife to pass under roadways.

Background on Wildlife Movement & Connectivity and Conflict with Roads & Highways

Maintaining wildlife populations in the face of human development involves not only conserving lands and populations of different species, but also protecting and aiding the natural interactions and processes that make up ecosystems (Soulé et al., 2005). Natural communities and their essential interactions are important to conservation of ecosystems (Keith 2009) and are important to maintaining resilient systems that can adapt to human changes at the local scale and potentially the global climate change scale (Gunderson 2000).

Interactions within ecosystems often involve movement across distances that can be disrupted by transportation systems. Water flow, wildlife movement to critical habitats, seed dispersal, and other processes are often dependent on the ability of these movements to move under and over roads that often impede their passage. In the case of wildlife, many species can move large distances across wild and semi-developed landscapes, where they encounter roads and highways at varying rates, depending on the species. Individual animals can be repelled from the roadway due to traffic, noise, pollutants, or the lack of passage opportunities under the road, they can be killed in vehicle collisions, or they can successful make it across the road. When animals are killed, it is not just the individual that suffers, but its entire population may be put at risk from multiple members being lost to vehicle collisions. Managing transportation systems with the realization that it is not just vehicle collisions that should be taken into account but entire ecosystems necessitates the understanding of these interactions over larger scales than transportation corridors.

Transportation planning and project development can begin to take wildlife movement into account by looking at wildlife movement at two levels:

> 1) Wildlife movement across regions: At the scale of the state, or of Regional Planning Commission (RPC) areas, different populations of the same and different species must interact for long term species' survival. Meta-populations are smaller more isolated populations of the same species that must interact with one another in order to replenish numbers in areas where the populations cannot persist in isolation. These meta-populations often must cross roads to access one another. In turn, predator and prey populations interact with one another over larger distances than individual populations would indicate. The long term and everyday planning and maintenance of transportation networks need to consider these region- and state-wide scale interactions in order to maintain these species and the ecosystems they depend upon. This approach is typically addressed at a more coarse scale of long term, state-wide planning.

2) Daily and migratory movement across road corridors: All wildlife move daily to forage, find water, escape predators, seek shade, look for mates, give birth or lay eggs, raise young, and to disperse. Larger animals and predators in general tend to move longer distances than smaller animals. This brings them into contact with more roads. If there is a biological imperative to cross a road, most species will do so, regardless of risk. Certain species may not cross and actually may have an aversion to roads. This movement and aversion reaction is at the scale of the individual animal and road segment and it is at this local scale that the problem can be addressed, Transportation planning and maintenance at this more fine scale level can be approached at the project level

Connectivity

Wildlife movement across the landscape is typically addressed in defining the connectivity of an area or region. Connectivity is an ecological term that is increasingly used in transportation planning and operations. Landscape connectivity refers to how much wildlife movement (and other ecological processes) can occur on a landscape. This connectivity is also defined by the species of interest. Connectivity can be defined by water, such as aquatic connectivity (referring to waterways and aquatic organism movement) trophic connectivity (referring to connections between predators and prey), and by physical landscape connectivity available to different types of animals. For instance, connectivity for moose is much different than that for turtles. Landscape, aquatic, and trophic connectivity are the types of connectivity most relevant to transportation. Connectivity is part of every landscape, with varying degrees. Connectivity has always existed in natural landscapes. What we often seek to protect or restore in conservation planning today is the connectivity remaining as humans have dominated the landscape.

In July 2007, Washington State Secretary of Transportation Douglas MacDonald signed Executive Order 1031 'Protections and Connections for High Quality Natural Habitats', which directs the agency to protect ecosystem health and preservation of biodiversity through the road and highways programs. This order directs Washington Department of Transportation (WSDOT) to protect aquatic and terrestrial connectivity for fish and wildlife. As part of WSDOT's actions to fulfill this order, WSDOT and its partners in the Washington Wildlife Habitat Connectivity Working Group released the statewide Washington Wildlife Habitat Connectivity Analysis (WWHCWG 2010). This document provides maps based on scientific analyses of how 16 target species of wildlife may need to move across the state through connected networks and where the most intact connected landscapes occur throughout the state. This connectivity assessment will influence road corridor plans and highway improvement projects, and will help to prioritize highway segments for wildlife-friendly improvements.

The term "wildlife corridor" refers to narrow zones of movement that certain animals may use to travel on the landscape. For example, pronghorn in the Great Basin and grizzly bear and elk herds in the Rockies may use approximately the same migratory paths year after year. For most animals in Vermont and most of the country, wildlife corridors only occur on paper. The majority of animals will move opportunistically across landscapes, avoiding barriers and preferring habitat that serves their cover, forage, and other needs. Connectivity is truly made of a matrix of land and water that has varying degrees of naturalness remaining that can accommodate movement of different species of wildlife. For instance, in a Vermont landscape of natural forests, streams, agriculture, and low density housing, moose, black bear, porcupines, and turtles will find varying levels of connectivity for their daily, migratory, and dispersal movements across the entire landscape.

With this in mind, connectivity can be thought of as an ecological property that occurs and can be managed for on most landscapes in Vermont. Roads and highways disrupt connectivity in ways that can be both obviously harmful to animals (when cars collide with them) as well as less obviously (when animals avoid roads and populations become separated). Informed with the science of wildlife ecology and landscape connectivity, and the lessons learned on how to promote both in transportation, it is possible to minimize some of the fragmentary effects of transportation on wildlife connectivity.

Goal and Outline of Manual

The intent of this Manual is to develop and implement ways to solve some of the connectivity problems caused by highways and their use. Today's transportation professionals have an important stewardship role in this regard. They can both repair broken connections from historical transportation decision-making and reduce the harm to connectivity from future decisions. The manual gives example of how this has been done in Vermont, the Northeast United States, and across the United States (see box below). It focuses both on how to prioritize areas for remedial actions, as well as how to improve wildlife movement during routine operations and maintenance of transportation infrastructure. The approaches here are compatible with highway retrofit approaches considered for improving flood resiliency.

In Section B of the Manual, the step-by-step processes of decisions (BMPs) involved in planning for wildlife and then maintaining connectivity are described. Section C describes the design and construction of facilities to improve wildlife crossing of the right-of-way. Section D gives BMP solutions for operations, maintenance, and monitoring. Also in this section research protocols and suggestions are given in order for users to best monitor

BMP effectiveness and to use the results in future decisions. Section F, the technical appendices include more detail for each of the sections as well as an extensive annotated bibliography. Throughout the manual there are story boxes that give clarity to the text, based on activities in Vermont. An overview of the BMP's pertinent to the stages of planning, project selection and design, and Maintenance and Operations is presented in Table 1.

Decision-support for resolving wildlife-vehicle conflicts

Decision-making consists of having a goal in mind, collecting information to make an appropriate decision, developing alternatives, selecting an alternative, and evaluating the outcome of the decision in order to make better decisions later. Best management practices to reduce transportation impacts to wildlife are based on robust decision-making, where the various phases of transportation planning, programming, design, construction, operations, maintenance, and monitoring are adequately funded and include in an adaptively-managed and sustainable transportation system.

The diagram below shows a possible flow of decision-making from planning through construction, operations & maintenance, and adaptive management of the transportation system. The assumption with this flow diagram is that wildlife movement will be intentionally planned-for in various steps of transportation system management. It is not necessary to begin with planning in this decision-process, one could just as easily begin with operations and maintenance. However, a cycle of practice and learning is assumed to contribute to more sustainable management of the system.

Beginning with Planning, there are two primary phases: regional planning and local planning. At the region scale, general assumptions may be made about disturbance, connectivity, and wildlife movement that may or may not be accurate. This could lead to identifying specific roads or road segments as priorities for BMPs to improve wildlife movement. However, in a relatively undisturbed landscape like Vermont's, it is likely that most roads and highways would benefit from improvements for wildlife movement.

Once roadways are prioritized, then specific actions can be designed, including modification and construction of structures providing wildlife passage across the right-of-way. These could either be stand-alone projects, or included as mitigation as part of transportation projects. In the latter case, reference to the BMPs could be included in bid documents to contractors to ensure that they are integrated into project design and budgeting.

Traffic operations are a critical feature of managing impacts to wildlife, managing traffic speeds and driver education may be critical features of a plan to reduce impacts to wildlife. Maintenance and modest enhancements of culverts and bridges to improve wildlife movement is also important. A combination of assessment of potential traversability of the areas within or under structures and monitoring of actual use of the openings should help prioritize where actions may be the most effective.

Adaptive management – monitoring and learning from past actions, can tie BMPs back to new decisions to improve wildlife movement and connectivity.

Table 1 Summary of BMP planning and implementation steps, tools, and locations in the Manual.

Step	Action	What to Use	Section in Manual
Section B: Planning Regional Scale Local Scale	ID areas of concern ID roadway segments with wildlife movement concerns ID roadway segments with high AVCs ID target species and associated Species Movement Guilds Research stage as well – monitor efforts to see if they meet objectives	STIP, local projects Wildlife Connectivity Reports & Plans Animal-Vehicle-Collision (AVC) carcass database Agencies identified species and areas of concern Check WIERS, Use PAS Work with VTF&W Create plan- mitigation or retrofit	Background - B.1b Connectivity Assessment in Vermont - B.1.d Exact Steps for Regional Scale – B.2 Exact Steps for Local Scale - B.3 Monitoring & Adaptive Mgt – B.5 WEIRS reporting – D.2.b Passage Enhancement Toolbox – Appendix 4
Section C: Project Selection and Design	Minimize footprint Maintain and promote connectivity w/infrastructure – enhance existing structures Build new wildlife crossings Control wildlife access to right-of-way Monitoring data informs actions for change, performance measures On the ground input	RFP instructions for contractors Construction guidelines for VTrans and contractors BMP bars for success for consultants, contractors Adaptive Management - Bring together monitoring data, AVC carcass data, new connectivity information, decide what is effective, what needs improvement	Enhance existing structures – C.1 Build new wildlife crossings - C.2 Control wildlife access to right-of-way – C.3 Performance Measures – D.3.c
Section D: Maintenance and Operations	Driver-based solutions Maintain mitigation to improve wildlife use: Clean culverts, fix fencing, report on what needs to be changed, fixed, maintained	WIERS for reporting maintenance Passage Enhancement Toolbox	Driver-based solutions – D.1 Improving Wildlife use – D.2.a WEIRS reporting – D.2.b Passage Enhancement Toolbox – Appendix 4

Best Management Practices to reduce transportation impacts on wildlife movement

The Manual describes the best approaches that VTrans can implement to reduce conflict between wildlife and highway infrastructure and traffic. The list below summarizes the BMPs within each section in the Manual.

Planning (Section B)

1. Plan for a low-impact network of roads and highways, using existing, enhanced, and new structures to facilitate animal movement across the right of way.

2. Identify species and species movement groups and planning/programming options that can be used to plan for and program remedial actions to improve wildlife movement.

3. Establish working partnerships with state and federal wildlife agencies, regional and local planning bodies, and local and statewide conservation organizations.

4. a) Identify areas of the state and segments of highway to protect movement where collisions with many species, or certain species in particular, has been measured to be significantly greater than other areas. b) Identify areas and segments of highway to restore movement where wildlife movement may not be apparent, but wildlife are present on either sides of rights-of-way.

5. Use GIS models to prioritize highway segments for wildlife movement actions, such as from the Staying Connected Initiative, when the models have been validated or created using field measurements of wildlife occupancy and movement.

6. Monitor effectiveness of remedial actions taken to protect or restore wildlife movement using field techniques (e.g., GPS collars, wildlife cameras, tracking), in order to improve future decisions and actions.

Project Design and Construction (Section C)

1. Focus on existing structures. Maintain openings and enhance culverts and bridge-underpasses to facilitate wildlife movement. For example, add appropriately sized and textured wildlife ledges and sidewalks through the structure.

2. During structural improvements for flood resiliency, co-benefits can be achieved for wildlife movement through simple and inexpensive design features, such as larger passages, vegetation maintenance, and more frequent structures.

3. When replacing culverts and bridges, make sure the structure provides light and line-of-sight to encourage wildlife passage.

4. Placement and size of new wildlife crossings should be tied to information about the adequacy of existing structures in providing opportunistic wildlife crossing.

5. Placement, frequency and size of wildlife crossing are closely tied together. Crossings for smaller animals are needed at more frequent intervals along highways than for larger animals; similarly, smaller animals need more accessible and smaller structures than larger animals.

6. Crossing structures should usually be accompanied by fencing that directs animals to the structure in order to be effective.

7. Crossing structures and associated fencing must be maintained to be effective.

8. Wildlife should be able to see the other end of a crossing structure for it to be generally effective. For very long crossings (> 50 yards), lighting at mid-way will tend to improve wildlife passage.

Operations and Maintenance (Section D)

1. Signs warning of wildlife crossing should include flashing lights and be periodically moved to garner attention.

2. Vehicle speed is a very important factor in wildlife-vehicle collisions, establish effective speed management in areas known to be critical for wildlife crossing.

3. Establish a long-term program to educate existing and new drivers about the importance of watching out for wildlife and reducing speed in wildlife movement areas.

4. Maintenance crews can play a critical role in wildlife passage by ensuring that maintenance actions are carried out and are consistent with wildlife needs.

5. Establish a record-keeping system for infrastructure maintenance to benefit wildlife passage.

6. Establish a performance-measurement system for wildlife passage through existing and new structures and across signed, or speed-managed rights-of-way.

Flood Resiliency and Wildlife Movement Best Management Practices

Recovery from Tropical Storm Irene has posed a variety of procedural, funding and construction issues for Vermont. It also has brought flood resiliency to the fore and created an opportunity to re-build a transportation system that is resilient to changing rates of large storms and other impacts of climate change.

One of the biggest and over-riding problems has been the requirement attached to federal emergency repair funding that the impacted culverts, bridges, and road segments be re-built identical to the original structure. In many cases, this requirement results in re-building stream-passage facilities that were apparently under-sized for large storm events. The risk from doing this is in repeating the damages from Irene when (not if) other large storms pass across the state.

The Manual includes approaches for repairing and re-building highways impacted by Irene, as well as other highways, with the goal of a transportation system that is more resilient to climate change and more effectively passes wildlife. It is consistent with the findings and recommended future steps in the recent Irene Recovery Report (AOT, 2012).

B. Regional and Project Planning

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B. Regional and Project Planning

Outline: This section discusses planning the highway system for wildlife connectivity. Local and regional scale analysis is discussed, as well as the role of information about wildlife observations, wildlife movement, and GIS models. Finally, conservation partnerships are discussed as a useful approach to improving connectivity.

B.1 Planning for Connectivity

This section describes the recommended set of practices for VTrans to take to reduce impacts of highway systems to wildlife and to improve public safety, which is often put at risk during collisions with wildlife. Development of this section was informed both by recognition that budgets are tight and by recent flooding in Vermont. Both factors affected culverts and bridges. The flooding provides an opportunity to retrofit these facilities to both pass water from increasingly-frequent large storms and improve wildlife movement beneath the road/highway surface.

B.1.a Planning Best Management Practices

The section begins with a discussion of the role of Planning in improving connectivity and wildlife movement at corridor to regional scales. It then describes the nexus between Planning and other transportation divisions and with outside organizations as part of wildlife conservation partnerships. It provides suggested actions and references on how to implement those actions to achieve an understanding of the overall wildlife issues and at a finer scale planning such as with a project. After planning best management practices (BMPs), the actions best addressed during the construction phase of the planning process are presented. Following the construction section, the BMP's that are best implemented during the operations and maintenance process are presented. Because these are conducted post-construction, the monitoring and research methods are also presented here, although monitoring is something that must be planned for and begun pre-construction. There are many instances where actions overlap these different phases of transportation planning; thus, BMP's are presented once in the most appropriate section, and cross referenced in other sections, as needed.

What Are People Saying? How We Can Help Wildlife Move

Stream corridors are natural funnels. A lot of animals use riparian corridors. Many culverts barely contain the stream flow, much less passage area for these associated species, and these may be hazardous crossing areas for wildlife. Other elements that funnel wildlife are wetland edge, and cover. Areas of cover on both sides of a road with little cover elsewhere around are likely to be used more frequently for road crossings than areas with no contiguous cover.

Look at the landscape – is it natural habitat (woods coming down to the road on both sides) or cleared lots on both sides?

What's in the cover – dogs, people, noise will dissuade use of an area by wildlife. Different species have different levels of comfort with human activity.

- Bobcats like riparian corridors. They use the hollow between 2 hills, often follow ravines.
- Otters and mink are closely tied to riparian areas. Fisher use riparian pathways, possibly for foraging and travel, in addition to other habitats.
- Red foxes are fine with grassland/field cover—they like to hunt in fields.
- Some predators such as coyotes and raccoons prefer wooded cover and avoid open areas where they are less secure. Edges are a common pathway for predators that hunt ecotones.
- Some animals (fox, deer, moose, bobcat) use roads, especially in the winter when snow cover makes movement difficult.
- Bears are skittish of people, and prefer natural wooded areas. They are affected by noise, which is a factor associated with highway crossing areas. There is one section on the north side of I-89 near Middlesex where the configuration of the landscape—cliffs in relation to the highway—amplifies traffic noise. There are no bear crossings there, and this area seems to be a delineation between bear populations.
- Smaller organisms have a security factor, i.e. amphibians stick to moisture. Invertebrates and smaller vertebrates respond to physical conditions of the road, such as dampness.
- Make the woods meet the road on both sides, especially where ravines or riparian corridors cross the road.
- Can plant natural vegetation such as silky dogwood so bobcats will have cover. They adapt. If they are comfortable and have sufficient prey (rodents, rabits) they will live in close proximity to humans.

(Steve Parren)

B.1.b Planning the low-impact road and highway system

The goal for the State of Vermont's transportation system is to support effective and safe transportation of people and goods, while minimizing impacts to the environment and providing for the movement of fish and wildlife. Impacts, as defined here, include restricting the ability of wildlife to move freely around on the landscape, such as at multi-town or Regional Planning Commission scale and to access important habitats. Roads (defined here as including highways), inhibit wildlife movement because they bisect wildlife habitat, cross streams and riparian zones, support development and traffic. The low-impact transportation system would help mitigate these effects by providing access for animals from one side of the right-of-way to the other. This can be accomplished through strategic use of crossing structures that range from overpasses and underpasses to box culverts and culverts. In Vermont, bridge replacement presents a unique and important opportunity to improve conditions for wildlife movement. Expanding the beam of a bridge can greatly improve mobility of many species of wildlife. This has been used in cases on the Bennington Bypass and Route 12 in Middlesex. This may meet part of the requirements for wildlife movement, but sometimes, enhanced or new structures are needed to reduce impacts to regional wildlife movement and biodiversity.

Planners can assist with meeting the needs of wildlife to move by considering the transportation system as a network of roads and highways that impacts wildlife movement throughout the landscape. This means thinking of the system as a mesh overlaying an often-continuous landscape available for wildlife to move, where the mesh varies in its effects based upon ROW size and traffic. Planning transportation systems at this scale necessarily interfaces with finer scale wildlife presence and movement across the various roads and highways in the system. In practice, this means that planners must communicate with engineers, operations and maintenance, and safety staff about the role of individual roadway segments in overall wildlife movement across large landscapes.

Landscape scale permeability for genetic and biodiversity connectivity

This section describes how transportation planning can contribute to connectivity and wildlife movement. An overall planning BMP objective is to integrate landscape permeability/genetic connectivity with transportation system planning. The importance of landscape permeability is described, including how it can be used in planning. In addition, the roles of studies of wildlife movement, roadkill, and landscape scale pictures of wildlife movement and connectivity are presented. Although concerns about wildlife-vehicle collisions are sometimes focused on one or two wildlife species, many animals are likely to be involved in collisions along any given stretch of road or highway. Planning for one species, or even a taxonomic group (e.g., ungulates) can make sense in unusual cases, but typically, planners should consider the needs of as a wide a group of animals as possible to increase the benefits for what can be costly actions.

Advantages

Planning for connectivity and landscape permeability has one main advantage: it is a cost-effective management action that reduces impacts to wildlife species and health and property costs from collisions between large animals and vehicles. Because of this, assessing and planning for permeability is both the starting point for many of the Best Management Practices described in this Manual and includes methods to measure the cumulative benefit of these actions. In other words, finding out where wildlife movement is limited can help to prioritize actions and by resolving the limitations, result in more effective wildlife movement.

Description

Genetic connectivity refers to the maintenance of the flow of genes within and among populations of a single species is critical for all wildlife. This kind of connectivity is maintained by ensuring movement of individuals of a species so that they effectively mate, raise young, and young disperse among and within populations. In extreme cases, genetic fragmentation can occur because of roads and highways, populations become genetically isolated and less related, which can contribute to local or regional extinction (e.g., Epps et al, 2005). Maintaining and restoring healthy genetic connectivity requires facilitating movement of individuals of each species across large distances and over time, as they try to meet their mating and dispersal requirements. Because of these large spatial scales and longer time-frames, transportation planning departments are the appropriate vehicles for making sure this happens. Planning staff don't have to learn about wildlife genetics to accomplish this. However, they do need to be aware of the importance at the species level of movement of individual animals.

Planning Nexus

Transportation system planning involves understanding the distribution of traffic, infrastructure, and change in these elements over time. Incorporating wildlife movement at the landscape scale into transportation planning is often accomplished using Geographic

Information Systems (GIS). Predictive models of wildlife movement and the spatial components of genetic connectivity are overlaid on the transportation system and models to understand where management action can be taken to improve connectivity.

The Staying Connected Initiative (Figure 1A), Vermont Habitat Block and Wildlife Corridor Analysis (Figure 1B), and similar projects around the US (Appendix 2), hypothesize about where wildlife might be moving based upon bio-physical landscape attributes (e.g., vegetation type, topography). These map-hypotheses should be validated using wildlife occurrence and movement data from past and future studies before being used for investment of financial, social, or political capital. Once validated, these maps can help planners to focus on areas that might currently lack sufficient connectivity for single or several species.

Planning for connectivity is a complex activity, involving combining several un-related disciplines. It involves several steps that may be taken in the sequence provided here, or some other order. However, these are the primary required steps for

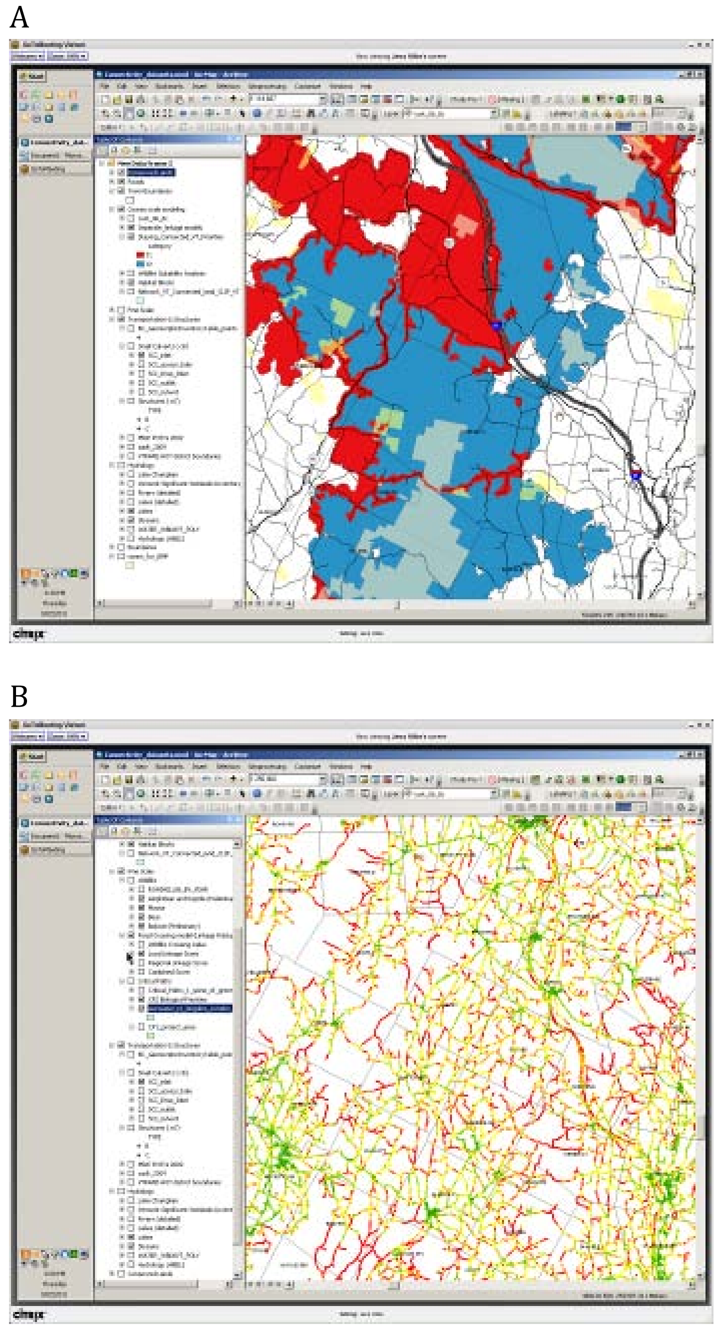


Figure 1 A. Map of the Staying Connected Initiative model output. This map shows the "core" and "linkage" areas that meet the Initiative's criteria. B. Map of the linkage ratings model output. This map shows ranks of the road and highways segments for their modeled connectivity value, with red being higher value and green lower value (Osborne and Sorenson, 2011).

effectively conducting planning for wildlife movement and genetic connectivity:

Step 1: Assessment of existing connectivity at the landscape scale for individual or multiple species and comparison of this connectivity to a reference or desired condition.

