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Vermont Transportation & Habitat Connectivity Guidance Document



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Preface

The information contained in this guidance document will inform transportation planning, design, construction, operations and maintenance activities, as well as related wildlife and ecological systems monitoring.

The document is organized into 3 main sections: 1) planning, 2) design and construction, and 3) operations, maintenance, and monitoring. The sections describe steps and procedures, and specific examples of how to address challenges associated with ecosystems, wildlife, and transportation focusing on step by step processes and checklists relevant to planning and managing roadways for increased habitat connectivity.

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Executive Summary

The purpose of this document is to provide best-management-practices addressing wildlife vehicle conflicts and habitat connectivity. Vermont's transportation network invariably intersects wildlife movement corridors thereby posing a threat to drivers and ecological health. The proposed practices incorporate habitat connectivity considerations into the planning, design and engineering, and maintenance and operational processes. The report is divided into three primary sections: Planning, Design and Construction, and Operations & Maintenance.

Vermont Agency of Transportation and Vermont Department of Fish and Wildlife officials should assess existing connectivity by monitoring wildlife movement, compiling existing data sources, and creating an analytical GIS model. Basing these models on quantifiable metrics such as genetic variability or wildlife-vehicle collision frequency will give planners a bench mark to measure the success of collision mitigation efforts. With these tools, planners can identify and prioritize areas with high collision rates.

Several guidance tools in this document match specific species needs with structural types to customize wildlife mitigation efforts. The *Species Movement Guild* (Table 2, page 19) and *Crossing-Structure Classes* (Table 4, page 30) guides project engineers and designers on selecting the most cost-effective structure or retrofit to enable enhanced wildlife crossing. Variables include location, frequency or spacing, size, and configuration of crossing structures. In addition, the document outlines deterrents and incentives to wildlife use of the right-of-way and crossing structures. Driver's based solutions and appropriate maintenance practices are proposed to further reduce wildlife-vehicle collisions.

A critical component of ensuring habitat connectivity is adaptive and responsive management of wildlife crossing structures. This proactive approach can generate philosophical and programmatic support for future wildlife crossing projects. Ongoing monitoring and data collection will give insight into design and plan effectiveness.



Figure 1: White-tailed deer using an existing Interstate 89 bridge over Muddy Brook in South Burlington/Williston, Vermont. This bridge preserved enough riparian habitat to allow safe wildlife movement under one of the busiest sections of I-89. Photo credit: C. Slesar,