Step 2: Development of a validated connectivity model that provides a testable map-hypothesis of where wildlife movement may occur and where this movement may conflict with traffic and transportation infrastructure.

Step 3: Identification of all locations of potential conflict between wildlife movement and transportation systems.

Step 4: Prioritization of parts of the transportation system that meet either of these conditions: 1) public safety is compromised by existing large wildlife movement and 2) the road/highway segment prevents enough individual animals from moving that genetic connectivity is compromised and/or populations become isolated.

Step 5: Description of actions which, when implemented, will result in measurably-improved wildlife movement, genetic connectivity, and public safety. These could be at the highway corridor or regional scale.

Limitations

One common finding with connectivity model maps that are based only upon bio-physical attributes is that they don't reflect the actual movement of the many animals that may be present in undeveloped areas. Another common finding is that the map output depends on how and at what scale the GIS modeling was carried out. In other words, fine scale, small extent modeling of connectivity often looks different than coarse resolution, large extent models. What this means is that GIS models of "connectivity" must first be validated to be useable in planning. In addition, this means that even validated models of connectivity may not be sufficient information to understand both how much effort is needed to improve connectivity for wildlife movement, nor is it enough to plan individual crossings intended to meet local or regional needs, or the needs of different species. This last limitation is because connectivity for turtle movement will be quite different from connectivity requirements for moose movement.

Monitoring effectiveness

Measuring the effectiveness of planning in meeting wildlife movement needs and genetic connectivity takes place over wide areas and long time-frames. For example, wetland species are naturally isolated, requiring movement over upland areas to link them. If roads interfere in this movement and fragment populations, then planning to reduce population fragmentation can be measured in the short-term by monitoring movement through multiple structures in a region and over the long-term by measuring genetic relatedness among populations. Landscape genetics and its associated tools is becoming a more and more cost-effective method for measuring connectivity at the regional (e.g., Regional Planning Council) scale.

Cost

The costs associated with carrying out assessments and planning for genetic connectivity and landscape permeability lie mostly with carrying out the research necessary to identify problems areas and roads. There are two types of costs: 1) field costs associated with measuring genetic relatedness and wildlife movement and 2) analysis and planning costs associated with understanding how to use the genetics and movement data to improve connectivity across multiple highway rights-of-way. The costs of then implementing management practices corresponding to the planning recommendations are not included here, but could be calculated based upon planned connectivity remediation actions.

B.1.c The four-legged stool of GIS modeling, wildlife observations, wildlife movement, and genetic connectivity

There are many techniques for hypothesizing about connectivity (e.g., connectivity modeling in GIS), measuring connectivity among wildlife populations (e.g., genetic monitoring), observing live and dead wildlife occurrences, and measuring wildlife movement in the field (e.g., with radio-collars). Each of these methods provides some information about individuals and populations of wildlife species. None by itself provides sufficient information to plan and implement management practices to protect wildlife movement. For example, modeling in GIS provides an approximation or hypothesis about where wildlife might be moving, but only field measurements can confirm or test this hypothesis. A common approach is to take the outcomes of predictive GIS modeling as a reasonable basis for prioritization of lands and roads for conservation of wildlife movement. However, this is not a method based in science and it is worth investing more in testing the models before investing in infrastructure. Testing GIS models is usually done using one or more of the other approaches described below.

GIS Modeling

Connectivity is often approximated using Geographic Information System (GIS) tools. It is a useful approach that can be applied uniformly across large areas. When done well, the approach is based upon detailed information about habitat quality, habitat suitability, animal behavior, and disturbance from human activity. The most accurate description of the outputs of this type of modeling is "landscape intactness", which is one proxy for connectivity. Despite the prevalence of this approach, the outputs of these systems are, at best, still only a hypothesis of potential wildlife movement and should be verified using wildlife occurrence and movement data.

Wildlife Observations

There is still no substitute for high quality wildlife observation data in planning for wildlife connectivity (see Section B.5 for a more detailed description of monitoring). These observations can be of live or dead wildlife on or near roads and highways. In order to be useful, a wildlife observation record should include what species, where it was observed, when the observation took place, who made the observation, and how the observation was made. Occurrences of wildlife at certain places and times can provide information about habitat suitability and use of areas near roads. These measurements are a cost-effective way to capture information about the occurrence of multiple species, but not necessarily about wildlife movement. For example, researchers have found that concentrated locations of carcasses from wildlife-vehicle collisions don't overlap with observations of live animals. This suggests that carcass ("roadkill") data tells us something about unsuccessful wildlife crossing roads, but not successful crossings. An important caveat is that the lack of wildlife movement does not indicate the lack of historical or potential connectivity. If a stretch of highway is acting as a complete barrier to movement, wildlife populations may avoid that stretch, or may have gone locally extinct because of the barrier (e.g., breeding movement of turtles). If wildlife crossings can be placed in that stretch of highway, the lost connectivity may be restored.

Monitoring Wildlife Movement

The ultimate measure of wildlife connectivity is tracking actual wildlife movement using radio-tracking or GPS devices. When these movements intersect transportation infrastructure, we can learn what parts of the ROW surface, or highway crossings, are used by various wildlife species. These measurements are usually expensive and often only represent the activities of single species, vs. multiple species approaches. The benefit of the approach is that movement is directly measured and the barrier role of roadways, or the corridor role of culverts and bridges, can be directly measured. (see Section B.5 for a more detailed description of monitoring)

Genetic Connectivity

Because roads and highways can bisect populations of individual animals, one way to measure connectivity for wildlife is to measure relatedness of individuals to each other across one or more highway barriers. This is done by taking genetic samples (e.g., of hair, blood, feces, or skin) and sequencing "marker" genes that are known to diverge within a few generations. Population genetic structure can then be used to describe population subdivision by roads, or other factors. Well-mixed populations, where individuals move and reproduce freely, will not have detectable genetic structure across landscapes. Actual populations naturally have some constraints on movement, so genetic structure in populations potentially separated by roads/highways are often compared to nearby non-divided populations, rather than a theoretical, well-mixed population. Although expert assistance is required to implement this approach, it is a very cost-effective way to answer questions about wildlife connectivity.

Bringing It All Together

The approaches described here are complementary and when taken together provide a complete picture of connectivity. It is probably not essential to conduct all of these methods together to support investments in transportation improvement for wildlife. Because the approaches provide different types of data, the following is a list of reasonable combinations of these approaches to support connectivity assessments and best management practices:

1) GIS modeling AND wildlife observations OR wildlife movement (can be used to validate models of connectivity for particular areas and/or species)

2) Genetic connectivity AND wildlife movement (can measure extent to which adult and juvenile movement and dispersal contributes to gene flow) OR genetic connectivity AND lack of movement (may indicate a broken connection that needs to be restored)

3) Wildlife observations AND wildlife movement (can be used to understand area occupancy and movement among different areas, with or without habitat information).

B.1.d Special Section: Connectivity Assessment in Vermont and the Northeast

The Northern Appalachians region of the northeastern U.S. and southeastern Canada is one of the most intact temperate broadleaf forests remaining in the world. Yet recent scientific assessments by The Nature Conservancy, Wildlands Network and Two Countries One Forest (2C1Forest a Canadian-U.S. collaborative of conservation organizations, researchers, foundations and conservation-minded individuals), reveal that this ecoregion is increasingly at risk of being fragmented by development and roads into a gradient of variably-connected habitat (Anderson et al. 2006, Reining et al. 2006, Trombulak et al. 2008, Beier et al. 2011). This fragmentation, in turn, risks isolating wildlife populations and limiting their ability to move across the landscape to meet their life needs, ensure adequate genetic exchange, and adapt to a changing climate. These assessments identify a handful of high priority habitat "linkages" – areas that are thought to be critical for maintaining the ability of wide ranging mammals to move among less-disturbed areas within the Northern Appalachians ecoregion. Maintaining, restoring, and enhancing connectivity among areas of less-disturbed habitat has emerged as a top conservation priority for the region in recent years. Linkages are an interesting planning concept, but it remains to be determined whether protecting or restoring "linkages" is sufficient to preserve wildlife movement. The term "linkage" is used here as it used in conservation planning, with the recognition that its ecological meaning or validity can vary substantially from very little to quite important.

Vermont stands at a kind of north-south and east-west crossroads within the Northern Appalachians, with at least five potentially significant habitat linkages falling within the state. One linkage ties the Adirondacks to the southern Green Mountains via the southern Lake Champlain valley; a second linkage connects the Taconic Mountains across the Valley of Vermont to the southern Greens; a third links the Sutton Mountains of Québec through the Green Mountains of Vermont to the Berkshires of Massachusetts; a fourth runs from the Worcester Range through the Northeast Kingdom of Vermont to the Connecticut Lakes region of northern New Hampshire; and a fifth ties the central Green Mountains to the White Mountains of New Hampshire.

Ecoregional analyses provide the essential big picture to demonstrate the importance of Vermont within the larger conservation context, but their results are too coarse to provide useable information for planners, engineers and conservation organizations. Fortunately, public entities, notably the Agency of Transportation (AOT) and the Fish and Wildlife Department (VTFW), and local researchers and non-profit organizations, have developed fine-scale analyses of habitat blocks and landscape connectivity over the last five years.

The first state-wide project, a GIS-based, landscape-level model designed to predict the location of potentially significant wildlife linkage habitats associated with state highways, was completed in 2006 as a joint initiative of AOT and VTFW (Austin et al. 2006). This project assigned Wildlife Habitat Suitability (WHS) values to land throughout the state, using factors such as housing density, land use/land cover (LULC) and core habitat information. It also describes Wildlife Crossing Values (WCV), which in turn uses the WHS coverage to identify sections of Vermont roadways that are associated with high WHS values. The project thus provides a relative prioritization of road crossings within different regions.

A more recent collaboration between VTFW and the Vermont Land Trust (Sorenson and Osborne, 2011) expands on the base developed in the 2006 project to:

1. Identify habitat blocks using best-available GIS data.
2. Rank the relative importance of habitat blocks for their biological/conservation value and the potential threat to them.
3. Identify and rank the relative importance of potential wildlife road crossings statewide.
4. Identify potential wildlife corridors between habitat blocks using “least-cost-path” analysis.
5. As a monitoring tool, analyze change in habitat block size and degree of fragmentation using GIS data that will be regularly updated (CCAP land cover and E911)

The State continues its efforts to map areas that contribute to the State’s biological diversity. In 2011, the Agency of Natural Resources initiated a Natural Resource Mapping Project (NRMP). The goal of the NRMP is to create a statewide map and supporting database identifying the lands and waters that support high priority ecosystems, natural communities and habitats and therefore are deserving of conservation and/or restoration in order to secure Vermont’s natural heritage for future generations. The Agency has set a goal of completing the project by December 2012.

The statewide data developed by Sorenson and Osborne have been used to refine connectivity analyses for subregions of the state. For example, VTFW (Hilke, unpublished) has developed a “connectivity network” for the Taconics-Greens and Worcesters-Northeast

Kingdom regions. The Staying Connected Initiative (SCI) has used these results, plus additional analyses, to identify dozens of "structural pathways" within the 61-town region where the Initiative is active. SCI defines a structural pathway as an "area with sufficient structural connectivity to function as a habitat corridor." SCI defines a habitat corridor as the "components of a landscape that provide a continuous or near continuous pathway that may facilitate the movement of target organisms or ecological processes between areas of intact habitat."   These structural pathways are relatively small – a few hundred to a few thousand acres, have clear boundaries and encompass specific road segments. The Staying Connected Initiative (SCI) was formed in 2009 to protect and maintain landscape connectivity across the Northern Appalachians for the benefit of wide-ranging, forest dwelling wildlife such as bear, moose, lynx, marten and bobcat. SCI is an innovative 21-member, multi-state partnership that includes 13 non-profit organizations and eight state agencies from Vermont, New Hampshire, Maine, and New York1. The initiative focuses on seven priority landscape linkages identified by 2C1Forest, The Nature Conservancy and Wildlands Network.

Another project, called Critical Paths, surveyed 38 sites where roads cross the spine of the Green Mountains. A team of state biologists and conservation organizations assessed the physical features of the crossings and the natural features of adjacent landscapes. They also tracked and monitored wildlife movement patterns at each crossing over an extended period of time. From this work 11 critical "Priority Crossing Zones" were identified along the spine of the Green Mountains that are essential to south-north wildlife movement. Detailed strategies are being develop for road mitigation, roadside improvements for traffic safety and wildlife crossing, land conservation, and local land use planning for these zones. An important point about Critical Paths and the SCI structural pathways is that sometimes the stretch of highway or road bisecting a mapped corridor or linkage may not be traversable by wildlife. In these cases, restoring a lost connection can be accomplished by making the highway permeable by enhancing existing structures, or building new ones.

A take-home message is that there is a lot of information available to AOT personnel, and that there are resources available to help gather and analyze this information for a variety of AOT purposes. VTFW and the VTrans-VTFW Wildlife Steering Committee are available to provide technical support for VTrans.

B.2 Steps in Regional-Scale, Long-Term Planning and Wildlife Connectivity

This approach for planning for Vermont is based on looking at transportation planning from a more coarse scale that looks at long term plans (long time scale) and the state and its role in the regional connectivity of wildlife (larger spatial scales). The goal is to select the specific areas of concern for transportation plans, and find the species of wildlife that may need to be addressed in the plan.

Step 1: Use the State Transportation Improvement Plan (STIP) to select road segments of concern.

Step 2: The next important step is to determine the species of concern and their distribution that may be in the area. This will be based upon a combination of data about impacts to wildlife populations, field information about wildlife movement, and expert opinion about wildlife movement needs. To begin, one accesses GIS maps. The maps one uses at this level are based on GIS computer modeling with inputs on known wildlife presence, road kill carcass data, land cover, other data, and best professional assumptions. While Vermont has some of the best mapping methodology in the United States (see Section B.1.d), these databases are best guesses at where certain wildlife species live and move. The maps do not display where the majority of wildlife species actually occur and move in the state. It is critical that transportation planning take into consideration that these maps and databases are hypotheses and estimates of connectivity, something we measure on maps, but which may not be inclusive of all species or geographies. These maps are a first step, but not the end all.

a) Contact Vermont Fish and Wildlife's Conservation Planning Biologist for most important and recent data and maps. At the time of the final draft of this manual in early 2012, Vermont Fish and Wildlife added the following concerning species' maps:

"The Vermont Fish and Wildlife Department has developed a GIS analysis of forest habitat blocks and related statewide linkage areas that illustrate a network of connected lands throughout the state. These linkage areas represent critical, landscape scale connections for maintaining ecological connectivity within the larger northern forest from the Adirondacks in New York to northern Maine. In terms of how these linkage areas intersect with roads in Vermont, these areas represent regionally significant connections for wildlife and ecological connectivity and should be given high priority for protection and enhancement. [At a later date] These areas can be found at (location to be determined by Vermont Fish and Wildlife Department at a date to be determined). Vtrans planners should consult with the Vermont Fish and Wildlife Department conservation planning biologist, or other wildlife biologists."

b) Review maps of hypothetical connections referenced in (a) for region-area of concern and to see where the project lies within the mapped linkages.

c) Review this Best Management Practices Manual listing of Species at Risk and Consideration for each Biophysical region - see Species Movement Guilds and Biophysical Regions below. Identify the species this project needs to plan for in transportation planning and operations.

d) Access state, federal, The Nature Conservancy and NatureServe databases for species' presence

Step 3: The third step is to determine if the transportation project/corridor is within an area where there is undeveloped land and waterways that could harbor native wildlife species. Even agricultural areas can support wildlife populations, including movement across the landscape. For assistance with transportation planning projects, please contact the Vermont Fish and Wildlife Department Conservation Planning Biologist at 802-338-4862 or 802-476-0199. If the area is sufficiently developed to preclude wildlife movement, such as city areas with industrial, commercial, or residential development, then wildlife movement mitigation may not need to be included in transportation projects. It is important to check with Vermont Fish and Wildlife biologists to make that critical decision.

Step 4: Make a finding in environmental documentation for the project or plan about whether or not and how wildlife movement will be affected by projects and what kinds of mitigation and alternative selection could avoid or minimize these effects.

B.3 Fine Scale Tools to Identify Road Segment and Species of Interest

At this level of planning, the goal is to determine the segment(s) of road of interest, the species that may be residing there that are of state or federal concern, and the potential types of mitigation options available for wildlife. When one focuses on wildlife connectivity at a local level, such as a specific road section through a part of an ecosystem, what wildlife is doing on the ground (and along watercourses) is very instructive for transportation planning. One learns of wildlife movements through a variety of sources, all based on field data. This is a stage of planning that involves data searches and personnel contacts at the local level. In this stage planning will: a) identify stretches of road with animal-vehicle collision data, b) contact VTF&W personnel for species of concern, c) check WIERS for maintenance recommendations, d) Use Passage Assessment System (PAS) to evaluate retrofit and enhancement opportunities, e) ID target species and associated Species Movement Guilds of concern for the projects' biophysical region, f) use best-science to determine desired spacing and sizes of crossings, g) create plan for mitigation and or retrofit, and h) create periodic operations and maintenance schedule.

According to the Vermont Fish and Wildlife Department, it "*maintains a variety of databases. The biotics database contains all information related to rare, threatened and endangered species, significant natural communities and important wildlife habitats. This is the most useful set of information for transportation planning maintained by the Department. This information can be located through [Vermont Center for Geographic Information] VCGI, or through directly connecting with the ANR website. This information is updated on a regular basis and VCGI receives routine updates from the Department. Vtrans should contact the Biotics Database Supervise with any questions*."

In terms of interpreting the data, refer to the publication, "Conserving Vermont's Natural Heritage" which can be found on the Department website at:
http://www.vtfishandwildlife.com/library.cfm?libbase_=Reports_and_Documents

This document explains how to interpret biological data for land use and transportation planning purposes.

Step 1: Cross reference Table 4 below: Biophysical Region of Vermont and Potential Target Species for what the species of concern are for the specific Bioregion(s) the project lies within. Cross reference these species with state databases, maps, and literature to learn where these animals may have been recorded in relation to the study area/highway. See below.

Step 2: In tandem, begin planning for these species regardless of databases. The majority of Vermont wildlife species move across the state undetected. Even if wildlife is not identified in state or private databases, it does not mean they do not occur, attempt to move across roadways, and get involved in collisions with vehicles. To protect this legacy, transportation planning should concentrate on making the road and highway system permeable to native wildlife species. The standard for planning for wildlife connectivity is for transportation and wildlife agency personnel to conduct searches for maps, reports, and literature to determine what species are of concern in an area, and to plan conservatively for them, regardless if they have had carcasses recorded on the road.

Step 3: Review Vermont's road kill carcass data bases to learn of species commonly involved in wildlife-vehicle collisions (WVC), and where the highest incident areas ("hotspots") were/are. The standard approach for determining hotspots is to use geo-statistics tools (e.g., Getis-Ord in ArcGIS) to measure the spatial autocorrelation ("hotspots") of WVC locations.

Step 4: If the project area is in the Champlain Valley or along the Spine of the Green Mountains, refer to the 'Critical Paths' 1 and 2 documents for additional data on potential wildlife linkages.

Step 5: If area is determined to have wildlife presence, arrange and conduct site visit with Vermont Fish and Wildlife biologist (For assistance with transportation planning projects, please contact the Vermont Fish and Wildlife Department Conservation Planning Biologist at 802-338-4862 or 802-476-0199) for the area to determine what the concerns are, and what are the most important effects on wildlife connectivity and what areas, if any, have been formally found to be more important than others for wildlife movement.

Step 6: If the highway segment does not have evidence of wildlife movement, determine if there are land conservation and restoration actions planned nearby and whether or not the segment lies within a possible landscape linkage. This helps determine if the segment can be enhanced to restore connectivity.

Step 7: Contact Vermont Fish and Wildlife personnel to learn if there are wildlife studies documenting movements of different species in the area. This would encompass state, federal, university, and citizen science studies of wildlife of all sizes, from turtles to moose. Access the future VCGI database for such studies.

Step 8: Contact appropriate personnel within VTrans about planning for these wildlife species and about the specific locations; such as: Chris Slesar and colleagues, archeological resources, geology personnel, engineers, to learn of the feasibility of the potential mitigation.

Step 9: Create and plan for mitigation, with maintenance schedule. Identify goals and objectives of the mitigation.

Step 10: Decide if the project is a retrofit or new mitigation. This is based on a field visit to the site with the Passage Assessment System (below), which helps determine the retrofit enhancement potential of existing structures along the road of interest.

Step 11: If an area is under consideration for wildlife mitigation, a site visit is necessary to determine landscape variables, watercourses through the project, local development, and the potential of existing structures to pass wildlife. A trained biologist is instructed to visit the site along the road and use the Passage Assessment System (PAS) to evaluate if existing culverts and bridges could be retrofit or enhanced to pass wildlife with minimal changes. If the existing infrastructure will be replaced for transportation reasons, or because it does not function in wildlife passage, then the planning for this structure will continue through the process below. If the structure is to be enhanced, such details are included in Sections C.1 and D.2.

Types of Wildlife Crossing Mitigation

There are two types of wildlife mitigation that have been scientifically studied and proven to work at allowing wildlife to cross roads: wildlife under and overpasses in conjunction with fencing (Hedlund et al. 2004), and wildlife crosswalks in conjunction with driver warning systems. While funneling wildlife structures for crossing under and over the roadways has been extensively studied, there have been limited use of wildlife crosswalks where ungulates such as deer and moose are funneled with the use of fencing, to a specific strip of roadway where they are expected to cross and motorist are expected to slow and brake for those animals if necessary. Types of mitigation are listed below, in Table 2.

Table 2. Types of wildlife mitigation and their purpose and efficacy.

Type of Mitigation	**Purpose, efficacy**
Wildlife crossings made of culverts or bridges, in tandem with wildlife fencing for specific type of wildlife species (large fences for deer & moose, smaller mesh fences for smaller species) Culverts can be as small as two feet to dozens of feet in diameter; bridges can be as low as one foot off the ground to dozens of feet off the ground.	The fencing guides the animals to the culverts and bridges to cross under (or over, in the case of overpasses) the roadway. See Table 6 for specific types of crossings.
Wildlife crosswalks – made with fencing and driver warning systems	Funnel larger wildlife to specific zone across a two-lane road where drivers are warned when wildlife are detected in the crosswalk. See Appendix 4 for further photo examples.
Retrofits or enhancements to existing structures	See Section C.1 for a description of these

The initial step in identifying the type of mitigation is to identify the multiple species to benefit from the potential mitigation. How those species use crossing structures and the types of structures that would work for suites of species and ecological processes can be found in the Species Movement Guilds and the Structure Functional Classes in Tables 3 and 6, respectively. These tables will guide the process in evaluating the types of structures that would work best for the species of interest. Additional considerations include: identifying ecological processes that need to occur at the site, such as the movement of water; the topographic features that may affect movement and mitigation; identifying engineering constraints and maintenance concerns; weighing cost concerns with potential benefits; and then a final process of selecting the most appropriate mitigation.

Categorizing Wildlife Species into Movement Guilds for Vermont's Biophysical Regions

Transportation planning can more efficiently plan for connectivity for wildlife species across Vermont if the species of concern are first cross-referenced with geographic regions in the state, along with how to best facilitate those species' movements. The Manual describes a quick reference guide that can be used with the more detailed Manual sections.

Illustrated in Table 3 below is a description of how species can be classified into one of the eight Species Movement Guilds. Guilds are then paired with Vermont's eight Biophysical Regions. That matrix of guilds and bioregions is then populated (in collaboration with VTF&W) with Vermont Fish and Wildlife's Wildlife Action Plan list of Species of Greatest Conservation Need that also may be impeded in their terrestrial movement by transportation corridors. These species are categorized under the most appropriate Movement Guild, and then checked for their known or suspected presence in the eight Biophysical Regions. This table serves as a quick reference for transportation planners and ecologists interested in creating opportunities for wildlife to pass over and under Vermont roads. The information will be part of a larger document that helps users to create the Best Management Practices for wildlife and transportation across the state.

Recent research by Cramer, Kintsch, and Jacobson (Cramer et al. 2011) resulted in the documentation of 'Species Movement Guilds' which categorizes wildlife based on their modes of locomotion and preferred crossing structure characteristics as understood from past and current scientific studies. This is a unique classification designed to facilitate an understanding of 'what works' for different types of wildlife. The classification system allows transportation biologists to evaluate the physical and environmental conditions and potential constraints to movement from the perspective of groups of species, and develop mitigation strategies that carefully consider the behavior and preferences of each target species. The Guilds facilitate an understanding of why certain species have specific requirements and allow generalizations to be made across species in a given Guild thereby streamlining project planning and design processes.

Eight Species Movement Guilds are defined (Table 3): Low Mobility Small Fauna, Moderate Mobility Small Fauna, Adaptive High Mobility Fauna, High Openness High Mobility Carnivores, Adaptive Ungulates, Very High Openness Fauna, Arboreal Fauna, and Aerial Fauna. These Guilds provide a potential classification system for mitigating impacts to wildlife whose habitat or movement paths are bisected by a transportation corridor. Interested biologists may not know if a particular species has been studied relative to the effectiveness of various mitigation strategies. By placing that species within its respective

Species Movement Guild, generalizations can be made as to which mitigation solutions might benefit that species. The Species Movement Guild classification represents the best gathering of the current state of the science of wildlife and transportation in the United States and Canada.

Table 3. Species Movement Guilds (adapted from Cramer et al., 2011)

Species Movement Guild	Species Examples	Species Attributes	Preferred Passage Characteristics	Structures
Low Mobility Small Fauna	Invertebrates, frogs, toads, some salamanders & ground insects	Small, slow-moving species, require specific ambient conditions, including natural substrate, light, temperature and moisture.	Extensive bridges, wildlife overpasses, trench drains.	Trench drains , small culverts less than 4' in diameter either concrete or metal with natural substrate bottom.
Moderate Mobility Small Fauna	Small and medium mammals, some salamanders, lizards, turtles, & ground birds	Smaller animals, adaptable to different types and sizes of structures. Need hiding cover. Typically prefer water-free pathway. Could use cover within larger structures via rocks, vegetation, or smaller pipes. .	Small, medium or large underpasses -culverts and bridges, extensive bridges, wildlife overpasses	Small underpass – culverts less than 5' in rise and span. Medium underpass – culverts 5' to 8' span and rise. Large underpass – bridges, and culverts > 8' rise.
Adaptive High Mobility Fauna	Black bear, bobcat, coyote, lynx	Medium-sized mammals that tolerate some enclosure. Use a variety of structure types, prefer suitable habitat adjacent to the structure entrances.	Small, medium or large underpasses (culverts and bridges), extensive bridges, wildlife overpasses.	Small underpass – culverts less than 5' in rise and span. Medium underpass – culverts 5' to 8' span and rise. Large underpass – bridges, and culverts >

Species Movement Guild	Species Examples	Species Attributes	Preferred Passage Characteristics	Structures
				8’ rise.
High Openness High Mobility Carnivores	Mountain lion, wolf	Highly mobile and large-bodied animals. Prefer open structures that provide good visibility but can be tolerant of longer structures (>100’).	Large bridge underpasses, extensive bridges, wildlife overpasses.	Large bridge underpass – needs openness, > 8’ high.
Adaptive Ungulates	White-tailed deer, moose	Medium and large-sized prey animals that require good visibility, clear lines of sight, moderate amount of cover and natural substrate. Preferred structures are wider than they are tall and are less than 100’ in length.	Medium or large underpasses (culverts and bridges), extensive bridges, wildlife overpasses.	Medium underpass – culverts 5’ to 8’ span and rise (if these dimensions in one aspect, the other has to be much longer-wider). Large underpass – bridges, and culverts > 8’ rise.
Very High Openness Fauna*	Elk, pronghorn, bighorn sheep, open habitat grouse	Prey species very wary of predators, require large passages with wide openings (at least 15’) that are less than 100’ long, good visibility within and around structure, clear lines of sight from one end of a crossing	Large culvert or bridge underpasses, extensive bridges, wildlife overpasses.	Large culvert for these species is one that is measured in feet over 15’ high or wide, and is less than 100’ long, and still may not be used. Bridges are much more

Species Movement Guild	Species Examples	Species Attributes	Preferred Passage Characteristics	Structures
		structure to the other.		preferred.
Arboreal Fauna	Flying squirrels, some bats	Species that move primarily through the canopy rather than on the ground surface. Provide a continuous canopy-level structure across the road.	Treetop rope bridges, towers, or modified wire or metal structures.	45' high wooden platforms for flying squirrel launches to other side of a 2 lane road. Rope bridge is strung over road, made of rope or modified metal.
Aerial Fauna	Birds, bats, flying insects	Species that fly. Features aim to divert flying species out of the path of traffic, or raise level of road for flying beneath, or along overpasses.	Diversion poles, tall vegetation, extensive bridges, wildlife overpasses	These would include pvc pipe poles or tall vegetation placed to divert flight paths over roads, and large bridges and wildlife overpasses.

* -- *this guild is not relevant to Vermont, but is included here for completeness*

Classifying Vermont species into these classes allows users to quickly access information about a species or groups of similar species, and make inferences on how they may be best mitigated for with respect to transportation.

Vermont's Wildlife Action Plan aims to protect species across the spectrum of need of protection and conservation. The Vermont Wildlife Action Plan lists Species of Greatest Conservation Need (SGCN), which includes 144 vertebrate species of the 470 in the state. From that list of species, any species that moves solely or in part over the terrestrial landscape was listed in Table 4, below. This included all mammals, all reptiles and amphibians, select birds, and select invertebrates from the SGCN list. These species are listed under the most appropriate Species Movement Guild.

The columns of the table list the eight biophysical regions of Vermont, as taken from Thompson and Sorenson (2005). These are distinct areas in Vermont that share similar climate, geology, topography, soils, natural communities, and human history.

This approach is a way to meld species of concern, how they react to roadways, and the Biophysical Regions of Vermont where they reside, or may reside. It is considered a step in the process of creating Best Management Practices for Wildlife Connectivity with respect to transportation.

Table 4. Biophysical Regions of Vermont* and potential target species

Target Species in Species Movement Guilds	**Champlain Valley**	**Taconic Mountains**	**Vermont Valley**	**Northern Green Mountains**	**Southern Green Mountains**	**Northern Vermont Piedmont**	**Southern Vermont Piedmont**	**North-eastern Highlands**
Low Mobility Small Fauna								
Jefferson Salamander	X	X	X	X		X	X	
Common Mudpuppy								
Fowler's Toad	X						X	
Western (Striped)								
Chorus Frog	X						X	
Spotted Turtle								
Wood Turtle	X		X				X	
Spiny Softshell Turtle	X	X	X	X	X	X	X	X
Five-lined Skink	X							
Eastern Racer	X							
Eastern Rat Snake	X	X					X	
Eastern Ribbon Snake	X	X	X					
Blue-spotted Salamander	X	X	X	X	X		X	X
Spotted Salamander	X	X	X	X	X	X	X	X
Four-toed Salamander	X				X		X	
Common Musk Turtle	X	X						
Northern Water Snake	X	X	X					
Brown Snake	X	X	X	X	X		X	
Smooth Green Snake	X	X		X	X	X	X	
							X	
Water shrew**	X	X	X	X	X	X	X	X
Long-tailed shrew				X	X			
Pygmy shrew**	X			X		X		X
Rock vole**	X	X	X	X	X	X	X	X
Woodland vole		X	X		X		X	

Target Species in Species Movement Guilds	Champlain Valley	Taconic Mountains	Vermont Valley	Northern Green Mountains	Southern Green Mountains	Northern Vermont Piedmont	Southern Vermont Piedmont	North-eastern Highlands
Southern bog lemming**	X	X	X	X	X	X	X	X
Masked shrew**	X	X	X	X	X	X	X	X
Smoky shrew**	X	X	X	X	X	X	X	X
Hairy-tailed mole**	X	X	X	X	X	X	X	X
Muskrat**	X	X	X	X	X	X	X	X
Moderate Mobility Small Fauna								
Timber Rattlesnake	X	X					X	
New England cottontail**								
Long-tailed weasel**	X	X	X	X	X	X	X	X
American marten					X	X		X
Common gray fox**	X	X	X	X	X	X	X	X
Mink**	X	X	X	X	X	X	X	X
Northern river otter**	X	X	X	X	X	X	X	X
Bobcat**	X	X	X	X	X	X	X	X
Adaptive High Mobility Fauna								
Lynx						X		X
Black bear	X	X	X	X	X	X	X	X
High Openness, High Mobility Carnivores								
Wolf								
Mountain lion								
Adaptive Ungulates								
White-tailed deer	X	X	X	X	X	X	X	X
Moose	X	X	X	X	X	X	X	X
Very High Openness Fauna								
Spruce Grouse?								
Arboreal Fauna								

Target Species in Species Movement Guilds	**Champlain Valley**	**Taconic Mountains**	**Vermont Valley**	**Northern Green Mountains**	**Southern Green Mountains**	**Northern Vermont Piedmont**	**Southern Vermont Piedmont**	**North-eastern Highlands**
Southern flying squirrel**	X	X	X	X	X	X	X	
Northern Flying Squirrel**	X	X	X	X	X	X	X	X
Aerial Fauna								
Turkey	X	X	X	X	X	X	X	X
Woodcock	X	X	X	X	X	X	X	X
Indiana bat	X	X	X	X	X	X		
Small-footed bat	X	X	X	X	X	X	X	
Silver-haired bat**	X	X	X	X	X	X	X	X
Eastern pipistrelle	X	X	X	X	X	X		
Red bat**	X	X	X	X	X	X	X	X
Hoary bat	X						X	
Little brown bat	X	X	X	X	X	X	X	
Northern long-eared bat	X	X	X	X	X	X		
Big brown bat**	X	X	X	X	X	X	X	X
Tiger Beetles	X			X			X	
Butterflies and Moths	X		X					

* Biophysical Regions of Vermont taken from: Thompson, E.H. and E. R. Sorenson. 2005. Wetland, Woodland, Wildland: A Guide to the Natural Communities of Vermont. URL: http://www.vtfishandwildlife.com/books/Wetland,Woodland,Wildland/__20_to__55_Part_2_Biophysical_Regions_of_Vermont.pdf

** = Species occurrence not available in VTF&W RTE database. Occurrence estimated by A. Alfieri, VF&W Wildlife Specialist, through consultation with latest versions of New England Wildlife and personal knowledge, March 2012.

B.4 Wildlife Movement Conservation Partnerships

This section describes the critical role of partnership formation in designing, funding, implementing, and monitoring wildlife movement BMPs. Although VTrans could carry out many of these functions alone, inclusion of towns, RPCs, conservation groups, resource agencies, and others in planning and implementing BMPs is more likely to result in effective BMPS and investment of non-state resources.

A great deal of effort is being expended to develop detailed analyses of habitat and wildlife movement patterns across the region and state (see above Special Section on Connectivity Assessment in Vermont and Northeast). There is also the need to monitor how wildlife is actually moving on the landscape, where they are crossing roads and if they are using existing infrastructure and wildlife crossing structures. The mitigation of the impacts of transportation infrastructure on wildlife must encompass more than the infrastructure itself. As the Critical Path program demonstrates, land conservation and local land use planning, among other activities, must also be part of the mix.

From this understanding, "wildlife movement conservation partnerships" have emerged all over the country. These partnerships take many forms, from ones such as the Utah US 6 Wildlife Coordination Committee, which comprises individuals from FHWA, Utah DOT, U.S. Fish and Wildlife Service (FWS), Utah Division of Wildlife Resources (UDWR), the Bureau of Land Management (BLM), Uinta National Forest Service (USFS), and Utah State University (USU), see information box below, to much more grassroots efforts, such as the one in Monkton, Vermont to improve amphibian passage across a major road (see text box). The Monkton project emerged from a group of residents who monitored a road through a marshy area for nine years in the Spring, documenting the number of amphibian survivors and those hit by vehicles. Eventually the Monkton Conservation Commission proposed culverts under Vergennes Road, and Federal funding was obtained to carry out the project.

Other local efforts are underway to monitor wildlife movement. Vermont's own Keeping Track (http://www.keepingtrack.org) has provided technical training to professional biologists, citizen scientist volunteers, AOT personnel, land trust officials, and conservation planners over many years, and assists groups in establishing wildlife habitat monitoring programs in their towns. Staying Connected Initiative hosted Keeping Track training programs in the Northern Green Mountains in 2010 and 2011. Graduates of that training, and other volunteers, have expressed interest in monitoring specific stretches of roadway during the 2011/2012 season, and SCI and is providing the coordination to set up projects in at least two locales in the Northern Greens. SCI is also supporting similar "citizen science" monitoring efforts in the Adirondacks-Greens linkage.

Lessons from the Vermont Monkton Crossing

The Monkton Crossing consists of culverts under Vergennes Rd and amphibian fencing to provide salamanders with a safe way to cross the road, primarily in the Spring.

1) Identify the problem

A. Document salamander movement; B. Try to put parameters around it and quantify over successive years; This can be more practical than publishable in the scientific literature; C. Section of the road – where and how many roadkills; D. Time of year – some movement in fall, main issue is the spring period; E. Identify triggers for the movement (temperature, rain/snow cover)

2) Confirm that the magnitude is significant enough to require intervention

Monkton has: A. high species diversity and volume; B. species of concern (*rare or endangered*); C. high mortality

3) A good committee has a diversity of people

Monkton's Conservation Commission had: A. a great writer and tireless funding source researcher; B. a science base; C. an insider who understands the transport agency's workings; D. a close collaborator who is great at fundraising and deal-closing, and the type of skills that make her good at meeting people and asking for funding.

4) Volunteers – find through partners, press, anyone who might be interested. Start an email list.

They can help get the data you need.

5) Research the problem and get a description of what is needed to solve the problem

Enlist the assistance of wildlife agency personnel, academics, others

6) Research funding and identify funding sources (i.e. Transportation Enhancement Grants, State Wildlife Grant Program)

A. Need enough seed money to make project look feasible; B. Ask around for suggestions – if you have a great project, people who have done similar; C. projects will likely share funding suggestions, even if they are from a different region; D. Local fundraising—a brochure or fundraiser might help to raise funding from the community, especially if you are allied with a nonprofit with name recognition.

12 Steps Cont'd.

7) Talk to the town – get their input

A. Identify issues that need to be addressed structurally(i.e. does the proposed underpass really need permeable asphalt, and how does this affect safety and maintenance such as plowing and road repair? Can normal road treatments, such as salt, be applied in the area of the mitigation?); B. Political issues (town residents, permitting at town and county, state, federal level).

8) Partner and collaborate with local NGOs

A. They can provide letters of recommendation, and will likely know representatives and senators. We were lucky to partner with a local NGO who had more experience fundraising than any of us.

9) Raise public awareness – town, county, state (we got national and international which spurred the General Store get t shirts made up independent of any effort on the Conservation Commissions part!)

A. Press – great for awareness building, you need to create and tell a good story; B. Network – talk to the people making funding decisions, politicians, find out who provides their information and influences them. Get them interested in your project.

10) Apply for funding

A. Craft a proposal that meets the criteria of the funding agency. Try to figure out what benefits a partner or funding agency. This has worked well with corporations wanting to demo their commitment to the environment or an agency wanting to demo that they support community conservation. If you only consider what you need, you might miss out; B. Let them know about your project before your proposal is submitted so they are excited about it; C. If you don't get funded the first time, ask the funder for comments and incorporate changes into the next draft for the next funding cycle.

11) It may be possible to fill gaps in funding by making a local appeal

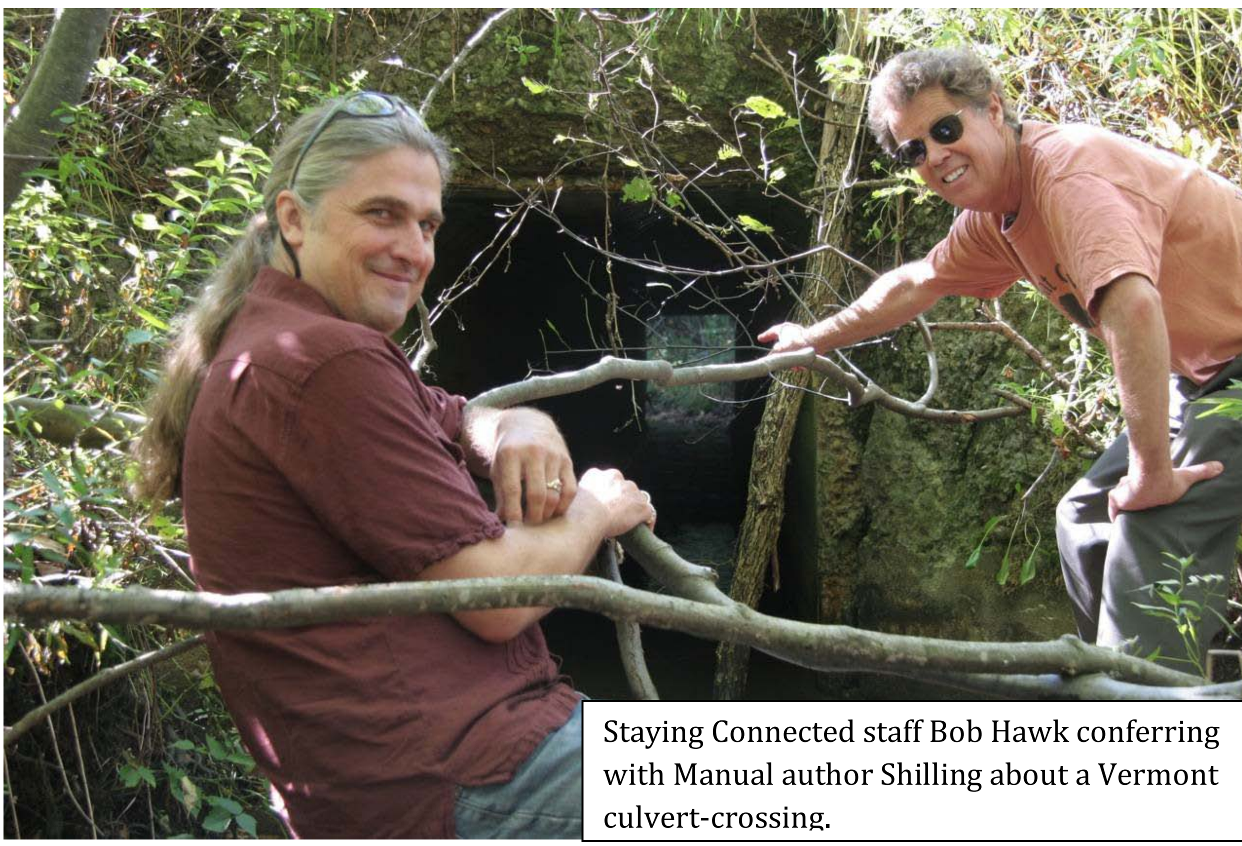
You could target certain sectors of the tax list, or members of certain associations. Or meet individually with individuals who are known to be interested.

12) Post project monitoring is important to document the success of the project (so you can do it easier next time)

(Steve Parren and Laura Farrell)

Maine and California have tapped into the interest and energy of citizen scientists and professionals alike by setting up websites to centralize roadkill observations in each state (http://www.wildlifecrossing. net/california and http://www.wildlifecrossing.net/maine). The goal of the California Roadkill Observation System, for example, is to encourage participation of large numbers of people in both understanding the extent of roadkill and helping develop innovative ideas for reducing roadkill. VTFW and University of Vermont are in the process of setting up a similar website, which should come on line in 2012.

Wildlife movement conservation partnerships in their many forms not only have great potential to provide reliable data over large areas but they also can help spur implementation of much needed projects in priority areas – and they can help provide the political backing needed to get such projects accomplished. Nevertheless, these partnerships often suffer from low or inconsistent funding, so every effort should be made to find sustainable sources of funds as these initiatives are being developed. Some efforts, such as committees of agency, academic, non-profit personnel, and the public do not need to be funded, but the actual mitigation is the piece that needs monetary support.



Staying Connected staff Bob Hawk conferring with Manual author Shilling about a Vermont culvert-crossing.

Utah's US 6 Wildlife Coordination Committee

In 2011, the US Federal Highway Administration awarded the multi-partnered US Highway 6 Wildlife Coordination Committee an Environmental Initiative Award. This committee worked together to plan for wildlife over a 75-mile stretch of road through the mountains of central Utah. Improvements to US 6 are planned to occur over a 20-year period as funding becomes available for individual roadway projects. Wildlife mitigation efforts are occurring project by project until the entire corridor is completed. To help develop these mitigation measures on a project-level basis, a Wildlife Coordination Committee (the Committee) was established. The Committee is able to keep a broad perspective of the entire US 6 corridor while developing individual project mitigation to benefit the ecosystem as a whole.

The Committee comprises individuals from Federal Highways Administration, Utah Department of Transportation (UDOT), U.S. Fish and Wildlife Service (USFWS), Utah Division of Wildlife Resources (UDWR), the Bureau of Land Management (BLM), Uinta National Forest Service (USFS), and Utah State University (USU). The Committee fosters information sharing and collaboration by meeting twice yearly and stays in communication between these dates. It is also charged with the efficient administration of funds set aside for impacts to biological resources.

Since 2005, the Committee has collaborated wildlife mitigation options, including four wildlife crossings; developed mitigation proposals for future crossings; and determined the priority of and locations for wildlife crossings, fencing, and escape ramps. Ongoing research supported by both UDOT and UDWR continues with USU researchers to evaluate the efficacy of the wildlife crossings and fencing in funneling mule deer, moose, elk, and other wildlife to the crossings. Collaboration between the participating agencies, as encouraged by the Committee, continues on other unrelated projects.

US 6 Wildlife Coordination Committee members at US 6 Starvation Creek culvert pre-construction

US 6 Starvation Creek new wildlife crossing bridge post-construction

B.5 Monitoring and Adaptive Management

Monitoring wildlife movement and habitat occupancy is critical for good planning of wildlife crossing best management practices and to understand the effectiveness of practices. The assumption in the Manual is that VT agency decisions and actions will be informed by field monitoring and that effectiveness monitoring will be used to improve future decision-making. Using monitoring information in this way is part of adaptive management and is a recommended BMP. A brief description is provided her of BMPs for monitoring. Additional, detailed information is provided in Appendix 5.

B.5.a Agency Detection and Monitoring Methods for Vermont Species

A number of detection and monitoring methods exist which can help determine where animals cross roads and where they occur on the landscape. These are equally applicable for planning purposes and for post monitoring of installations to determine use and success. More rigorous data collection that can help to determine fine scale movements and habitat use by animals depends on radio-telemetry and GPS collars. These can be fitted on animals as small as mice. Smaller animals can best be monitored with pit tags (inside their bodies), and ear tags and then recaptured. The more passive methods, including cameras, detection dogs, hair snares, track plates, and snow tracking, are all noninvasive, and do not necessitate interaction with animals.

Trapping and Monitoring Animals

Trapping animals involves two types of methods, based on animal size: collaring and tracking them with radio and Global Positioning System (GPS) technology, or trapping them and fitting the animals with pit tags, ear tags (small animals), or collars (large animals). GPS collars track satellites and take a reading on the animals' location at regular intervals throughout the day and night, and the data is either live fed to a website (expensive) or loaded on the collar (less costly). This technology provides precise animal location data, but is costly (GPS collars can cost $2,000 to $4,000 for a large ungulate) and somewhat invasive in that it involves capturing and collaring animals, but provides intensive data which is invaluable in determining how an animal moves across the landscape, including where it may have crossed a road. Tags allow specific animals to be re-trapped and their movements and habitat preferences tracked. Bellis (2008) performed these types of studies in conjunction with monitoring cameras at the Bennington Bypass bridges in southern Vermont.

Censusing with Non-invasive methods

Non-invasive methods, including fecal pellet surveys, scat sniffing dogs, snow tracking track plates, hair snares, nest, hiberium, and bird surveys, road kill carcass surveys, hunter surveys, aerial flight surveys, and camera monitoring are lower in cost than GPS collars and monitoring and can provide multiple species and region surveys for costs similar to a single species GPS study. For site monitoring where cost, or more precise estimates of the date of a species use of an area are considerations, these more passive methods with longer latent times to detection may prove just as effective, if deployed for the correct length of time in the most opportune season(s). More detail is provided in Appendix 5.

Remote motion-sensed cameras are a cost-effective and increasingly-popular method for surveying wildlife at fixed locations. These cameras are triggered by movement or heat in motion. They take anywhere from one to 10 pictures, or video when triggered, and can sometimes remain activated as long as there is motion. Date and time stamps are standard for most cameras, and can provide precise information on times of wildlife visits. The professional cameras made by the companies Reconyx and Bushnell (2011 Trophy Cam) are used by wildlife researchers across the world, and have proven to be the most reliable and accurate wildlife research cameras. These cameras must be mounted and locked in protective boxes so they are not stolen, since they cost between $200 and $600.

Monitoring Cost

There are several ways to cost-effectively monitor the use of crossing and thus determine how well they meet biological and management goals. These methods vary in cost and in the types of information provided. Parks Canada commissioned a recent study of the most economical ways that local organizations and agencies could scientifically monitor wildlife movement and use of crossings (Ford et al., 2009). For short-term studies (several months to a year), the most economical method that provided sufficient data was the use of track-pads, which is a way to record the type and sometimes individual animal crossing a particular area. For longer-term studies (>1 year), the most economical method was the use of cameras alone. Cameras have high up-front costs, but for many hundreds or thousands of crossings and over long use-periods, they are less costly per animal passage than track-pads, require less maintenance and can withstand a wider range of weather conditions.

B.5.b Citizen science collection of opportunistic live and dead wildlife observations on roads

People from all walks of life observe live and dead wildlife while they are on roads. Formal surveys of road-killed animals are sometimes used to indicate where animals are trying to cross roads. Many surveys of live animals have taken place on roads because they provide a way of covering large areas and because roads provide a means to survey live and dead animals. However, it is a biased method, because the surveying is only representative of "roaded" parts of the landscape.

For transportation agencies, understanding where and what kinds of animals are moving near and across roads is important information. Transportation agency biologists, resource agency staff, and increasingly citizen scientists can provide wildlife observations from opportunistic events or from formal surveys along roads. Maine Audubon collaborated with the Road Ecology Center at UC Davis to develop a program where citizen scientists report live and dead wildlife observations along roads and highways (Maine Audubon, 2010). Although anyone can participate, at least a third of the observers on this system are professional scientists. Currently, this system provides the most extensive wildlife reporting process in the state of Maine. In Vermont, the Vermont Herp Atlas provides a similar service for observers of herpetofauna (reptiles and amphibians). A combination of involved citizenry, robust surveying protocols, and easy-to-use reporting tools could make this a powerful approach.

Data Quality

A common concern about citizen science projects is that the resulting data may be of low or unknown quality. When observers upload photographs of the animal with their record, then independent verification of species identification can be carried out. In a wildlife observation system in California (http://www.wildlifecrossing.net/california), it was found that species-level identification of road-killed animals was >95% accurate, with similar locational accuracy (Shilling, unpublished observations). If data are to be used from citizen monitoring to support wildlife passage management actions, it would be appropriate for VF&W to verify the data quality prior to use. Given the very high data return rate on investments in citizen science programs, it is worth considering this method for both opportunistic and formal surveys of live and dead wildlife associated with roads.

Data Collection

Agency staff collection of wildlife observations is an increasingly-common method for obtaining large amounts of data about wildlife-road associations. Staff involved in roadkill carcass collection, or casual live animal observations, are unlikely to be expert taxonomists. Environmental scientists and biologists with VTrans could conduct surveys of highway corridors or regions. Surveying frequently (<weekly) over short periods can provide seasonal estimates of impacts of highways on animals (carcass surveys) or potential impacts (live and dead observations). A simple approach to adapt data collection to smart phones and online systems is to make sure that the web sites are usable on the smart phone screen itself, avoiding the cost of phone app development, adaptation and upgrading. This is the system used in Maine (http://www.wildlifecrossing.net/maine).

It is likely that the combination of agency staff and citizen scientist-collected data will provide the richest and most useful set of wildlife observations. By standardizing how data are collected and reported, analyses can be conducted using both datasets.

Lead Entities

Vermont's Regional Planning Commissions (RPC) are an appropriate lead entity for collecting or collating local agency and citizen-science based wildlife observations. The RPC geographic scale is good for understanding how wildlife are moving in a region and locally. In addition, the RPCs are often involved in land-use, transportation, and cultural processes and decision-making. Supporting RPCs in a role to bring together local and regional knowledge and data about wildlife occupancy and movement is an excellent management practice.

C. Project Design and Construction

[Insert tab page here]

C. Project Design and Construction

Structural retrofits of existing roads, culverts, and bridges are a typical and effective way to improve wildlife movement and connectivity, as well as benefiting human safety. This section describes considerations for placement and management of these structural retrofits. The BMPs described here are complementary to the planning BMPs in that good planning is often a necessary precursor to retrofitting roadways for wildlife movement.

C.1 Enhancing Existing Structures

Many existing structures that permeate the right-of-way, such as culverts, natural feature bridges, street over and under-crossings, and rail crossings, may already provide a path for animals to traverse road and highway rights-of-way. This section describes our understanding of wildlife preferences for different structure types, determining actual use of these structures, and planning for existing structures.

Many existing structures may not be used by wildlife, but if they were enhanced (or retrofitted) through sometimes very inexpensive measures, they could become useful crossing structures. Enhancements include: wildlife sidewalks, culvert enlargement, culvert ledges, and benches under bridges, among other retrofits.

Enhancing or retrofitting existing culverts, bridges, fencing, and other transportation infrastructure can be cost-effective actions that create more permeable passage for all wildlife in an area. These enhancements can be classified into six types:

1. remove obstacles,
2. facilitate movement and create pathways,
3. reduce intimidation,
4. enhance structures' approaches,
5. addressing the fencing and barriers,
6. and add or adjust structural features.

These enhancements can be as simple as repairing fencing, to more involved actions such as adding several dump trucks of soil on top of rip rap to create a wildlife-friendly path under a bridge.

Departments of Transportation have traditionally lacked a means for understanding how transportation infrastructure currently functions to support or impede connectivity for terrestrial wildlife. Recent research Cramer and Kintsch (2011) completed for Washington DOT (WSDOT) created protocols for evaluating existing structures – bridges and culverts – with regards to their potential to pass different types of wildlife. The Passage Assessment System (PAS) created from this work provided an assessment process that differentiates – among different types of wildlife – between structures that are currently functional, those that could be enhanced to become more functional, and those that are not functional for wildlife passage. In this manner, the system enables transportation agencies to evaluate infrastructure in a standardized manner, and prioritize these enhancement opportunities for the greatest cost efficiency, and identify locations where improved permeability will require new infrastructure investments.

In order for Vermont to initiate such a system of evaluation of bridges, culverts and other infrastructure, several steps would first need to be taken.

1. Vermont would need to have a collective understanding of wildlife connectivity is present or restorable, in order to pinpoint areas in the state where restoration of wildlife movement is important. Given the natural land cover across the state, a majority of the state could fall into this category. In turn, where these existing or restorable habitat areas were bisected by roads would be the priority areas to begin a Passage Assessment System evaluation.

2. The state long term and STIP plans would need to be reviewed by the biological personnel within VTRANS to identify sections of roads that will be receiving transportation funds for upgrades. These areas could then also be improved (retrofit) in those operations and possibly with additional funds, new wildlife crossing structures or fencing could be constructed. Since the fall of 2011 when dozens of culverts and bridges were temporarily repaired following Irene, any list of new projects that address these structures would also be an opportunity to build in retrofits for wildlife.

3. Appendix 3 of this document details what constitutes the PAS. The original PAS needs to downloaded from the internet (URL: http://www.wsdot.wa.gov/research/reports/fullreports/777.1.pdf) and VTrans and Vermont Fish and Wildlife personnel can create a Vermont-specific version of the questionnaire to be used at existing culverts and bridges.

4. The species of interest for every biophysical region of Vermont would need to be incorporated into the PAS for each region so biologists conducting the surveys knew what species they were evaluating the culverts and bridges for movement potential underneath the road. That table is available in this report, Table 4 Biophysical Regions of Vermont and Potential Target Species.

5. Training of biologists who would potentially use this system is important to create a common understanding of what structures wildlife are thought or known to use to safely pass under roads, and the potential retrofits available to improve that movement, such as that found in Appendix 4.

6. The information would need to be input into VTrans databases for planning purposes. This information would include the results of the questionnaire, pictures, and suggestions on retrofits.

C.1.a Factors that Affect Wildlife Use of Structures

There are many interrelated factors that affect an individual animal or a population of animals' decisions to use crossings. The two main factors that affect these decisions can be grouped into characteristics of the external environment and internal motivations based on the biology of the species. Understanding why animals behave the way they do and their basic biological needs is an essential component to help planners, biologists, and engineers design suitable wildlife crossings and enhance existing infrastructure that considers both the internal and external factors motivating animals to use or avoid a given structure.

Biological factors important to wildlife movement include the following (note that not all of these factors are of equal importance for all species):

- Mode of locomotion, i.e., crawling animals move differently than running animals and may spend more time in a crossing structure;
- Predator avoidance strategies, i.e., the need for prey species to feel safe using a crossing structure;
- Defense strategies, i.e., skunks stop to spray a threat, while porcupines back up to it, and rabbits and deer may run in a zigzag fashion;
- Herd mentality versus solitary movement;
- The need to access basic resources such as food and water;
- The need to find mates;
- The need to migrate to meet basic biological needs such as breeding, calving, egg laying, winter, summer habitats;
- The need to escape human pressures such as development or recreational activities;

- The need to disperse to establish new territories;
- The need for specific types of habitat such as a semi-aquatic condition.

Environmental factors that affect how wildlife perceives structures for potential passage include (note that not all of these factors are of equal importance for all species):

- The presence of natural area or specific habitat on both sides of the road;
- The presence of human development or disturbance nearby or within the structure;
- Vegetative cover leading to the structure;
- Vegetative or woody debris cover within a structure;
- Visibility through the structure and at the approaches to the structure;
- Light contrast inside and outside of the structure;
- Elevation gradients that may affect water flow or large gradients that may affect an animal's approach to a structure;
- Traffic noise that is present outside the structure and that may be amplified inside or changed in pitch inside or beneath the structure;
- Traffic volumes, i.e., heavy traffic volumes may deter animals from coming near the road, and crossing through a structure, while low traffic volumes may encourage animals to cross at-grade rather than use structures unless they are otherwise prevented from doing so with fences or other funneling devices;
- Similarity of the conditions in, under or on a structure relative to the natural environment in which it is located;
- The feel of openness (rather than confinement) for an animal crossing through a structure.

C.1.b Standards for Classifying Wildlife and Structures

In order for a standard to work across a state and other areas, there needs to be common understandings of types of transportation infrastructures such as culvert sizes, and types of wildlife, such as taxonomic groups (animals that have similar characteristics). Below, a quick guide to structure classification used in this assessment (Table 6), and types of wildlife taxa are presented. Also see Table 3 in Section B.3 for species movement guilds. In developing the PAS, it became first necessary to refine our understanding of how landscape and structure characteristics affect a species' willingness to pass through a structure. The researchers developed a classification system for wildlife based on how different types of species move and behave, and how they perceive potential crossing structures as understood from past and current scientific studies. The resulting *Species Movement Guilds* provide a unique classification designed to facilitate an understanding of 'what works' for different types of wildlife see Section B.3, Table 3, above.

A 'wildlife crossing structure' connotes many different structures from the smallest culverts that may pass a salamander, to the space under an expansive highway viaduct. To characterize these distinctions, the researchers defined *Structure Functional Classes*, providing a breakdown of the types of road crossing structures that can function as passageways for wildlife under or over a roadway and the types of wildlife that may use these structures (Table 6). The critical dimensions for breaks between classes are dictated by engineering designs as well as the characteristics that define individual species' willingness to move through a structure.

C.2 Building New Wildlife Crossings

This section gives guidance in creating new structures to promote wildlife connectivity in transportation corridors. These new structures may replace existing structures that failed during Irene, or have been found to be under-sized, or were due for replacement anyway. In rare cases, new wildlife crossing structures should be built where there are wildlife movement needs, but no existing structure to facilitate movement.

When transportation is planned within natural settings, the first mitigation priority is to avoid destruction or harm to natural areas. The second priority is to minimize the size of the road footprint and effect on the natural world. The final priority, after avoidance and minimization of harm is compensatory mitigation. The options to mitigate existing road infrastructure (Section C.1) are the dominant choices of states with little new road building. The 2011 transportation planning environment that occurred with the passing of Hurricane Irene created a unique situation where Vermont had to replace dozens to hundreds of culverts and bridges washed out from flood-swollen rivers and streams.

When transportation planning is carried out with concern for the natural world, wildlife mitigation can be planned for and constructed in a systematic manner. This section reviews the steps to implementing wildlife connectivity mitigation. It begins with the methods to determine the best placement of wildlife crossings, and then discusses the frequency and size of crossings, crossing configuration, maintenance needs, estimating cost-effectiveness, determining the monitoring and evaluation plan, constructing the passage, and the final monitoring plan, the results and how they can be evaluated and used to adaptively manage, see Figure 2. Several of the points covered in this section are interwoven with other areas of the report.

C.2.a Placement of Crossings

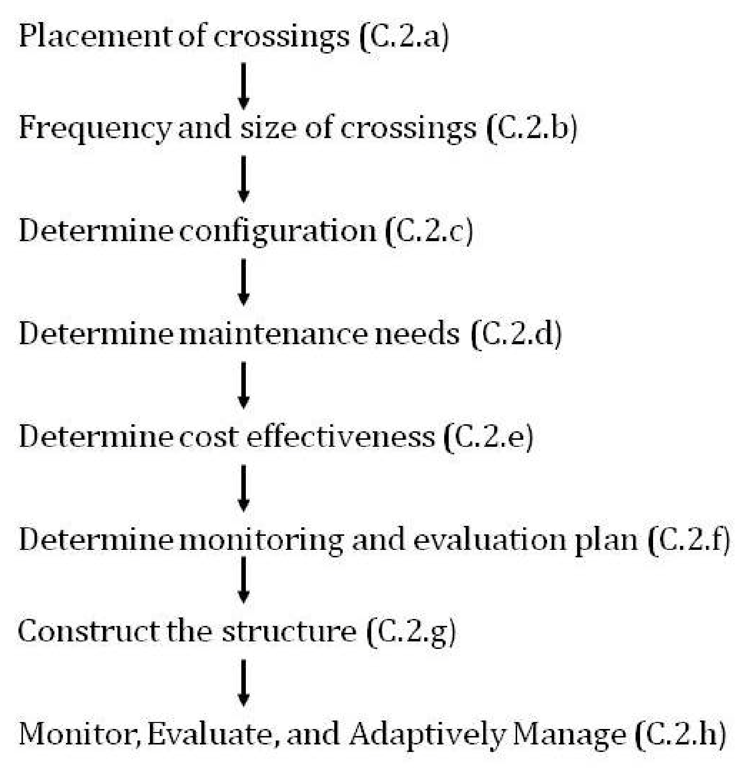


Figure 2. Flow diagram of steps to create new wildlife crossings, as covered in Section C.2.

The placement of wildlife crossings is an important step in the creation of mitigation for wildlife and depends on ecological and safety factors. Successful crossing placement relies on understanding where wildlife is most likely to approach a road. (Barnum 2003a, 2003b Barnum et al. 2007). It is clear from recent research that places where animals are hit by automobiles on roads are not necessarily the same places where they first approach the road Right-of-Way (see below). Effective mitigation placement, which includes siting fencing, escape ramps, and other mitigation, can first be generalized to certain sections of road through coarse scale analyses (e.g., hotspots of wildlife-vehicle collisions, or where protected lands exist on both sides), and then more specifically placed with finer scale methods (Section B.3). These methods are described largely above in the fine scale analysis for connectivity, but also include:

- consideration of land ownership and protection from development in perpetuity;
- characteristics of the area at the openings of the mitigation as a natural movement area with appropriate vegetative cover and landscape variables conducive to movement, such as topographic gradients;
- pre-construction monitoring and studies to determine what species of wildlife are in the area and how they prefer to use the landscape near the roadway (vanManen et al. 2001); and
- GIS modeling for specific species' movements across the road (Alexander et al., 2004)

C.2.b Frequency and size of crossings

The size and frequency of wildlife crossings should be determined by the size and movement of target species in the area of concern. In general, smaller animals need more frequent and smaller crossing structures than larger animals, because of a combination of smaller home ranges and tolerance of smaller, more-confined spaces. Planning for a combination of crossing sizes at distances along a highway that suit animal home ranges is more likely to result in effective wildlife movement and connectivity than infrastructure placed without input on wildlife needs.

Advantages

Grouping wildlife species and planning a network of crossings possibilities for these groups is probably more cost-effective and efficient than dealing with individual wildlife crossings. This can be done first by grouping wildlife species according to wildlife species movement guilds, (Section B.3 Table 3), and by grouping types of structures based on their size and type (Table 6, below). These overall generalizations can help transportation and wildlife professionals and others to "speak" the same language in planning for wildlife movement under and over the road.

Description

Sufficient size (combination of cross-sectional area and length) and frequency (number of crossings per unit length of highway) of wildlife crossings can be calculated for groups of species found in a particular area. Although large crossings can accommodate small animal movement, small crossings are typically only used by small animals. The openness ratio (Figure 3) is one way that the potential adequacy of a structure for wildlife passage can be assessed (AZDFG, 2006). Larger animals will tend to tolerate only greater openness ratios, meaning a combination of larger cross-sectional areas and shorter traverse distances (Table 5). Medium and smaller mammals and herpetofauna (amphibians and reptiles) may tolerate smaller openness ratio, but will vary in their sensitivity to enclosed spaces.

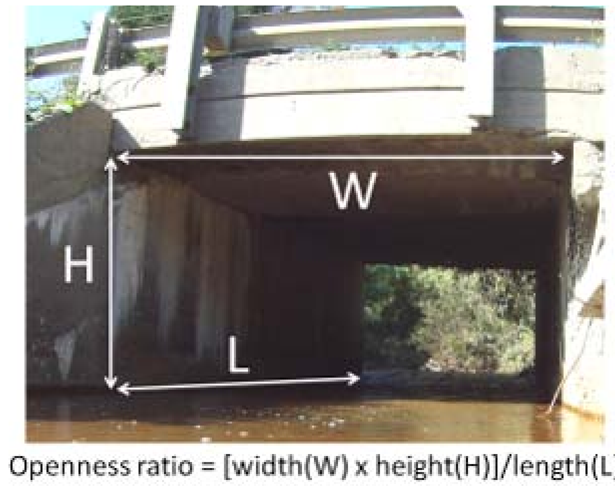


Figure 3 Method for calculating the openness ratio of a wildlife under-crossing structure (Arizona Department of Game and Fish, 2006).

In any given network of roads and highways, there are areas with sufficient culverts and bridges to provide animals of various kinds to safely cross and other areas needing retrofitting and enhancement. The main issue is finding the right combination of higher frequency small crossings and lower frequency larger crossings to meet the needs of a wide range of species.

The Arizona Department of Game and Fish developed guidance for bridge and culvert planning to meet the needs of fish and wildlife (AZDGF, 2006 and 2008). Both sets of guidance address the size of crossing structures to meet the needs of various species groups. The culvert guidance also includes a description of approximate frequencies that are needed by different size-groups of wildlife. These approximate frequencies are shown in Figure 4 for a stretch of Route 100 near West Bridgewater, Vermont.

Bissonnette and Adair (2008) used principles of scaling of animal size and movement distances to recommend approximate intervals between crossings. They used animal species' typical home range sizes (area) and dispersal movement distances as a function of body size to determine how far a species would move in search of a pathway under the roadway. Typical distances are approximately one mile maximum between crossings for all deer species where there are wildlife-vehicle collision (WVC) hotspots and dozens to hundreds of yards for smaller fauna such as reptiles.

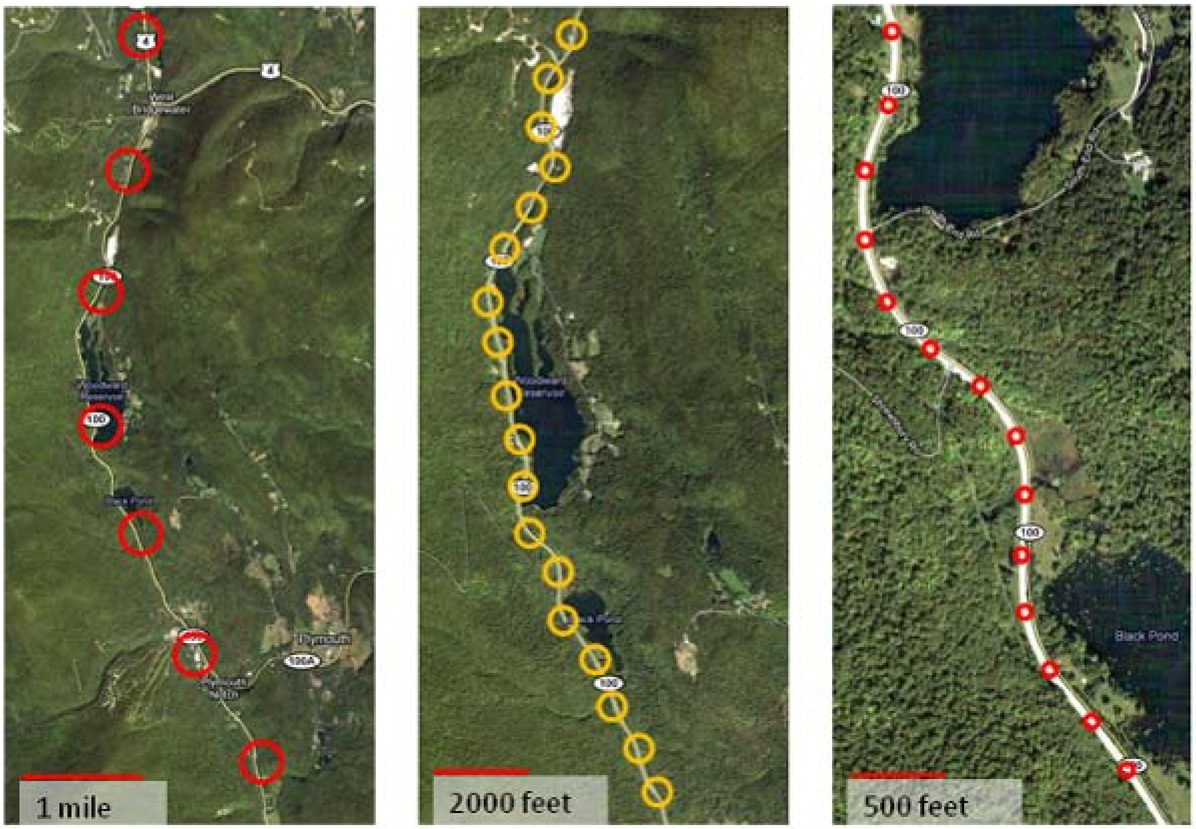


Figure 4 Representation of minimum crossing structure frequency. Based upon the AZ Department of Game and Fish (2006) guidance for culverts, for Route 100 between West Bridgewater and Plymouth Notch. The pictures from left to right zoom in on an area between the reservoir and the pond. Large red circles represents approximate locations for large mammal crossings, medium-sized orange circles represents the approximate locations for medium-sized mammal crossings, and small red circles represent approximate crossing frequencies for small mammals, and herpetofauna.

<u>Limitations</u>

Although grouping species provides more efficient planning processes, not all species fit well within groups. Individual species may have special habitat requirements or behaviors which make them fit poorly into groups with other species. In addition, general rules about crossing sizes (e.g., the use of the openness ratio) may not suit all species equally. Compensating for these limitations can occur by considering the needs of individual species and ensuring that they are met in a system planned for groups of species. This is often accomplished in conjunction with wildlife professionals in both agencies and academia.

Table 5 Crossing size requirements for various animal groups

Animal Group	Crossing Width	Crossing Length
Herpetofauna	1-2 feet okay	Short as possible (under 200'), need natural lighting for longer crossings
Small mammals	>1 foot high, cross-sectional area 2-4 square feet	Need natural lighting for longer crossings, keep length <250'
Medium mammals	>3 feet high, openness ratio >0.4, cross-sectional area >60 square feet for >75-foot crossing length	As short as possible (<300')
Large mammals	>6 feet high, openness ratio >0.9, cross-sectional area >30 square feet for >75-foot crossing length	Open line of sight to other end, keep <200'

C.2.c Types of Structure: Culverts

Roads may initiate channels or contribute to their initiation on slopes, connect drainages, and otherwise exacerbate natural geomorphic and hydrologic processes (Montgomery, 1994). The combination of roads and road-facilitated land development can be the predominant cause of erosion, channel geomorphic change, and radical changes in local and watershed hydrology (Sidle et al., 1985; Reid, 1993; Reid and Dunne, 1996). Drainage-management facilities like culverts are the water and sediment work-horses of the highway system and when well-planned can reduce road impacts on natural processes. When appropriately sized, these facilities will allow un-hindered geomorphic and hydrologic processes to pass through the network of roads and highways. This is not just to protect the health of streams, it is also to preserve the transportation system itself, as well as upstream and downstream lands and communities. When culverts are too small, not only can they wash out, as about 1,000 did during Irene, but they can accelerate flows, eroding upstream and downstream river-banks and stream-beds. This can exacerbate the damaging effects of storm and flood events.

Culvert Sizing

In general, building bigger culverts is better for water, sediment, wood debris, fish, amphibians and wildlife (Figure 5). Fish passage culverts that have been slightly enlarged for terrestrial wildlife have been shown to be effective for this purpose (Cramer et al. 2011). Deer seem to prefer more open spaces and greater height is less important than greater width in culverts (Cramer et al., 2011). If a culvert can be enlarged with modest increases in cost, it is likely to also be beneficial to multiple species of wildlife (see information box below).

Figure 5 Bobcat crossing under California interstate via a 60" diameter concrete culvert

In a large fill area, smaller culverts could be placed in the lower area of the fill, along with the larger culvert, to allow smaller wildlife species to move through a more protected culvert. Bellis (2008) found medium sized mammals such as raccoons, otter, and mink using a 300 foot long culvert under the fill at the Bennington Bypass bridges.

Enhancing Existing Culverts

Many culverts are made of corrugated metal or ABS (plastic), neither of which is an attractive surface for wildlife movement. Wildlife will tend to prefer flat surfaces with some texture to provide traction. Corrugated pipe can be surfaced along the bottom with enough concrete to provide this surface without inhibiting the hydrologic or geomorphic (sediment-moving) function of the culvert. Another approach is to create ledges along the side of culverts that allow small and medium mammals to walk above water that may be moving through the culvert (Leete, 2010).

Washington Fish Passage was Enlarged with Success for Terrestrial Wildlife.

When Washington DOT (WSDOT) fish biologist Jon Peterson designed a fish passage culvert at Mosquito Creek along US 101, he also created a successful terrestrial wildlife passage. The first priority for this culvert was fish passage, but WSDOT informally agreed to do a "stream simulation" design, which is 1.2 times the width of the stream plus two feet. This is done on the majority of their fish passage projects (see Washington Department of Fish & Wildlife (WDFW) design guidance at http://wdfw.wa.gov/publications/00049/wdfw00049.pdf) in part because WSDOT is being sued by 21 Western Washington Tribes in Federal Court. The culvert was built primarily for fish, but was also built to be six feet tall, to accommodate deer.

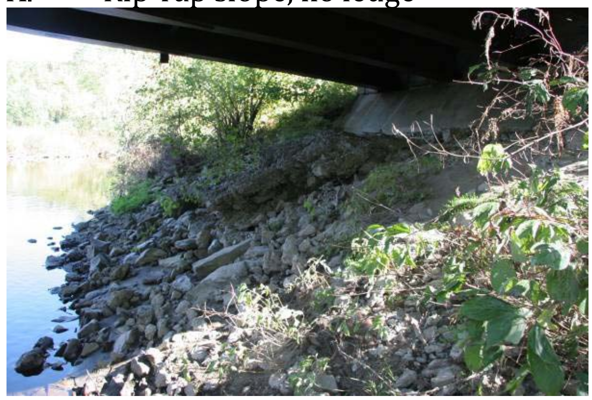
In 2010 wildlife monitoring cameras were placed on this culvert to see if it functioned for terrestrial wildlife as well. Hundreds of picture of black tailed deer were generated in the first four months of monitoring (see picture below; Kintsch and Cramer 2011). Jon Peterson wrote in an email, "*It has opened our eyes to the fact that if you make the structures a little wider and taller than what you would "normally" do for fish you can get the added benefit of wildlife passage*." Jon also gave advice on this culvert for this VTRANS Best Management Practices Manual: "*For Mosquito specifically we were going to build it at 16 feet wide as per WDFW guidance for stream simulation design. The taller part of the project can be tricky if there isn't enough fill height in the road already. It isn't economical to build up the road height. If you have good road height already, then, making the structure taller is just a matter of having the concrete manufacturer making the 3-sided precast culvert a little taller, which we feel really doesn't add much cost. We don't really have any quantifiable information on that. I guess someone could ask a manufacturer like Contech (*http://www.contech-cpi.com/*) what the cost difference would be. The pre-cast structure (16' wide x 10' rise x 138' length for Mosquito Creek) was $92,000 and the expensive part is digging out the fill and putting the structure in. The engineer's estimate for construction was $868,331 and the low bid was $728,349*." The bid for the project: http://www.wsdot.wa.gov/biz/contaa/BIDTAB/JUL/JULY2009/09C509.PDF
Project plans: ftp://ftp.wsdot.wa.gov/contracts/7784MosquitoCreekFishPassagePlans.pdf/

Black tailed deer use Mosquito Creek culvert in Washington. Photo credit: P. Cramer, J. Kintsch, and WSDOT.

C.2.d Types of Structure: Bridges and Revetment

Bridges often span locations ideal for wildlife movement (riparian areas). Depending on the bank treatment, space between the waterway and bridge abutments, and vegetation, wildlife may pass under the right-of-way using bridges. Erosion-reduction treatments (revetment) are often made from rip-rap (large rocks), or a mixture of rip-rap and concrete (Figure 6A). Larger animals, including ungulates, will tend to avoid these types of surfaces. Alternative revetment involving soil and vegetation treatment of rip-rap can provide surfaces that are still resistant to erosion, but provide surfaces attractive for wildlife movement. Alternatively, a soil ledge away from regular stream erosion (e.g., near the bridge abutment, Figure 6B) may provide a pathway for wildlife.

A. Rip-rap slope, no ledge



B. Dirt ledge and vegetated slope

C. Un-developed (dirt) sidewalk adjacent to a minor street, underneath an interstate

Figure 6 Wildlife sidewalks under highway over-passes.

Stumps, logs, and other woody debris can be placed in a line under a bridge or through large culverts to promote smaller animal movement. These smaller animals such as snakes and small mammals use the woody materials as hiding cover to pass under the road. This type of woody material placement is common in Europe. Bellis (2008) used this type of woody materials for smaller wildlife under the bridges in Bennington Bypass.

Street over and under-crossings provide an opportunity to send wildlife alongside secondary roads, rather than across a highway surface. An un-developed (dirt) surface could provide a wildlife sidewalk alongside the secondary road, under the highway (Figure 6C).

C.2.e Openings: Vegetation, Fencing, & Light

Vegetation-choked culverts don't pass water or wildlife. Although most wildlife like some vegetation cover on the approach to a culvert or bridge, they may not enter if they can't tell what is on the other side of that curtain of vegetation. Keeping a clear and naturally-vegetated path for water will often be perfect for wildlife too (Figure 7A). When planting vegetation at a site, at the crossing/culvert/ bridge entrances, plant vegetation preferred by white-tailed deer and moose. This can act to encourage these species to use the structures. Check with Vermont Fish and Wildlife on appropriate plant species.

A smooth, at-grade transition from the natural landscape to the inside of a culvert helps manage storm-water and can often help wildlife too (Figure 7B). A fenced-off approach, one that is over-grown, or one that is flooded even in mid-summer doesn't help wildlife much. If they can easily slither, crawl, or walk from a stream-bed, or riparian area onto a textured culvert bottom surface, they are more likely to cross through.

Small and under-sized culverts don't pass much water, or light. For most animals, if they can't see the light at the end of the tunnel, they won't enter. Light at the half-way (median)

A. Appropriate vegetative cover in front of an arched box culvert opening

B. At-grade transition of textured-concrete culvert scaled to stream size

C. Well-lit box culvert, with down-welling light at mid-point

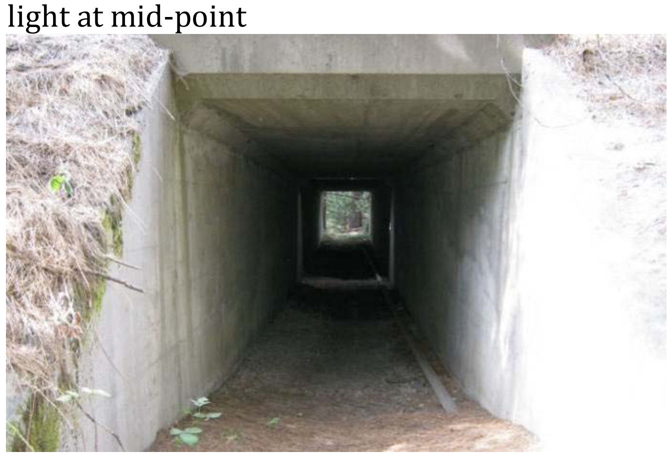


Figure 7 Culvert attributes appropriate for wildlife.

point, or larger culverts, will pass light (and lots of water and sediment, Figure 7C)

If there is a need to re-install field fence (typical right-of-way fence), the kind that keeps wildlife off of roads, use rail fencing at the entrances to bridges and culverts so wildlife, especially young deer and moose, and smaller wildlife, can access the entrance. Rail fencing is made of 2 to 5 inch logs, and placed at least 14 inches off the ground to allow these smaller animals to crawl under. See Appendix 4 for photographs.

Any excess dirt from these replacement operations could be piled at the edge of the road right of way for future use as escape ramps for wildlife caught on the road where there is or will be wildlife fencing.

C.2.f Determine Configuration

Wildlife use wildlife crossing structures according to their genetics and experiences. If their bodies, modes of movement, and predator avoidance strategies dictate what they do when they detect a road and then when they encounter a wildlife crossing or retrofit structure, it is their experiences that help them decide to use that structure. Wildlife can learn to override their instinct to avoid such structures, to a point. It is largely up to the humans to make structures and the approaches to the structures as wildlife-friendly as possible. In order to make sure the types of structures chosen align with the types of wildlife movement, the Species Movement Guilds and Structure Classes approach is used (Kintsch and Cramer 2011, Table 3, Section B.3, and Table 6, below). The approach generalizes both the wildlife and the structures to give a well informed idea of what different kinds of wildlife will use. In Table 3, Species Movement Guilds above, wildlife species types are classified according to how they move, avoid predators, and the kinds of wildlife crossing structures they've been documented to use. In Table 6 (Structure Classes) the types of structures wildlife will use are classified as to the species movement guilds in Table 3. These tables will give planners a better idea of what structural configurations will pass specific wildlife types.

Table 6 Crossing structure classes viewed from a wildlife perspective. Generally, species that use small structures will use larger structures if appropriate cover and other features are provided, but most species cannot use smaller classes. This table is for terminology only and is not intended to be used for structure design. It can be used for generalized discussions early in planning process. It is not intended to be prescriptive since each site requires site-specific planning by qualified biologists and engineers. Developed in Kintsch and Cramer 2011.

Crossing Structure Category	Function	Approximate Dimension Range (Span x Rise)	Passage Examples	Species Examples
Class 1: Small Underpass	Provides enclosed protection for small animals that require cover.	Metal pipe culverts or small box culverts 1.5 m (5') span or less	Small bridges, dry culverts, and ephemerally flooded drainage culverts. Continually flooded drainage structures have limited functionality for terrestrial species but may function for some aquatics.	Amphibians, reptiles, small mammals and some medium-sized mammals (badger, fox, bobcat). Aquatic species include fish, aquatic amphibians, and invertebrates.
Class 2: Medium Underpass	Provides some cover yet more openness than Class 1 structures for animals smaller than deer. If water is conveyed, allows for stream simulation including unwetted natural banks.	Underpasses larger than 1.5 m (5') span, to 2.4 m (8') span x 2.4 m (8') rise	Box culverts, arch pipes and other culvert shapes, small bridges.	Coyote, bobcat, ocelot, lynx and some large carnivores (black bear, puma); alligator.
Class 3: Large Underpass	Provides an approximate minimum for ungulates, especially deer, and other species that require visibility, maneuverability, and moderated noise. May allow some natural processes including vegetation growth	Underpasses with minimum dimensions: 6.1 m (20') span x 2.4 m (8') rise, or 3.1 m (10') span x 3.1 m (10') rise, and open span bridges	Box culverts, large arch pipes, bridges including open span bridges. Multiple chambered structures are considered as individual units.	Ungulates use structures in approximate proportion to their size (ie, deer can use smaller structures than elk or moose) although pronghorn require larger structures (minimum 18.3 m span x 5.5 m rise). Large carnivores (wolf, grizzly bear, black bear, puma).

Crossing Structure Category	Function	Approximate Dimension Range (Span x Rise)	Passage Examples	Species Examples
	and stream processes.			
Class 4: Extensive Bridge (includes Viaducts)	Allows ecosystem processes to permeate highway such as wetland water flow, vegetation growth, and entire floodplains. Provides excellent horizontal visibility for animals requiring openness.	Bridge extending over several spans. Designed for each site so dimensions vary. May allow more sunlight under structure than other types.	Viaducts are long bridges elevated over the landscape in a series of smaller spans, often connecting points of equal height. Typically over wetlands, steep terrain.	Most species including wetland species, birds, pronghorn.
Class 5: Wildlife Overpass	Provides an open top and expansive visibility of the horizon for animals preferring unenclosed spaces. Allows full sunlight and precipitation for vegetation growth. May allow small, sunlit water features.	Overpass structure for wildlife to pass over roadway, as small as 6.7 m (22') wide, but preferably at least 50 m (164') wide.	Overpasses with soil and plant growth.	All ungulates (pronghorn not proven yet), carnivores (bear, puma, forest carnivores). Songbirds and insects including butterflies.
Class 6: Specialized Culvert	Allows outside environmental conditions to occur within the entire structure, including light, temperature and moisture.	Current designs are small culverts less than .5 m (24") span but could be larger structures.	Trench drains and slotted culverts.	Reptiles and amphibians
Class 7: Canopy Bridge and Launching Platforms	Provides an arboreal passage for animals that typically do not descend below tree canopy to ground.	Adequate to cross all lanes. May be connected to trees in the median. Launching platform provides launch pads high above 2 lanes of traffic for flying squirrels	Treetop rope bridges, or modified wire or metal structures. 15 meter high wooden platforms for flying squirrel launches to other side of 2-lane road.	Squirrels, arboreal rodents, opossum, monkeys. Potential for insects and plants. Launch pad; all flying squirrel species.

C.2.g Determine Maintenance Needs

Wildlife crossing structures and their accompanying fences often need annual maintenance. It is essential that future wildlife mitigation be planned in conjunction with personnel involved in daily operations and maintenance of transportation infrastructure. Some types of mitigation, such as cattle and wildlife guards, need to be planned with equipment needs (such as snow plows) taken into account. Fencing needs bi-annual inspection for pull downs, holes, and missing sections due to vehicle crashes, and the funds for repair. Planners are advised to work with the state and town departments of transportation on estimating the maintenance needs, costs and schedules of mitigation. Further recommendations are made in Section D Operations and Maintenance.

C.2.h Estimate Cost-Effectiveness

Although most ecological mitigation helps ecosystems provide ecosystem services such as flood control and wildlife movement, there are few methods to calculate the value of those services. The most typical methods to evaluate the cost-effectiveness of wildlife mitigation is to calculate the predicted number of wildlife-vehicle collisions that would occur in the project area in the coming years, take an average cost per incident (using either Clevenger and Huijser 2009 or Bissonette et al. 2008), and estimate how costly the future accidents would be if no actions occurred to mitigate the situation. Then the cost of the mitigation is estimated, and amortized over the projected life time of the structure, and those costs are compared with the estimated costs of future wildlife-vehicle collisions.

Potential Planning and Structural Costs

The cost of carrying out the assessment and planning for this practice are primarily associated with the spatial planning (similar to Section B.1). The field component is primarily assessment of the existing capacity of the culvert and bridge network to meet the needs of wildlife movement, based upon the size and frequency guidance provided her. To be cost-effective, calculating crossing size and frequency could be combined with GIS assessment of connectivity (Section B.1) and the assessment of the existing system based upon knowledge of existing culvert and bridge dimensions and placement.

Building new wildlife crossings is sometimes the only solution to connection problems across road and highway rights-of-way. The most expensive of these solutions are wildlife over and under-passes that have similar dimensions to street over- and under-passes. These typically cost approximately $1-2 million for a 30- to 50-yard (span length) bridge under-pass, although installation of large pre-cast box or arched culverts has reduced the cost to <$1 million for under-passes that still provide wildlife passage (Huijser et al. 2007). In 2009 in California, Caltrans opened a bid for a box culvert under a rural 2-lane highway to facilitate deer crossing (bid # EA 03-2A6904) with a cost of $117,600 to construct the culvert and associated costs for 3 deer escape ramps (which allow escape from roadway, $30,000) and fencing ($50,100). This combined cost of $200,000 for a single new deer crossing is a reasonable estimate for permitting passage of all sized animals under 2-lane major roads and highways. In Utah, a recent wildlife underpass culvert in Utah (four lanes of road) cost $600,000 and in Montana and Nevada, the departments of transportation in those states were able to construct arched wildlife overpasses over two-lane sections of US Highway 93 for 1.8 million dollars each in 2009 and 2010. Costs would presumably be proportionally higher for segments with more lanes, or a wide road prism.

The materials costs of several types of structures for enhancing wildlife passage for a variety of mammals are estimated in Table 7 below and were derived from the 2003 Caltrans Contract Cost Data book, available at: http://www.dot.ca.gov/hq/esc/oe/awards/2003CCDB/2003ccdb.pdf.

Table 7: Crossing structure materials costs

Crossing Structure Type	Approximate Range of Cost(s)
Box culvert, Class 1 concrete	$565-$1,380/cubic meter
Box culvert, Class 2 concrete	$620-$3,630/cubic meter
12" alternative pipe culvert	$113/linear foot
18" alternative pipe culvert	$192/linear foot
1050 mm alternative pipe culvert	$1,250/meter

These costs vary based upon site and application-specific characteristics, and include material costs alone; installation and maintenance costs are additional. Collaboration between environmental planners, design engineers, and project manager are essential in understanding the design and costs associated with proposed structural improvements or installation.

C.2.i Construct the Structure

The construction phase is the end of the planning phase and beginning of the implementation phase. At this point, the DOTs have the majority of the responsibility for ensuring the agreements made to date are carried out in the spirit of the planners. An implementation liaison, can greatly assist in this effort. It is important to also develop the Request for Proposals (RFP) with the exact specifics of what the fencing, structure, contour of the lands, water flow, rip rap, vegetation and other specifics are to be. Also included in the contract should be detailed agreements on how the construction of mitigation components will be monitored to make sure all components are to specifications (Section C.2.j), and that monetary payments are tied to fulfilling these requirements.

C.2.j Monitoring and Evaluation Plan

If a mitigation project is created, it is essential the efficacy of that mitigation is evaluated. If taxpayers are expected to support agency efforts to help wildlife under and over roads, it is critical that wildlife crossing efforts are documented in their success. Monitoring wildlife mitigation costs approximately two percent of the total cost to install a crossing structure (Cramer 2011). It is important that mitigation areas are monitored pre-construction for at least one year. Research (Gagnon et al. 2011, Clevenger 2011) has demonstrated that it takes three to four years after construction of a wildlife crossing for the wildlife use of the structure to reach its maximum use. This is because adult of various wildlife species may take years to learn that the passage is safe for movement and pass the learning to their progeny.

If budgets allow, wildlife monitoring is best done with remote motion-triggered cameras, also called camera traps. These professional level cameras are being used to monitor larger wildlife such as wildlife all over the world, and are being tested by wildlife ecologists for use with smaller wildlife such as amphibians and reptiles. Cameras made by Reconyx are at the high end of the performance and price range (~$500); however, cameras made by Bushnell (Trophy Cam II) have many comparable abilities and cost less than half the price ($180). In areas with a lot of people around, these cameras are placed inside metal utility boxes, with locks linking the cameras to 60 to 120 pounds of concrete in the base of the utility boxes. The cameras are placed at both entrances to the crossing structure or existing culvert or bridge, to evaluate all wildlife that attempt to use the structure. In areas without human travel, cameras can also be temporarily locked to trees or posts (and camouflaged to reduce theft) at either end of potential crossing structures. Either approach allows researchers to calculate a rate of repellence as well as a usage rate for each structure. The cameras in use today are powered by batteries (rechargeable NiMH batteries), and the photos are stored on a retrievable memory card. Cameras are checked every month to two months (up to 6 months for Bushnell Trophy Cam II), depending on the activity levels at the site and whether still photos (less frequently) or videos (more frequently) are recorded.

During these visits, batteries are replaced, if needed, and memory cards are exchanged. Vegetation that grows up near the cameras is cleared. Data is entered into spreadsheets for later analyses. At this step, it is critical to spend time defining the fields necessary for analyses so that data entry does not have to be re-visited. Each picture file has an associated "Exif" file that contains the date, time, and camera information, so this information can be automatically stripped from the picture files, reducing data entry time and chance of error.

Wildlife can also be monitored by other methods, described above in Section B.5 and Appendix 5. Prior to the completion of post-construction study, it should be determined how success is defined for a crossing structure. This bar of success should be decided upon by scientists and agency personnel familiar with the project and area. Past studies have aimed for a wildlife-vehicle collision carcass reduction of 75% for mitigation efforts that funnel deer to wildlife crossing structures with fencing (Rosa 2006).

If stakeholders are interested in both investigating the success of the mitigation and creating the best working mitigation at the site, then monitoring and adaptively managing the mitigation will take some time over the years to "get it right." This approach can lead to the most cost-effective and ecologically-effective solutions for wildlife movement in Vermont. This approach is described in detail in Section B.5 Monitoring and Adaptive Management.

C.3 Controlled wildlife access to right-of-way

As traffic volumes increase, it becomes increasingly dangerous for animals and drivers for animals to access the road surface. Animals will often try to cross busy roads to forage, disperse, mate, and otherwise move around to meet their needs. By reducing wildlife access to road surfaces, risk to individual animals and drivers may go down, but this has both a fiscal and biodiversity cost. For example, fencing is not very expensive over only a few miles. However, fencing all highways and busy roads to reduce wildlife access would be very expensive and would severely reduce genetic connectivity, wildlife movement, and other important functions for many species. Inhibition of daily and reproductive movement (e.g., amphibians and reptiles laying eggs) would result in wildlife dying and reduced population viability in the fenced area. Controlling wildlife access to roadways is best done when traffic volumes and wildlife presence are both high and where over and under crossings are available at frequent intervals (with respect to the species present) along the right-of-way.

C.3.a Wildlife fencing

Advantages of wildlife fencing

Fencing is an effective way to protect people and wildlife, when it is combined with wildlife crossing opportunities and regular maintenance.

Keeping wildlife out of the right-of-way, but providing them with a crossing alternative, is a good way to reduce harm to wildlife and people. Fencing, combined with crossing opportunities, can help do this.

Fencing has two discrete functions, each at different scales: 1) keeping wildlife from accessing a stretch of road or highway, except at pre-determined crossing points and 2) keeping wildlife from passing through all segments of the fence-line.

Fence-lines are the established boundary between wildlife habitat and the immediate road-side and roadway (Figure 8). They function only when they are extensive and intact.

Figure 8 An eight-foot-tall fence-line suitable for excluding ungulates.

Description

Wildlife fencing is composed of good location planning, robust materials, logical end-points, escape ramps, available crossing points, and regular maintenance. If any of these are missing, then the fence may, in the worst case, actually trap animals next to the road.

Fences are composed of posts, fabric, and fasteners. All of these must be strong and durable. Size and materials for fencing are based on the species of concern that fences are intended to keep off the road and guide to crossing locations. The most common fencing is that created to deter ungulate species such as deer and moose. The requirements for this type of fencing have been summarized by California and Washington DOTs (e.g., http://transwildalliance.org/resources/2009415101329.pdf). They include: Based on research in Washington, basic guidelines for a fence in snowy environments includes:

1) well-buried metal or 8" wood posts
2) Double-bay, diagonal bracing
3) A single row of fabric (vs. double), buried at least 12" in the ground
4) Stainless steel tension cables, with tension springs
5) Sturdy fasteners for fabric-post joining
6) V-mesh and/or variable mesh fabric
7) Escape ramps for wildlife trapped on the road-side of the fence

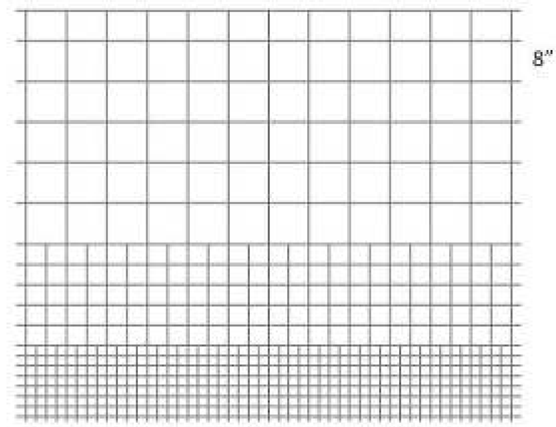


Figure 9 Fence fabric mesh-size

An important possibility to consider is varying the mesh-size of the fence fabric vertically (Figure 9). This acts to inhibit small animal movement low to the ground, while remaining effective in inhibiting large animal movement at all heights.

Location

Figure 10 Fence anchored at bridge abutment, over riparian wildlife-crossing

Wildlife fencing is effective at keeping wildlife of the road and alive when it is associated with crossing structures (Figure 10). This makes it "directional fencing" in that wildlife is directed toward crossing opportunities. Fencing can be established where wildlife movement through structures or over the road surface is well-known to occur because of direct observations AND indirect evidence (e.g., traffic accidents caused by collisions with animals, animal carcasses from collisions). Fencing could be placed along numerous roads in Vermont that also have culverts and bridges in place and natural or agricultural vegetation support wildlife. A prioritization scheme for fencing would rank the following:

- There are obvious opportunities for wildlife to access natural and semi-natural areas which the fencing can link by guiding them to existing culverts and bridges.

- There is direct evidence (e.g., radio-collared animal movement, wildlife pictures) of wildlife movement along the stretch of road/highway.
- There is indirect evidence of unsuccessful animal movement (e.g., traffic accidents, animal carcasses).

Combined with:

- Moderate to high traffic volumes (>1,000 cars/day)
- Poor line-of sight due to road curvature, vegetation/topography, or climatic conditions

Planning and Project Nexus

Fence-lines are best studied and described early in corridor or project planning so everyone is on the same page. They should be built to coincide fairly exactly with new activities associated with wildlife crossing (e.g., new culverts). To function well in snowy environments, they should be inspected and maintained at least annually.

Limitations of wildlife fencing

As indicated above, wildlife fencing is only effective when the ends of the fence-line join landscape elements or structures that keep wildlife out (Figure 10). Other limitations on effectiveness are related to sturdiness, regularity of inspection and maintenance, height of the fence, fabric mesh-size, number and adequacy of associated crossings with respect to the species present, and location relative to wildlife movement.

Monitoring fencing effectiveness

There are two components of monitoring – fence integrity and wildlife crossing response. Criteria for effectiveness include: structural integrity (year-to-year maintenance requirements), fence line integrity (wildlife are inhibited from crossing the roadway except through structures), fence line length adequacy (wildlife aren't just going around the ends), wildlife behavioral response (wildlife are successfully directed to crossing structures, not just blocked and repelled), and increase in animal and public safety for roadway.

Costs

Fencing can be inexpensive to erect (e.g., amphibian and reptile fencing), but in the long-run may be expensive to maintain. Starting out with sturdy materials will reduce maintenance cost. Eight-foot deer fencing costs about $100,000/mile, including escape ramps and gates (as erected in westerns states). Electrified fence strands may be more cost-effective in some cases than standard fencing because of its proven inhibition of large mammals and lower profile. Regular inspection and maintenance is a critical part of fence function and should be considered as part of the cost.

Document decisions and develop agreements

Fences interact with other land-owning and regulatory entities, which should be consulted during planning. Because fencelines are often planned for the edge of the legal right-of-way, adjacent landowners should be consulted about how the fencelines may impact them. Wildlife agencies should be consulted because of possible negative and positive impacts on movement of legally-protected and other animals.

Escape Ramps

If wildlife is fenced out of the road right-of-way, there is a need to install devices wildlife can use to escape the right-of-way when they become inadvertently trapped in the area. This may be due to end-of-fence runs, openings in the fence, open gates, and other ways animals mistakenly access the road. Since the creation of wildlife exclusion fencing, states have been creating wildlife escape ramps. These are mounds of earth piled on the road side of the fencing built up to the top of the fence, to allow trapped animals to jump over the fence to the wild side (See Figure 11). Each western state has their own standards, but the minimum standards are that the earthen pile be large enough that wildlife can run up on it, that there is a perpendicular fence at the top to "force" wildlife to make a turn to the wild side, and that the height from the wild side be over five feet (six feet in the case of elk and bighorn sheep). This approach rapidly pays for itself and is more effective than one-way gates (Bissonette and Hammer, 2000).

Figure 11. Elk using escape ramp along US 93 in Montana to access wild area.

C.3.b Median barriers

Median barriers are designed to separate opposing traffic. These barriers may be vegetated separators, guard-rails, concrete walls, or other structures. An unintended consequence of median barriers is that they may inhibit wildlife movement across the surface of the roadway, but in the middle of the road, rather than the edge. This means that animals may become trapped in the median and eventually involved in a collision with a vehicle, or not try to cross at all because they can't see across the road.

At first, it might seem beneficial if median barriers deter animals from entering the roadway. This is true from the point of view of individual animals because they are less likely to become involved in a collision with a vehicle. However, if there are not other crossing alternatives above or below the road, animal populations may become separated from each other, or from essential reproductive, hibernation, foraging, or other habitat. In other words, median barriers can cause population reduction and loss when they prevent or severely inhibit animal movement across the road or highway right-of-way. Because of this and despite benefits they may have for humans, median barriers should seldom, if ever, be considered as a BMP for wildlife.

C.3.c Guard rails

Concerns about driver safety on windy roads with steep drop-offs has resulted in construction of guard rails with post and W-beam design. The 1999 Vermont Guardrail Study Committee recommended five suitable types of guardrails: w-beam, 3-cable, box beam, steel backed timber, and stone masonry. The first four types are all recommended as guard rails and potential median barriers where wildlife is present. These devices are intended to prevent vehicles from driving off the road, while limiting impact to the vehicle and driver. An unintended consequence of guard rails may be to either prevent certain wildlife (e.g., moose) from crossing the road surface, or worse, to trap them on the roadway because of animals' hesitation to cross the guard rail (Figure 12A). An animal that does not exit the roadway may move erratically until it eventually collides with a vehicle.

Where guard rails may be having one of these effects on wildlife, they could be replaced with box beam barriers (Clevenger and Kociolek, 2006), 3-cable barriers, steel-backed timber, or stone masonry. All wildlife species can see through or over these barriers, and all can theoretically get over or under them (Figure 12B). Because of the additional cost of installing this type of barrier and its unknown effectiveness in Vermont, pilot installations should be monitored for their effectiveness.

A

B

Figure 12 Guard rail types. A. W-beam guard rail separating a highway in the Green Mountains from wetland-forest habitat (to the right). B. Box-beam rail in forested habitat (VTrans, 1999).

D. Operations, Maintenance, & Monitoring

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D. Operations & Maintenance

Once constructed, transportation systems are operated to maintain public safety (e.g., through speed control), drainage, goods movement and driver access. Stewardship of this system is the mission of the divisions in charge of structural maintenance and traffic operations. Transportation stewardship is both about keeping a transportation system functioning and making sure that it is not damaging to other natural and human systems. Integral to stewardship is monitoring the effectiveness of structures and management practices in order to make better future decisions (adaptive management). In terms of wildlife movement, operations and maintenance are tied to planning and program development, which plan and implement based upon the results of effectiveness monitoring.

D.1 Traffic Operations – Driver-Based Solutions

Potentially less-expensive than infrastructure modification to improve wildlife movement, driver education and traffic control has the potential for reducing wildlife-vehicle collisions (WVC) to benefit public safety and wildlife health. Vehicle speed is one of the main factors determining the likelihood of vehicle collision with wildlife and the risk of property damage and injury upon collision. This management practice can range from roadside signs informing drivers of the likelihood of wildlife crossing on a particular stretch of road to active control of traffic speed.

Roadside information (passive and dynamic signs)

Signs can be used to inform drivers of changing driving conditions. Limited visibility, such as at sharp curves, undulations in the road surface, and roadside vegetation reduce a driver's line-of-sight, reduce driver response time, and may increase the risk of collision should an animal appear on the roadway (Hedlund et al. 2004). Signs warning drivers of reduced speed zones, work zones, and possible animal crossings have been used for decades in the hope that people will slow down. Passive signs are generally ineffective at making people slow down (e.g., Figure 13), but dynamic signs have been shown to be effective and not so distracting as to cause safety issues (McAvoy, 2011). The message on dynamics sign may determine effectiveness of the sign. McAvoy (2011) found that a sign flashing “slow down 45” was more effective and for a longer distance/time than a sign flashing “speed limit 45”. In addition, it appears that dynamic signs may be most effective, in terms of percentage speed reduction, with the fastest drivers (Hallmark and Oneyear, 2011). If signs are used in specific areas warning of possible wildlife crossing, they should be dynamic signs that are also moved among sites so people don’t become accustomed to them and eventually ignore them.

Recent research has examined the effectiveness of dynamic signs that respond to the presence of animals on or near the road-way (Huijser et al., 2009). These animal-detection systems alert drivers through dynamic signs that an animal has triggered the detection mechanism (e.g., cable buried in ground adjacent to right-of-way). Alert drivers may slow down slightly (1-2 mph, Huijser et al., 2009), which reduces the likelihood of serious collisions (Kloeden et al., 1997) and decreases the reaction time of drivers (Green, 2000). However, it is worth questioning whether this degree of slowing down is worth implementing these systems. Animal detection systems are relatively expensive and may only be feasible for highway segments where wildlife crossing and WVC is a persistent problem.

Figure 13 “Moose” sign on I-89

Public information (media, schools, license and vehicle registration opportunities)

New drivers learn about appropriate driving behavior from adults and at school during drivers education. There is no reason why this education can't include driving behavior that is responsive to the presence of wildlife. Public campaigns have been effectively carried out to change particular behaviors that are seen as environmentally damaging (e.g., littering, dumping chemicals in drains) and it is likely that similar campaigns could be carried out to reduce wildlife-vehicle conflict. The recommended BMP is for VTrans to develop a public relations campaign to reduce vehicle speeds and increase driver alertness. This should be dynamic in that effort and concentration varies over time of year and for different parts of the state. Schools could participate through their science curricula where they learn about the risks to wildlife and people of WVC and potential solutions. Finally, during driver training and vehicle registration, new and continuing drivers could be provide with special material and education that parallels the school curriculum.

Speed limits

Speed is one of the main factors in all crashes, including collisions with wildlife. As speed limits have increased among US states, so have speed-related crashes (NHTSA, 2005 & 2008). Speed limits are set by states and reflect the maximum speed considered to be safe for a given roadway under favorable conditions (Donald, 1994). It could be reasonably argued that wildlife attempting to dash across roadways in front of vehicles results in potentially unfavorable conditions and that where this is more likely, a lower speed limit would be reasonable and predictably improve driver safety.

Researchers have found that as speed limits increase to a peak of 60 mph, and thus driving speeds, so does the rate of animal-vehicle collision (Wang et al., 2010). Somewhat counter-intuitively, rates of collision have been observed to decline at speed limits >60 mph (Wang et al., 2010), possibly related to the corresponding roads (primarily interstates) having fewer access points and potentially being less attractive to animals for crossing. In a related study, based on WVC observations on a variety of road types, a reduction in speed of 20% (from ~65 mph) was calculated to result in a 50% drop in WVC (Hobday and Minstrell, 2008). Because the rate of collision with wildlife increases dramatically at speed limits $\geq$ 50 mph, Wang et al. (2010) recommend setting speed limits at 50 mph in areas known to experience wildlife crossing, especially by large animals.

Slowing drivers down is the cheapest and likely most-effective way to reduce the rates of wildlife-vehicle-collisions. Posted speed limits don't necessarily result in slower vehicle speeds on specific roads and highways, but it does provide transportation and public safety officials with a tool for generally reducing speeds. Speed limits may be challenging to reduce, so the benefits should be clearly estimated and described. A first step recommended here as a BMP is to reduce speed limits and increase enforcement on highway segments and at times of year when WVC, or wildlife movement, has been shown to be more frequent and both wildlife well-being and driver safety shown to be impaired.

In Colorado, in areas where wildlife (especially mule deer and elk) are known to be more likely to be hit by vehicles, wildlife crossing zones have been established (Figure 14). These areas are marked with signs that warn drivers to reduce speeds during particular times of year and day. Recent legislation has created increased speeding fines in these zones.

Figure 14. Speed enforcement in Colorado's Wildlife Zones. These are areas where speeding fines are doubled during specific hours and months of the year.

Physical controls (e.g., rumble strips)

Drivers are familiar with road features that are intended to slow vehicles (e.g., speed bumps) or reduce the chance of crossing into oncoming lanes (e.g., raised pavement markers). These features could be used in association with signs to alert drivers about their speed and about the potential presence of animals on the right of way. These methods have been used to reduce driver speed and have resulted in significant reductions in rates of WVC and recovery of threatened species (Jones, 2000).

D.2 Maintenance

Improving wildlife crossing opportunities across roads and highways is often thought of as a job for planners and project managers installing wildlife crossing structures and fencing. However, most wildlife crossing occurs across the surface of roads and through existing culverts and bridges. Wildlife access to road surfaces may increase if fencing is not maintained and culverts and bridged areas are blocked by debris. This makes stewarding wildlife crossing as much a job for operations and maintenance personnel as anyone else in VTrans.

D.2a Maintenance – Improving Wildlife Use of Structures

The best way to improve wildlife crossing of rights-of-way is to think about what the animals are likely to do and prefer. There are many interrelated factors that affect an individual animal or a population of animals' decisions to use crossing structures. The two main factors that affect these decisions can be grouped into characteristics of the external environment and internal motivations based on the biology of the species. Understanding why animals behave the way they do and their basic biological needs is an essential component to help planners, biologists and engineers design suitable wildlife crossings and enhance existing infrastructure that considers both the internal and external factors motivating animals to use or avoid a given structure. Maintaining culverts and bridges to fit those biological needs and keeping track of field conditions is a job for maintenance staff.

Environmental factors that affect how wildlife perceives structures for potential passage include (note that not all of these factors are of equal importance for all species; repeat of information in Section C.1.a):

- The presence of natural area or specific habitat on both sides of the road;
- The presence of human development or disturbance nearby or within the structure;
- Vegetative cover leading to the structure;
- Vegetative or woody debris cover within a structure;
- Visibility through the structure and at the approaches to the structure;
- Light contrast inside and outside of the structure;
- Elevation gradients that may affect water flow or large gradients that may affect an animal's approach to a structure;
- Traffic noise that is present outside the structure and that may be amplified inside or changed in pitch inside or beneath the structure;
- Traffic volumes, i.e., heavy traffic volumes may deter animals from coming near the road, and crossing through a structure, while low traffic volumes may encourage animals to cross at-grade rather than use structures unless they are otherwise prevented from doing so with fences or other funneling devices;
- Similarity of the conditions in, under or on a structure relative to the natural environment in which it is located;

- The feel of openness (rather than confinement) for an animal crossing through a structure.

D.2.b Maintenance – Evaluating Crossings Using the Wildlife Infrastructure Enhancements Recording System (WIERS)

When wildlife-oriented changes or enhancements are made to existing or new infrastructure, it is important that these features be protected in perpetuity. Often maintenance personnel or contractors are unaware that features such as a small removal of rip rap or fencing brought to he ground are situated in a way to promote wildlife connectivity. As Tropical Storm Irene recovery infrastructure-replacements are planned and installed, a new recording system could be added to the current bridge and culvert data base that details what changes were made for wildlife. The newly-created Wildlife Infrastructure Enhancements Recording System (WIERS) is proposed for this purpose.

The first step would be to add a wildlife data entry box in standard culvert and bridge databases for details on what was added or changed at a site to promote wildlife connectivity. This would act as a marker for future and on the ground VTrans personnel to understand why there may be something such as a natural earth floor to an aquatic culvert, why the fencing was placed at the abutments of the bridge to allow wildlife access to slopes under the bridge as well as the bottom of the area, or why there is a natural path among the rip rap, among many other features. This would help the maintenance and daily operations personnel as well as contractors understand how and why infrastructure features are placed to encourage wildlife use, and to continue the infrastructure as intended. For example, in western states, state DOT maintenance personnel will dump deer, elk, and moose wildlife-vehicle collision carcasses over the edge of the road at the site of bridges and culverts because they can be easy access spots for trucks to pull up to. This leads to sometimes the piling up of dead bodies at the entrances to the intended wildlife crossings. Knowledge of the intended use of these culverts could prevent these types of actions.

The second step to this system would be to have the culvert and bridge database in the computers of the maintenance vehicles or, an application could be created to allow smart phones access to the databases from the field. This would allow all individuals, including contractors, access to the important data on infrastructure. The new infrastructure being installed from this point forward could be marked with GPS applications, and these locations would be linked with the structure's entry in the database. The smart phone application or one within the vehicle computer would take a GPS location on where the user was, and bring up all nearby culverts and bridges. From the list, the user could select the culvert of interest, see the year the culvert was built, maintenance concerns, what was done for wildlife, and the maintenance schedule. Permitted users could also add data via the internet connection. This information could pertain to recommendations for future actions. For example, if maintenance personnel know that a culvert floods every April and that it should be cleared of debris by March 30th, this information could be input into the database, which would then appear on the smart phone application and the database. Wildlife enhancements, such as annual clearing a culvert of debris, checking fencing for fallen trees and holes in the spring, no-spray zones for herbicides, cleaning bridges after passerine bird nesting seasons, cleaning of bat boxes, and other actions could be entered into the system by environmental staff within VTrans. This system would allow future VTrans personnel and others to continue the intended wildlife enhancements of the infrastructure. There is a similar program in a hand held personal data device in Washington DOT's environmental and maintenance programs. That program was not built with access to an on-line database. This WIERS approach allows for continuous real time updates. This is a unique idea created specifically for this Best Management Practices manual.

Vermont Fish and Wildlife added this note to this and past systems of reporting:

"The Vermont Fish and Wildlife Department has partnered with Vtrans and the Vermont Department of Environmental Conservation to assess culverts associated with state roads for their ability to pass or restrict the movements of fish and wildlife. The Department has analyzed this information to determine its value in better understanding the relationship between existing culvert infrastructure and wildlife movement. The data provides relatively limited value in identifying those culverts that may be providing wildlife movement or restricting movement. However, it is useful to highlight areas that merit additional investigation and consideration for replacement. We recommend that this data be consolidated in a place that can be made accessible to both agencies, and that results from a more thorough analysis be used to guide decisions on whether to conduct additional surveys and to guide decisions on culvert replacements. This information will be made available to Vtrans by the Department through the Department website and on CD. This sort of infrastructure assessment is the kind of work that needs to be supported by Vtrans as we continue to develop a more detailed understanding of how existing infrastructure influences wildlife movement and provides opportunities for improvement."

D.2.c Advantages, Limitations and Costs of Existing Structure Maintenance

There are a variety of costs that accompany developing wildlife connections across transportation rights-of-way. Retrofitting existing structures will almost always be less expensive than building new structures. Serving the crossing needs of multiple animal groups with a single structure will be more cost-effective than with several single-group structures. Monitoring the use of crossings must be done to encourage future crossing enhancements and to demonstrate biological effectiveness.

Existing culvert and bridge structures provide a cost-effective solution to maintaining and improving wildlife movement across road and highway rights-of-way. In many cases and places, appropriately maintaining and enhancing these structures will benefit wildlife movement. Although it is tempting to rely on existing structures to provide this benefit, not all structures will enable wildlife movement and they will vary considerably in their actual utility for wildlife. The following are examples of limiting factors for the use of existing structures by wildlife:

1) Bottom substrate unattractive for wildlife movement (e.g., corrugated pipe);

2) Openings perched above the ground, or stream surface;

3) Structure too long, curving, or down-grading limiting line-of-sight and/or light;

4) Road surface comparatively more attractive and accessible to wildlife than the available crossing structures; and

5) Openings inaccessible because of over-grown vegetation, stream-side rip-rap, or fencing.

Costs of Retrofitting and Maintaining Culverts

In a study for the Colorado Department of Transportation, Meaney et al. (2007) found that retrofitting culverts with ledges for small mammals was both effective at providing passage for several species and relatively inexpensive. The cost at the time was $17-$20/linear foot, including shipping and installation. Maintaining culverts so that the openings are usable by herpetofauna (amphibians and reptiles), small mammals, and medium-sized mammals is an additional expense. Arched culverts with natural bottoms are more expensive to install than pipe culverts, but have natural bottoms and are very inexpensive to maintain. There are a variety of maintenance needs that drainage structures have to provide for (e.g., water flows) while maintaining both the structure's integrity and that of the immediate environment (Kocher et al., 2007). A study in Maine estimated an annual maintenance cost of $600 for a 2.5-foot diameter round-pipe (Maine DOT, 2009).

Many countries and states have developed special amphibian tunnels to reduce impacts to common and endangered amphibians alike (Federal Highways Administration). One common feature of these is to provide down-welling light into the tunnel through periodic openings in the tunnel ceiling. Culverts are essentially tunnels, but they lack the apertures that could enable natural lighting and use of the culverts by amphibians and small mammals. Retrofitting culverts to function as amphibian tunnels would require cutting apertures from the road-surface through the roof of the culvert. Factors such as engineering, design, and construction costs may prohibit this retrofit.

D.3.c Measuring wildlife connectivity BMP performance

Measuring the effectiveness of BMPs serves two important purposes: 1) informing future management about which approaches will benefit wildlife movement, and 2) building public support for effective approaches, that often require public investment. Many of the metrics useful in developing BMPs for improved wildlife movement can also be used to measure the performance of the BMPs. The table below (Table 8) provides examples of suitable metrics/indicators and monitoring methods for performance measurement.

Table 8 Wildlife crossing performance measures/indicators and methods.

BMP	**Performance measure/indicator (desired target/direction)**	**Monitoring method**
Speed control	➢ Density of carcasses from WVC (decrease) ➢ Injuries and death from collisions (decrease)	Standardized survey (>1/week) Existing collision reports
Wildlife fencing	➢ Density of carcasses from WVC (decrease) ➢ Injuries and death from collisions (decrease)	Standardized survey (>1/week) Existing collision reports
Under-crossing enhancement	➢ Density of carcasses from WVC (decrease) ➢ Number of target wildlife passage events (increase) ➢ Diversity of wildlife species, Shannon Diversity Index (increase) ➢ Injuries and death from collisions (decrease)	Wildlife camera traps Track plates/beds
Wildlife under-crossing and over-crossing construction &/or retrofit	➢ Density of carcasses from WVC (decrease) ➢ Number of target wildlife passage events (≥ 1/day) ➢ Diversity of wildlife species, Shannon Diversity Index (> 1.5) ➢ Injuries and death from collisions (decrease)	Wildlife camera traps Track plates/beds

E. Literature Cited

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E. Literature Cited

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F. Technical Appendices

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F. Technical Appendices

The following appendices are intended to provide more background material and detail for the Best Management Practices. The appendices are organized to correspond to the Sections in the Manual, for example, Appendix 1 provides more detail and background for Section A Executive Summary.

(scientific rationale, summaries of practices from other states, annotated bibliography)

Appendix 1: Section A Background on Wildlife Movement & Connectivity and Conflict with Roads & Highways

Resources from other states and federal governments

"Wildlife Crossing Structure Handbook: Design and Evaluation in North America" 2011. Federal Highways Administration, FHWA-CFL/TD-11-003

"Design of Bridges and Culverts for Wildlife Passages at Freshwater Streams" 2010. Massachusetts Department of Transportation

"Wildlife Crossing Guidance Manual". 2009. California Department of Transportation

"Wildlife Vehicle Collision Reduction Study: Best Practices Manual" 2008. Federal Highways Administration, FHWA-HRT-08-034

"Highway Median Impacts on Wildlife Movement and Mortality" 2006. California Department of Transportation, Research Report # F/CA/MI-2006/09

"Best Practices for Meeting DNR General Public Waters Work Permit GP2004-0001" 2011. Minnesota Department of Transportation

"Guidelines for Culvert Construction to Accommodate Fish & Wildlife Movement and Passage" 2006. Arizona Game and Fish Department, Habitat Branch

"Guidelines for Bridge Construction or Maintenance to Accommodate Fish & Wildlife Movement and Passage" 2008. Arizona Game and Fish Department, Habitat Branch

Appendix 2: Section B Examples of Connectivity Assessment from Other Regions/States

Maine Beginning with Habitat Connectivity Project
http://www.beginningwithhabitat.org/

Who did the Analyses?
Beginning with Habitat (BwH), a collaborative program of federal, state and local agencies and non-governmental organizations, is a habitat-based approach to conserving wildlife and plant habitat on a landscape scale. The goal of the program is to maintain sufficient habitat to support all native plant and animal species currently breeding in Maine. BwH compiles habitat information from multiple sources, integrates it into one package, and makes it accessible to towns, land trusts, conservation organizations and others to use proactively. Each Maine town is provided with a collection of maps, accompanying information depicting and describing various habitats of statewide and national significance found in the town, and with tools to implement habitat conservation in local land use planning efforts. BwH is designed to help local decision makers create a vision for their community, to design a landscape, and to develop a plan that provides habitat for all species and balances future development with conservation. Since its inception in 2000, BwH has met with and provided information to more than 140 cities and towns and 35 land trusts and regional planning commissions within the state. Many towns and land trusts have incorporated the information they have received from BwH into their comprehensive plans and strategic approaches to conservation. The Beginning with Habitat (BwH) landscape approach to habitat conservation was initially developed by the University of Maine's Cooperative Fish and Wildlife Research Unit (CFWRU) under the direction of the Department of Inland Fisheries and Wildlife (MDIFW) (Krohn and Hepinstall 2000). Data on plants, natural communities, and wildlife habitats of national interest were later added by the Maine Natural Areas Program (MNAP) and the US Fish and Wildlife Service (USFWS)

How was it done?
By overlaying maps of the habitat needs of all of Maine's vertebrate species with Maine's primary land cover types (forests, fields, wetlands) in a geographic information system (GIS), the CFWRU reports that 80-95% of all of Maine's terrestrial vertebrate species would likely be present if riparian habitats, high value animal habitats, and large habitat blocks are strategically protected in a landscape that is linked together. There are three primary maps for any given area: water resources and riparian habitats, high value plant and animal habitats, and undeveloped habitat blocks. Four additional maps provide supplemental information on public and conservation lands, functional characterization of wetlands, habitat for US Fish and Wildlife Service "priority trust species" and a regional map.

What are the instructions for the use of this data?

The Beginning with Habitat (BwH) Toolbox is a guide to help towns develop and implement a "conservation blueprint", or suite of local actions that will achieve a municipality's land conservation goals. The purpose of this toolbox is to assist you, as a concerned citizen, municipal committee member, elected official or land trust member, achieve your land conservation goals by providing you with a series of tools that can be used to address common conservation issues that arise in many Maine towns. The toolbox includes an introduction to using BwH data and principles in municipal comprehensive planning and open space planning and provides tools, including example ordinance language, which can be used to address conservation concerns. We have attempted to include local lessons learned and the advantages and disadvantages of each tool to help you evaluate which approach will best fits your local needs.

We strive to provide the best and most current examples of tools that are being used throughout the state to implement habitat-related goals and will continually be updating and adding to the list of examples provided here. We are interested in hearing your feedback as to the usefulness of these tools. **Please also forward any additional examples that you feel should be included on this site**.

To Use the Toolbox- Click on subject headings to the right to find more information about comprehensive planning and open space planning, to find example tools that can be used to address common conservation issues, and to find methods for financing your town's habitat protection efforts. An outline of the Toolbox with summary descriptions and direct links to each tool is provided under the Table of Contents link.

Ontario Modeling and Mapping Connectivity in Conjunction with Herp Roadkill Hotspots

Gunson, K. E., D. Ireland, and F. Schueler. 2007. Incorporating road-mortality hotspot modeling and connectivity analyses into road mitigation planning in Ontario, Canada. In, the 2007 Proceedings of the International Conference of Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, N.C. Pp 197 – 205. URL: http://www.icoet.net/ICOET_2009/downloads/proceedings/ICOET09-Proceedings-Session142.pdf

A group of non-government, government, scientists, educators, and transportation planners, called the Ontario Road Ecology Group (OREG) developed 2 initiatives: 1) GIS habitat modeling for wetland-forest animals, and 2) combination of a validated road hotspot model with natural heritage systems to incorporate landscape connectivity in a final model. This combination of landscape modeling and hotspot analyses was used to predict future wildlife crossing locations. They made assumptions about habitat suitability scores for wetland and forest species. They then compared the number of herps killed in a section of road with the habitat suitability scores to best validate their model. They used Chi-square analyses to compare the observed mortalities with what was predicted for each score class. They then validated the model using occurrences of dead and live animals. They analyzed the cost of doing this and if it was a feasible way of validating predictions about where animals could be killed. Results of the modeling and field work helped plan 6 new wildlife crossings in the area analyzed, five of which will be for only small animals.

Washington Wildlife Habitat Connectivity Working Group
http://waconnected.org

The Washington Wildlife Habitat Connectivity Working Group is a collaborative science-based group that identify opportunities and priorities to provide habitat connectivity in Washington and surrounding states and British Columbia. They have analyzed connectivity at a statewide scale and are currently creating a finer scale analysis at the eco-regional level. In the future they will incorporate anticipated shifts in habitat conditions over time with climate change and map those connections. These analyses included a performance measures section to see if the work was initiated in the future. The performance measures included a reduced number of wildlife-vehicle collisions, and an increase in the number of wildlife crossings in the state. They first developed connectivity models for 16 focal species, which were intended to represent other species and a wide range of habitat types. It was intended to provide a coarse filter for species and processes that are sensitive to human disturbance, but not substitute for fine-filter planning for species or ecosystems of special concern. This modeling of connectivity used a cost-weighted distance modeling based on Singleton et al. (2002) and Adriaensen et al. (2003). The work produced areas of large habitat blocks for focal species and intact natural areas. The maps produced were records of cumulative hypothetical movement cost, which reflected barriers to movement and mortality risks encountered, and modeled hypothetical least-cost corridors which were swaths of land expected to encompass the best route for each focal species to travel between habitat blocks. Second, they modeled connectivity between areas of high landscape integrity, which are areas that have low levels of human modification and are in relatively natural condition.

An added component was the Landscape Integrity mapping which looked at the least possible human footprint of areas. There was a high amount of overlap among the focal species model and the landscape integrity model. The landscape integrity model will be used for climate change modeling and other efforts. The maps from this project are then used in conjunction with several other data sources to better adapt roads for wildlife.

The WSDOT biologists also look at the traffic volume of the roads of interest because what is done for wildlife is also dependent on this variable. There is a flow diagram that goes through the process of looking at habitat connectivity in an area that includes: 1. Select project area, 2. Bring in the connectivity analysis for that area, 3. Bring in carcass removal data, 4. Ask the questions – does the area overlap with species networks? Does it have high carcass removal or animal-vehicle-collision data? Does it have public or other agency concerns? If the answers are no to these above, there is a second chance review process that asks: Are there public lands on both sides of the road? If yes, the user is told to continue with habitat connectivity best practice flow chart. When it is understood that there should be some mitigation effort, the steps to consider follow. The user is asked to consider low cost habitat connectivity considerations. If the project is in the transportation corridor plan, the user understands it is time for long term partnerships. The user is then instructed on best practices for habitat connectivity. These are important for any DOT to consider. This is where the Best Management Practices come in. If there are less than 2,000 vehicle per day, fences are not a consideration. Users are instructed not to use Jersey or Texas barriers and to opt for cable barriers instead. Another option would be for wide open visual zones for drivers and wildlife. If the traffic is 2,000 to 8,000 vehicles per day, the following instructions are provided: fence to move animals to existing structures; enhance existing culverts and bridges for wildlife permeability; explore partnerships with agencies, non-profits, the public; consider crossings at grade where they can be accommodations for wide open visual zones. If the traffic volume is greater than 8,000 vehicles per day biologists are told to discourage all crossing at road grade and to create barriers to these types of movement. Animals should be channeled to existing bridges and culverts. New crossings should be planned.

Appendix 3: Passage Assessment System

Using the Passage Assessment System

The PAS guides practitioners through a series of targeted questions designed to characterize a bridge or culvert relative to its potential to functions as a wildlife passage. The PAS is composed of three sections: General Questions, Undivided Highway, and Divided Highway, as well as a User's Guide provided for additional reference. For each structure that is being evaluated the user will complete 1) the General Assessment Questions, and 2) either the Divided or Undivided Highway Assessment Questions, depending on whether the structure of interest is located on a divided or undivided highway.

Upon completing the PAS the user will be equipped to answer the question: 'can this structure be improved to accommodate passage for the target species present in this area?' It is possible, in some cases, that a given structure may be enhanced to accommodate one or several of the target species, but cannot be suitably improved to accommodate all target species.

Having determined that a structure *can* be enhanced for wildlife passage, biologists are then confronted with the question of *how* to enhance the structure to facilitate passage. Given the unique characteristics of every structure and the specific permeability objectives at each site, there is no simple answer to this question, however a number of commonly encountered situations are addressed in the accompanying Passage Enhancement Toolbox. This toolbox addresses a number of situations and provides examples of each. For example, at a location with a culvert that conveys water but could also be used by smaller animals, the toolbox describes shelves that can be installed inside the culvert to facilitate wildlife movement above the flow of water (see picture). Or, if the support slopes of a bridge are covered with large boulder riprap down to the stream bank, the site can be enhanced for wildlife movement by the installation of a dirt pathway through the riprap (see below). The user is encouraged to consider the range of possible enhancements and how they could be implemented at each site being assessed.

Racoon using a raised shelf as a dry pathway through a culvert under Highway 93 in Montana ©K. Foresman

Dry pathway installed through riprap slope under a bridge in Minnesota ©P. Cramer

Steps in Passage Assessment System

1. Identify focus areas for evaluating wildlife passage

    -Select road(s)

    -Locate connectivity data for that area

    - Access wildlife-vehicle carcass data for that section of road

- Identify road projects in that area in the State Transportation Improvement Plan (STIP)

-Select Road Segment

2. Identify Species Movement Guilds species (Table 3 above) of consideration for wildlife in that area
3. Locate Existing Structures in area of interest
4. Conduct Passage Assessment System evaluation on structures

- Identify the Structure Functional Class
- Characterize the structure and surrounding environment using the PAS (below)

-Evaluate structure functionality relative to the different Species Movement Guilds of interest

5. If the structure can be enhanced as is: Make recommendations to:

-Remove obstacles

-Facilitate movement

-Reduce intimidation

-Enhance approaches

-Address fencing and barriers.

6. If the structure cannot be enhanced for terrestrial movement, make recommendations for replacement.

Passage Assessment System Summary of Questions

The PAS is a lengthy series of questions designed to be filled out on sheets in the field, and also to be programmed in a hand held personal data device, or through a smart phone and website. The overall questions are categorized below. The full PAS can be presented in Index if there is an interest.

General Questions

Date, location GPS points, Route number, mile post, bridge number,

Structure Functional Class of structure

Species Movement Guilds of concern

Highway divided or undivided, highway direction, photo numbers

Divided or Undivided Highway

Is there extensive human development in the immediate vicinity?

Is this a culvert over 300 feet?

Is your view through the structure obstructed?

If the answer to any of these questions is yes, then the structure may have fatal flaws that are not fixable with enhancements. Further discussion with personnel involved would help determine if this could be used by wildlife.

-Structure shape, materials, are there multiple chambers?

-Road attributes: number of lanes, parallel infrastructure such as rail lines, clear zone, guard rails and jersey barriers

-Inlet/Outlet questions: is there an apron, wing walls, perched pipe?

-Approximate Dimensions: height/rise, width/span, length

-Obstructions blocking entrances or nearby, fill slopes, vegetation at approaches

-Land use within 100 feet, water features,

- Inside structure: visibility, water features, dry pathways, substrate, vegetation, noise

-Fencing nearby: height, length, wildlife-proof for different types

- Nearby intersections with driveways and roads

- Is there wildlife use in the structure, near the structure, any carcasses along road?

- Is there evidence of human use in the structure and nearby?

Species Movement Guild Rankings

Each question is ranked A for this animal type could use the structure as is, with no to small modifications, C for animal movement in this guild with modest modifications, or F, the structure could not be enhanced for this type of species.

Low mobility small fauna, Moderate mobility small fauna, Adaptive high mobility fauna, High openness high mobility carnivores, Adaptive ungulates, Very high Openness fauna.

Which features could be changed to make the structure more functional for any Species Movement Guild?

This question leads to the next section, Enhancement of Existing Structures.

Once the planning process has accomplished many of the tasks in this sub-section, the next steps would be to create actual solutions to the barriers transportation posed on wildlife connectivity.

Appendix 4: Section C.2 Enhancement (Retrofits) of Existing Structures

Types of Enhancements

Enhancement, sometimes referred to as retrofits, are changes that could be made to existing culverts, bridges, and fencing without replacing the structures. These changes could be as simple as clearing some vegetation, or more detailed solutions such as installing wildlife fencing. Enhancements can be classified into six types: remove obstacles, facilitate movement and create pathways, reduce intimidation, enhance structures' approaches, addressing the fencing and barriers, and add or adjust structural features. Each enhancement type is summarized below.

Remove Obstacles

The Goals: Remove obstruction or barrier at one or both structure entrances, inside the structure, or in the approaches to the structure (e.g.,cattle fencing across structure entrances; trash or debris).

Action		References
Clear debris and install sediment traps and/or regularly maintain to prevent structure from being blocked, filled or clogged.		Yanes, M., J.M. Velasco, and F.Suárez. 1995.
Keep culvert entrances clear of heavy vegetation growth that could block wildlife passage.		Clevenger, A.P., B. Chruszcz, and K. Gunson. 2001.
Add a dry, natural pathway through structure, on both sides of waterway if a stream or river is present. Photo example: Minnesota DOT routinely adds dry, flat, soil pathways to areas under new or retrofit bridge structures to allow for human and terrestrial wildlife passage. Photo credit: P. Cramer		Forman, R. T., Sperling, D.,Bissonette, J. A., Clevenger, A. P.,Cutshall, C. D., Dale, V. H., et al.2003. AND OR – MNDOT BMP manual

Minimize or cover riprap on side slopes with dirt to create a dry, smooth pathway. Photo example: Minnesota DOT removed lower slope rip rap and added a retaining wall to assist in the creation of a soil pathway under a bridge. A stream is also present at this site. Photo credit: P. Cramer		MNDOT BMP manual – Leete 2010
Install interlocking brick to support slopes instead of riprap to open up a pathway and facilitate wildlife passage.		

Install a raised shelf through water-filled culverts to provide a dry pathway for small mammals; include a shelf tube to provide protective cover for voles. Photo example: metal shelf installed in 3 feet by 3 feet culvert that also conveys water. Shelves were designed from research by Kerry Foresmen in Montana along US 93, where this photo was taken. Montana DOT regularly adds these shelves in areas where small and medium sized mammals need to move to both sides of the road. Photo credit: P. Cramer		Raccoon uses shelf in MT US 93 culvert. Photo credit: K. Foresman. 
Add baffles to culvert floor to retain sediment on artificial culvert floor (where water flows occasionally through the culvert).		

Install woody debris (e. g., down logs) through a structure for small species requiring cover from predators. Photo example: At Vermont's Bennington Bypass, wildlife researcher Mark Bellis dragged tree stumps and other tree parts under a new bridge to facilitate small mammals movement across the entire pathway under the bridge. Photo is shot from above. Photo credit: P.Cramer		Ehinger, W., P. Garvey-Darda, R. Gersib, K. Halupka, P. McQueary, W. Meyer, R. Schanz and P. Wagner. 2006.
Maintain natural stream banks through the structure.		
Add a strip of natural substrate and vegetation along one or both sides of a road through a structure to encourage small animal use; they need cover, and amphibians need to stay moist, which vegetation can help with.		
Where scour has resulted in perched culverts, build up scour resistant materials to create a navigable pathway into the		

culvert. Use natural materials; if riprap is used to build up the entrance pathway, it should be covered with natural substrate.		
Rearrange substrate material around inlet/outlet of small culverts to allow greater visibility through structures.		
Add salamander ramps at curbs.		
Add grates to existing culverts to allow light/moisture/temperature penetration into the culvert.		Carr, T., R. Dacanay, K. Drake, C. Everson, A. Sperry and K. Sullivan. 2003.
Modify existing trenched drains to allow animals to enter.		Bank, F.G., C.L. Irwin, G.L. Evink, M.E. Gray, S. Hagood, J.R. Kinar, A. Levy, D. Paulson, B. Ruediger, and R.M. Sauvajot. 2002.
For Multi- chambered structures with waterflow, divert waterflow so that one chamber remains dry for terrestrial wildlife.		

Promote waterflow through culverts to prevent standing water from inhibiting passage through a culvert or deterring entry into the culvert.		
Prevent polluting agents and road sediment from being flushed through culverts.		

<u>Reduce Intimidation</u>

These types of actions enhance structure attributes so prey species are less apprehensive about entering an area for fear of a predator hiding inside or near the structure, to reduce light and sounds associated with roads and vehicular traffic, and to minimize human use of structures intended to pass wildlife.

Action		**References**
Replace steep abutment slopes or walls with natural 2:1 slopes for Adaptive Ungulates, Vermont's white-tailed deer and moose.		Dodd, N.L., J.W. Gagnon, A.L. Manzo, and R.E. Scheinsburg. 2007.

Remove f ill predator perches - ledges or places where prey species may be fearful of unseen predators.		Little, S.J., R.G. Harcour, A.P. Clevenger. 2002.
Add median skylights or openings. [This measure is not appropriate for all culvert situations. Avoid creating very high contrast conditions inside the culvert; Avoid where there is a narrow median that would result in a large increase in traffic noise inside the culvert; Avoid allowing precipitation to center the culvert where winter temperatures could cause the creation of ice mounds inside the culvert, thereby inhibiting wildlife passage.		Reed, D.F., T.N.Woodard, T.M. Pojar. 1975.

		
Avoid/remove highway lighting near structure entrances.		Jackson, S. D. (2000).

If wildlife is to be funneled to use an area at an existing paved interchange, remove asphalt from one side of road, parallel to road, to promote wildlife movement parralle to the road on this pathway. Photo example: UDOT removed asphalt at an interchange under I-80 in hopes wildlife would use it. This approach is still in the testing stage. Photo credit: P. Cramer		
Implement measures to reduce traffic noise inside culvert and/or at structure entrances (e.g., concrete shoulder barriers placed above the structure)		Jackson, S. D. (2000).

To the extent possible, avoid laying trails or other human access through crossing structures. Where trails do pass through a structure, separate human trails from wildlife pathways through the structure.		Hartmann, M. (2003). Evaluation of Wildlife Crossing Structures: Their Use and Effectiveness.?
Install signs near crossing structures or where trails cross through structures to limit human activity in and around wildlife crossings [Avoid drawing attention to unobtrusive crossing structures with unnecessary signage]		Clevenger, A. and N. Waltho. 2005
Install barriers (e.g., large boulders) to prevent motorized travel through crossing structures.		

<u>Enhance Structure Approaches</u>

Wildlife need to be able to find a potential crossing structure. Enhancements that increase the visual appeal of a structure can increase its use.

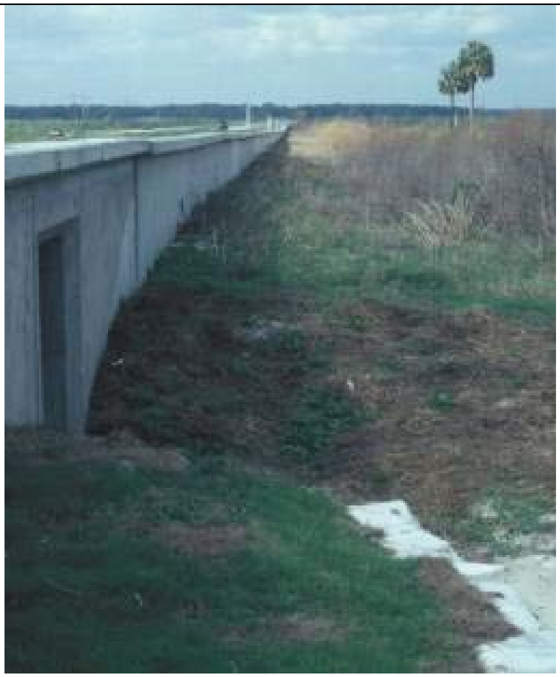
Action		**References and Comments**
Enhance/maintain native vegetation cover in front of structure entrances. Example photo: Florida DOT planted fast growing pine trees to lead from forest to crossing entrance for Florida black bear. Us 40. Photo credit: P. Cramer		Ng, S., J. Dole, R. Sauvajot, S. Riley, and T. Valone. 2004.
Thin heavy vegetation that may obstruct wildlife passage at structure entrances.		Maintain a balance between enough cover for prey species to feel safe entering a culvert, but not so much that animals cannot enter or have good visibility into and through the culvert.

Avoid the use of herbicides around structure entrances.		Vegetation amounts and heights similar to the surrounding landscape are important, as is the absence of herbicides.
Plant shrubs and trees in the median to provide better cover and insulation from highway traffic noise and lights. Photo example: Arizona DOT planted trees along median at a newly established wildlife crossing bridge. The new construction eliminated all natural vegetation. Note: tress are protected from grazing ungulates. Photo credit: P. Cramer		

Avoid the use of erosion netting in landscaping around crossing structures, which may ensnare snakes. Photo example: garder snake in nylon erosion netting. VTrans is a leader in using errodable mesh netting in areas where erosion control is necessary. Photo credit: Peter Leete, MNDOT.		Leete 2010. and VTRANS practices manual
Convert cattle fencing near structure approaches to wildlife friendly rail fencing to allow young to pass through to access structures. Example: Utah DOT works with Utah Division of Wildlife Resources to install rail fencing at entrances to wildlife crossings to fence cattle out and allow wildlife of all sizes and ages to access the crossing. Photo credit: P. Cramer		Common practice in western states.

Fencing and Barriers

Wildlife need to find structures in order to use them. This may take some re-routing “encouragement” from fences that prevent wildlife of different types from entering the road right of way.

Action		Reference
Add wildlife fencing and/or guide walls to existing suitable structures - do not install extensive fencing where there are no suitable crossing structures. Photo example: In Florida, FLDOT installed a one meter high concrete wall with a lip at the top to prevent amphibians and reptiles from accessing US 441. This wall “encourages” wildlife to use one of eight concrete box culverts along this 2 miles wall. Research demonstrated a 95% decrease in wildlife-vehicle collision carcasses within one year of installation. The continuing challenge is to maintain vegetation so that it does not grow to and over the wall, allowing climbing wildlife to access the road. Photo credit: P. Cramer		For guidance on different types of wildlife fencing, see: http://www.azdot.gov/highways/EPG/EPG_Common/PDF/Technical/Wildlife_Connectivity/Wildlife_Funnel_Fencing/Wildlife_Funnel_Fencing_Summary.pdf

Modify existing right-of way fencing by adding height to convert it to wildlife fencing. Photo example: In Utah, UDOT added right of way fencing on top of existing fencing to bring fence height to 8 feet. New poles were installed mid-way between existing poles. Photo credit: P. Cramer		FHWA. Keeping it Simple - Arizona. http://www.fhwa.dot.gov /environment /wildlifeprotection
Angle fence ends away from roadway to prevent 'end arounds'.		Hardy, A.R., J. Fuller, M.P. Huijser, A. Kociolek and M. Evans. 2006.
Place large boulders at fence ends to prevent animals at grade crossings at fence ends.		Clevenger, A.P., B. Chruszcz, K. Gunson, K. and M. Brumfit. 2002.

Install wildlife fencing across a median to adjacent structures. Photo example: Arizona DOT installed median fencing in conjunction with wildlife crossings and wildlife fencing. Note: fencing should attach to abutments. This fencing is incorrectly placed along the slope. Many prey animals prefer to walk along the slope rather than the lower surface. Photo credit: P.Cramer.		
Install escape ramps along fenced sections. Photo example : we can replace this one. For now: Elk prepares to jump from escape ramp to natural side of fence. Ramp was installed by Montana DOT along US 93. Photo credit: P. Cramer		Bissonette, J.A. and M. Hammer. 2000.

Maintain fencing to prevent gaps in fence. Photo example: Dr. John Bissonette of Utah State University removes mule deer hair from a hole in wildlife fencing in Utah. Holes even 8 inches high are known to allow deer to enter road right of way. Photo credit: P. Cramer.		

Install Electromat at gaps in fencing, such as highway on/off ramps, driveways. Photo example: several states and Canadian provinces are working with Electromats, which are electrified cattle guards, to prevent wildlife from entering roadway. This photo example is from Utah where the local maintenance crews purchased and installed these mats. They took care to make the mat flush with the road to minimize snow plow blades from catching on the mats. As of 2011 the UDOT maintenance crews in the area (Price, UT) are happy with them.		http://www.electrobraid.com/wildlife/highway_fence.htmlDodd, N. and J. Wise. The Nation's Most Advanced Game Crossing System. IMSA Journal 45(2); T.W. Seamans, Z.J. Patton, and K.C. VerCauteren. ElectroBraid Fencing for Use as a Deer Barrier. http://www.itre.ncsu.edu/cte/icoet
Construct crosswalk at controlled gap in fencing to allow animals to cross at-grade. Photo example: In New Mexico’s Tierjas Canyon along US 66 . . .	 Electro-mat, Electrobraid fencing, 8-foot fence and solar collector on N.M. 333.	Sprague, K. Ogren, and R.E. Schweinsburg. 2010.

Install shoulder or median barriers with scuppers (at least 25cm high and 100cm wide) every 5th barrier to facilitate small animal passage through the barrier.		Clevenger, A.P. and A.V. Kociolek. 2006.
Arrange shoulder or median barriers with intermittent gaps to facilitate wildlife passage at grade.		Same as above
Replace concrete shoulder and median barriers with cable median barriers where it is desirable to facilitate at-grade wildlife passage [cable barriers are considered more permeable for all species guilds than boxbeam barriers, though more research is needed]. Photo examples: In Utah, cable barriers (below) are used in areas where they serve to prevent head on collisions and allow the mule deer, elk, and moose, as well as other wildlife to cross the road. Box beam barriers area also used in Utah in areas where wildlife are present. The picture to the right is along I-70 in an area prone to mule deer and elk crossings.		Same as above. Also common practice is specific regions within specific DOT's.

		
Install double cattle-guards and convert existing flat-bar cattle guards with round bars at controlled gaps in wildlife fencing, e.g., driveways or county roads. Install wildlife guards.		Hardy, A.R., J. Fuller, M.P. Huijser, A. Kociolek and M. Evans. 2006. Allen 2011
Avoid gaps in wildlife fencing or walls.		

Add or Adjust Structural Features

These actions are for aerial, terrestrial, and aquatic wildlife that are more unusual than the above ideas.

Action		**Reference**
Fix perched outlets to allow access into culvert, for both aquatic and terrestrial wildlife.		
Add a gutter pipe for small mammals.		Foresman, K.R. 2004.

Keep drains fitted with grate to all edges, close openings to drain, so turtles and other small animals do not fall in. Create a sloped curb rather than a 90 degree ubrupt curb so turtles, and other animals can escape road bed. Photo example: Minnesota DOT has a BMP to create drains that are completely covered with grate, and sloped curbs in areas with amphibians or reptiles. Photo credit: Peter Leete, MNDOT.		Leete 2010.
Bore new dry culverts adjacent to inundated culverts to promote wildlife passage through drainages.		Anne Burrows work and diagram from NCDOT
Add bat boxes.		
Install poles placed on bridge edges to help birds perceive the barrier and avoid colliding with vehicles.		FHWA. Keeping it Simple - Oklahoma. http://www.fhwa.dot.gov/environment/wildlifeprotection
Install aerial bridges across highways between poles to facilitate arboreal crossings.		NCDOT flying squirrel platforms Rope bridges over

		roads
Decommission old roads through a structure and restore natural landscape features to convert to a wildlife crossing.		
Find alternative deicing agents along roads where moose and other wildlife may be attracted to the salt-based deicers,. Salt based deicers increase chances of wildlife–vehicle collisions. Photo example: bighorn sheep licks salt from road.		

Appendix 5 (Section B.5 Monitoring and Adaptive Management)

This section describes how field data collection and modeling can assist in effectiveness monitoring and new planning as part of an adaptive management cycle. The assumption here is that agency decisions and actions will be informed by field monitoring and that effectiveness monitoring will be used to improve future decision-making.

B.5.a VTrans Detection and Monitoring Methods for Vermont Species

A number of detection and monitoring methods exist which can help determine where animals cross roads and where they occur on the landscape. These are equally applicable for planning purposes and for post monitoring of installations to determine use and success. More rigorous data collection that can help to determine fine scale movements and habitat use by animals depends on radio-telemetry and GPS collars. These can be fitted on animals as small as mice. Smaller animals can best be monitored with pit tags (inside their bodies), and ear tags and then recaptured. The more passive methods, including cameras, detection dogs, hair snares, track plates, and snow tracking, are all noninvasive, and do not necessitate interaction with animals. When animals approach the road, more proactive methods (not covered here) can be used to warn drivers of approaching larger animals. These rely on cameras that activate lights or other signals when animals are approaching an area to help mitigate wildlife related accidents, see passive and dynamic signs in Section D.1.

There are two general approaches to detecting wildlife on the landscape and their movements: trapping the animals to attach collars or tags and seeing where those individuals move, and censusing animals with less invasive methods.

Trapping and Monitoring Animals

Trapping animals involves two types of methods, based on animal size: collaring and tracking them with radio and Global Positioning System (GPS) technology, or trapping them and fitting the animals with pit tags, ear tags, or collars. Radio telemetry is a long used method of tracking animals on a regular basis (one to three times a week) with radio signals coming from the animals' collars to see where each animal is in real time. GPS collars track satellites and take a reading on the animals' location at regular intervals throughout the day and night, and the data is either live fed to a website (expensive) or loaded on the collar (less costly). The collars are typically loaded with a cartridge that then blows the collar off the animal after about one year, and the researchers use the radio telemetry to locate the collar and download the data. This technology provides precise animal location data. This approach is costly (GPS collars can cost $2,000 to $4,000 for a large ungulate) and somewhat invasive in that it involves capturing and collaring animals, but provides intensive data which is invaluable in determining how an animal moves across the landscape, even with respect to where it may have crossed a road. Analyses and modeling of collar location data can illustrate habitats that have a higher likelihood of being used, and where problems with road crossings may occur. When these collars are used on herd animals such as deer, it may help identify areas where multiple animals may be using the landscape and crossing the road. Departments of Transportation have sponsored studies with these collars to learn more about where populations of large ungulates such as elk and moose move in relation to road crossings. Currently Idaho Transportation department has 17 collars on moose and 23 collars on elk in the Greater Grand Teton area to learn of their movements along local highways. In a similar study, Caltrans is funding the GPS collaring of 45 deer over 18 months to monitor movements adjacent to a highway that experiences very high rates of deer-vehicle collisions, in order to design mitigation solutions to protect both the deer (and other wildlife) and drivers.

Trapping smaller animals can also involve radio telemetry and GPS collars (animals as small as mice and fish have been radio-tracked), but typically these animals are live-trapped and re-trapped to detect movements and population trends. Fish and reptiles can also be fitted with tags inserted under the skin (pit tags), small mammals can have ear tags attached, birds can be banded, turtles can be fitted with tags on skin, and tortoises can be marked on their shells. The animals are then turned loose and there is a systematic trapping effort to catch and therefore sample the population to see if these same animals can be caught again and their movements estimated. Bellis (2008) performed these types of studies in conjunction with monitoring cameras at the Bennington Bypass bridges in southern Vermont.

Censusing with Non-invasive methods

Non-invasive methods, including fecal pellet surveys, scat sniffing dogs, snow tracking track plates, hair snares, nest, hiberium, and bird surveys, road kill carcass surveys, hunter surveys, aerial flight surveys, and camera monitoring are lower in cost than GPS collars and monitoring and can provide multiple species and region surveys for costs similar to a single species GPS study. For site monitoring where cost, or more precise estimates of the date of a species use of an area are considerations, these more passive methods with longer latent times to detection may prove just as effective, if deployed for the correct length of time in the most opportune season(s).

Surveying fecal pellets and feces (scat) can be conducted in two ways: researchers conduct fecal pellet surveys along set transects, or detection dogs are used to find scat. The former method is a long used method that biologists have conducted to look for ungulate fecal pellet groups to help determine deer presence and densities in an area. It can also include looking for all scat of all species along these transects and plots. Cramer (2011) conducted fecal pellet surveys in Montana, Utah, and Washington in an effort to determine species' presence near monitored wildlife crossings. For the later method, detection dogs are trained to indicate when they detect evidence of wildlife, most often dropped scats (feces) from target species. They are proven to be more effective at detecting presence of target species than other noninvasive survey methods in short term site surveys (Long 2007). Accumulation of scat samples can provide data on relative abundance of visits to an area, though caution must be taken with species that use these droppings as markers, or deposit them in communal latrines. This method requires long range planning in order to schedule field time with a trained handler and dog, and is relatively expensive. Surveys are typically conducted in a grid fashion, with the scale defined by conditions including the openness of the habitat. All grid cells or randomly selected cells may be surveyed. If there is a specific area of interest, such as a roadside, surveys may be run parallel to the roadway and increasing distances. The scat sniffing dog method can be very costly (thousands of dollars for several weeks of work, and then thousands of dollars for genetic analyses).

Wildlife can also be surveyed through tracking. Typically tracking is done with snow conditions, but animals can also be monitored with track plates or sand beds in areas where there is a restriction to funnel them in an area, such as a wildlife crossing. In Vermont snow-tracking has been found to be a good indicator of the many species that occur in an area throughout the year, not just in the colder months (Bellis 2008). This method requires favorable conditions which include sufficient snowfall and a time period after this to allow animals to move through the area before data collection. Snow tracking can be done in standardized transects across the landscape, or alongside a road right of way to determine where wildlife are entering and exiting the road area. Barnum et al. (2007) snow tracked 22 species along roads in New Hampshire to help determine where these animals were entering and exiting the roads and the correlated of this data with wildlife-vehicle collisions.

Track plates are effective in most seasons, and for many smaller species, though are not effective for canids (dog-type species). Track plate can be composed of enclosures that contain an aluminum plate dusted with toner cartridge powder and clear contact paper or a smooth surface piece placed next to the toner section, or they can be made from wood laid down with fine talcum-type material laid throughout the board (as Bellis 2008 did for the Bennington Bypass research). Smaller species such as long tailed weasels, mice, and some reptiles and amphibians, can be monitored using track-plates.

Track beds, made of fine sand placed along a road, can be used to record wildlife approaches to the road. All tracking beds require researchers to check the plates and beds every few days, making this method very labor intensive for limited amounts of information. Creating and maintaining sand beds along roads has also been found to be costly (thousands of dollars per bed, and as much as $50,000 per bed in Montana along US 93) very energy intensive to maintain through raking or herbiciding, and limited to only warmer months when there is no snow. Researchers in Montana along US 93 had very low rates of success with species identification and crossing success of individuals with sand beds and have stopped using them in research (Hardy et al. 2007).

Hair snares are typically made of barbed wire or pads of nails that easily snag animal hair as the individuals pass over the snag to either eat bait or smell a scent station made with very odoriferous materials, such as rotting fish. The hair is gathered by researchers and genetically analyzed for species, and possible gender and individual identification. These data can help determine individual movements and genetic relatedness of animals across the landscape and roads. Hair snags are typically deployed with remote cameras to better identify the animal and possibly the individual. Typically researchers are looking to sample the carnivore populations with this method. Hair snares have not proven effective on northeastern species other than black bears (Long 2007, Farrell in prep.). Weather related malfunctions led to high rates of missing data during winter 2008-09, indicating that winter in this region would not always provide accurate data on detection probabilities for cameras and track plates. Currently there is a study in western Washington, sponsored in part by Washington DOT, to use hair snares to survey carnivores in areas where the natural areas are bisected by highways such as Interstates 5 and 90 to better identify if populations are genetically isolated (Long 2001).

Visual and auditory surveys can also be conducted to detect different wildlife species' presence in an area. The traditional bird surveys are standardized to visit areas of interest at regular intervals in the spring when birds are calling at their territories. Success of those birds at raising their young to the point they are fledglings and leave the nest can also be measured by monitoring the birds' nests over the course of the spring and summer. This can be important to determine if an area is actually a successful breeding area that is a source of bird species rather than a place they only sing, or worse yet, a sink for individuals that come to an area but are not able to reproduce for various reasons. Surveys can be conducted for turtle nests, snake hiberium, deer densities at certain times of year, and salamander numbers during times of movement. Survey methodology is critical, as unit of effort and ability to detect individuals and places of interest can greatly vary among studies. Citizen scientists, those that are not typically formally educated in the area of wildlife, and who are not paid, are proven to be very capable and helpful in wildlife surveys of all kind across North America. Scientific oversight in such studies is critical.

Roadkill surveys can also be conducted to count wildlife carcasses on roads. These surveys help to determine what animals did NOT make it safely across the road. They do not necessarily indicate areas where wildlife is successfully crossing the road. The carcass data can be very important to wildlife agencies and transportation agencies in identifying areas where mitigation can be installed or simple retrofits of existing infrastructure can be undertaken. Often carcass surveys and data can also be used to indicate population trends. There are two main types of carcass surveys – intensive surveys that locate, count, and identify, every carcass occurrence and opportunistic surveys that record carcasses that are incidentally encountered by agency staff or volunteer scientists. The first approach allows calculation of the impact of collisions on populations, the first and second allows modeling of likely causes of collisions in different areas of the state.

Surveys of hunters can assist with population trends and distributions. This has been done for black bear occurrences in Vermont, and is currently underway in Utah.

Aerial surveys along set transects can be used to monitor populations of larger animals, such as white-tailed deer. These surveys are often cut as soon as budgets are reduced, and other survey methods have to be used to better ascertain population numbers and movements.

Remote motion-sensed cameras are a cost-effective and increasingly-popular method for surveying wildlife at fixed locations. These cameras are triggered by movement or heat in motion. They take anywhere from one to 10 pictures, or video when triggered, and can sometimes remain activated as long as there is motion. Date and time stamps are standard for most cameras, and can provide precise information on times of wildlife visits. The professional cameras made by the companies Reconyx and Bushnell (2011 Trophy Cam) are used by wildlife researchers across the world, and have proven to be the most reliable and accurate wildlife research cameras. These cameras take 4-12 AA batteries that can last for several months, depending on the activity in front of the camera and type of images recorded. The information is stored on memory cards that can be switched out like the batteries. These cameras must be mounted and locked in protective boxes so they are not stolen, since they cost between $200 and $600. This monitoring method does not require animals to interact with any devices, and infrared cameras (no flash at night) may go undetected by many species, which means they will maintain normal usage patterns of an area. This method allows for observing animal behavior, potentially individual identification and gender and age classification. The range of detection for these cameras is approximately 15-30 feet (5-10 m) at night to 40-60 feet (12-20 m) by day. This allows researchers to install these cameras at intervals that cover areas that would have been covered by sand beds, to look for smaller wildlife, wildlife that are difficult to detect in vegetated areas, and wildlife that are typically very wary of humans.

Monitoring Carnivores in Vermont

Farrell (unpublished observations) surveyed carnivores in Vermont for PhD dissertation research. The analyses helped to determine detection rates of different species using both remote motion-sensed cameras and two track plates at a specific location. Table A.5.7 demonstrates the ability of these survey methods combined to detect at least one animal movement by the different species over 10 weeks of surveying. The table includes the season that data was collected mostly consistently for the specific species. For instance, some species were only minimally detected by either cameras or track plates. Red fox were not detected at high enough levels to provide cross year seasonal comparisons. Grey fox were only detected at high enough rates for evaluation of summer and winter data. Farrell also found that track plates worked well for skunk, opossum, and raccoon.

Table A.5.7. Cumulative detection rates of different carnivore species using one motion-sensed camera and two track plates. The detection rates reflect the probability of obtaining at least one detection by camera or track plate during 5 visits over 10 weeks, and the season that was most consistent between years.

Species	Season	**Cumulative detection rate**	Standard error
Black bear	Summer	**0.95**	0.046
Bobcat	Fall	**0.65**	0.172
Coyote	Fall	**0.78**	0.116
Fisher	Spring	**0.97**	0.029
Grey fox*	Summer	**1.00**	0.000
Opossum	Summer	**0.87**	0.106
Porcupine	Spring	**0.84**	0.081
Raccoon	Summer	**1.00**	0.001
Red fox*	Spring	**0.70**	0.146
Skunk	Summer	**0.94**	0.036

Farrell's study helped determine the duration cameras and track plates need to be used to detect a species' presence in an area. Increasing camera survey duration from 3 to 14 days and the number of seasonal visits to 5 improved detection for each of the 13 species, and added detection sites for all species every season they were detected. Surveying over multiple seasons added detection sites for 10 species (raccoon were detected at all sites the first season), especially more mobile generalist species such as bear and bobcat. Single detections of bobcat in spring and fall at one site suggested that some areas, though used infrequently, may be important for seasonal movements and dispersal. This information is important in preparing future studies to detect different carnivore species' presence in an area. As scientific monitoring methods become more widespread with agencies, this information can inform how to monitor over time and space and species.

Monitoring Cost

There are several ways to cost-effectively monitor the use of crossing and thus determine how well they meet biological and management goals. These methods vary in cost and in the types of information provided. Parks Canada commissioned a recent study of the most economical ways that local organizations and agencies could scientifically monitor wildlife movement and use of crossings (Ford et al., 2009). For short-term studies (several months to a year), the most economical method that provided sufficient data was the use of track-pads, which is a way to record the type and sometimes individual animal crossing a particular area. In their example, a 4-month study with 200 animal passage events cost $7,552 for track-pads and $22,375 for cameras (multiple cameras). For longer-term studies (>1 year), the most economical method was the use of cameras alone. Cameras have high up-front costs, but for many hundreds or thousands of crossings and over long use-periods, they are less costly per animal passage than track-pads, require less maintenance and can withstand a wider range of weather conditions. These values are in line with: 1) a 2010-2011 study by a UC Davis investigator (Shilling) along a California interstate, which cost ~$60,000 for monitoring 15 existing culverts, over-passes, and under-passes, combining track plates and wildlife camera traps for ~12 months of field study and 2) a 2011-2012 field study by Dr. Cramer in Idaho that cost $25,000 to monitor three existing culverts and one area of interstate with a total of 10 cameras, over one year studying mule deer and elk movement.

B.5.b Citizen science collection of opportunistic live and dead wildlife observations on roads

People from all walks of life observe live and dead wildlife while they are on roads. Formal surveys of road-killed animals are sometimes used to indicate where animals are trying to cross roads. Many surveys of live animals have taken place on roads because they provide a way of covering large areas and because roads provide a means to survey live and dead animals. However, it is a biased method, because the surveying is only representative of "roaded" parts of the landscape.

For transportation agencies, understanding where and what kinds of animals are moving near and across roads is important information. Transportation agency biologists, resource agency staff, and increasingly citizen scientists can provide wildlife observations from opportunistic events or from formal surveys along roads. Maine Audubon collaborated with the Road Ecology Center at UC Davis to develop a program where citizen scientists report live and dead wildlife observations along roads and highways (Maine Audubon, 2010). Although anyone can participate, at least a third of the observers on this system are professional scientists. Currently, this system provides the most extensive wildlife reporting process in the state of Maine. In Vermont, the Vermont Herp Atlas (see box insert) provides a similar service for observers of herpetofauna (reptiles and amphibians). A combination of involved citizenry, robust surveying protocols, and easy-to-use reporting tools could make this a powerful approach.

Data Quality

A common concern about citizen science projects is that the resulting data may be of low or unknown quality. However, assessment of a sister system in California revealed that species-level identification of road-killed animals was >95% accurate, with similar locational accuracy (Shilling, unpublished observations). Given the very high data return rate on investments in citizen science programs, it is worth considering this method for both opportunistic and formal surveys of live and dead wildlife associated with roads.

Data Collection

Agency staff collection of wildlife observations is an increasingly-common method for obtaining large amounts of data about wildlife-road associations. Staff involved in roadkill carcass collection, or casual live animal observations, are unlikely to be expert taxonomists. Environmental scientists and biologists with VTrans could conduct surveys of highway corridors or regions. Surveying frequently (<weekly) over short periods can provide seasonal estimates of impacts of highways on animals (carcass surveys) or potential impacts (live and dead observations).

Departments of transportation are especially responsible for ensuring that carcass data collection is accurate and recorded in a timely matter. Currently transportation agencies are working with their maintenance departments, their wildlife agency personnel, and

What Are People Saying? Data Collection of Amphibian Occurrences in Vermont

In an interview with author L. Farrell, Vermont ecologist Steve Parren gave some tips for monitoring amphibians with respect to how they move across roads.

Creating and Executing the Monitoring Plan

- You want to have an index of use over some period of time to get an idea of what uses an area. Need data from over a span of time each year, (a number of days through a season, not just one night per year), and comparison between years, over a particular span of road.
- Sampling should remove the background variability due to weather. Different nights have different weather, so monitoring for multiple nights per year removes some of the variability in animals' response to the conditions. Incorporate weather variability data such as temperature, precipitation, snow-cover if relevant (these for amphibians) and monitor at relevant times of the year, in appropriate conditions (i.e. not on dry or below freezing nights for amphibians).
- Data should include at least 3 visits per year for 3 years before, and at least that after project completion. This takes a lot of effort. It is key to have someone who is dedicated to rounding up folks on short notice, giving a heads up as soon as it becomes apparent conditions may be favorable, and keeping them updated.
- Provide a protocol and organize transportation to and from site, and site parking if necessary.
- Amphibians are easy, but larger organisms such as turtles or mammals may become trap happy or, more likely, trap shy so one would need a monitoring regime that won't influence their behavior, so they don't avoid detection. This may include infrared (non flash) cameras for bobcats. Trained observers can read turtle nesting substrate to determine turtle nesting behavior, nest emergence, and predation.

Interpretation of data**–** You need to understand the limits of the data and not over interpret. Folks sometimes hesitate to draw conclusions without statistically robust findings...real world does not always deliver clean results and you have to avoid paralysis by analysis (unless your primary goal is publishing). It is best to have a pre conceived framework to examine data, rather than going on a fishing expedition, but sometimes you think of things when you are at the analysis stage.

Note on monitoring after project completion**—**Some variables in construction may introduce mortality associated with construction design. Different lengths of wing-walls used to funnel animals into passages may not be long enough, and surveys should capture extra mortality where animals cross over at ends. This data is hard to capture, and takes commitment.

(Steve Parren)

carcass pick up contractors to ensure wildlife carcasses are recorded to the nearest tenth of a mile, and if possible the sites are recorded with GPS equipment. At the time of this writing, Utah DOT was rolling out the first phase of a smart phone application that will enable carcass pick up contractors, wildlife agency and transportation agency and public safety personnel to record exact GPS locations of wildlife carcasses along roads, and to answer 5 questions about the species, time of day, etc. The data is uploaded immediately or later, to a website, where it is organized and available to all authorized personnel. The code for this application was written in a manner that will allow other states to use this application for their personnel. A similar smart phone app is being used with the California Roadkill Observation System (REC, 2009) and will be developed for the similar Maine program (Maine Audubon, 2010), both of which are volunteer-scientist programs. A simpler approach is to adapt the data collection web sites to be usable on the smart phone screen itself, avoiding the cost of app development, adaptation and upgrading.

It is likely that the combination of agency staff and citizen scientist-collected data will provide the richest and most useful set of wildlife observations. By standardizing how data are collected and reported, analyses can be conducted using both datasets.

What Are People Saying? Volunteer Monitoring of Vermont Amphibians and Reptiles

Vermont Herp Atlas

More data on the distribution and abundance of reptiles and amphibians in Vermont was needed for the Reptile and Amphibian Scientific Advisory Group to the Endangered Species Committee to make more informed recommendations for listing and permitting. Distribution maps were just lines drawn on maps, with little statewide data. Herps are not visible for long periods. It is difficult for a limited number of paid staff to get to enough areas within windows of opportunity. Herps are easy to catch and photograph. So he initiated The Vermont Reptile and Amphibian Atlas, a website where people could get information and post sightings, to compile statewide information. (http://www.vtherpatlas.org/). To get the VT atlas off the ground he used press, email, posters saying he was interested, and would love to hear what people were seeing. Once a website was established and identification information provided, many visitors are 'accidental', looking up ids on site. Often these visitors keep coming back to see what's going on. The atlas is almost 20 years old and has built up over time. This approach to recruiting local people who are in the area year round now provides 6-10 reports daily. Jim answers everyone who contacts him though the site. Radio interviews on Vermont Public Radio and other press have added legitimacy and gotten more people to submit records to the website. An Atlas Facebook page would probably get more hits but given the time needed to review and enter data, Jim feels he is currently getting all the reports he can handle.

Salisbury, VT Road Crossing Monitoring Groups

The goal of this monitoring effort was to look at wildlife (mammals and turkeys) crossings to inform permits for development, not for structural construction, though the information could be used in this way if and when appropriate. Detailed data on wildlife in the town was not available through the state, it was necessary to get this info at the local level. Work from the Bennington Bypass showed that winter tracking was the best indicator of year-round use. Jim's first attempt at recruiting people for snow-tracking consisted of hiring someone part time to guide a volunteer group who had worked tracking bald eagles. It worked for only one year. People who were interested in the mission were needed, so he gathered volunteers via Conservation Commission members and their associates. Because correct ID of snow tracks is important to provide accurate information, and becoming a knowledgeable tracker takes years, there is a need to provide ongoing support morally and educationally. So he initiated social tracking. On Saturdays they went to different people's routes to work together on IDing what they came across. After a couple of years people moved off and took up their own routes. A local crew was built from personal contact and continued educational opportunities. Route maps were generated after talking to the Planning Commission. A minimum goal of 5 surveys per route was set. A route could be finished within one year, or over 2 to 3 years. They did what they could with the people they had, some folks got out 3 times, some 7 times. The glue that held this together was having a dedicated cheerleader.

(Jim Andrews)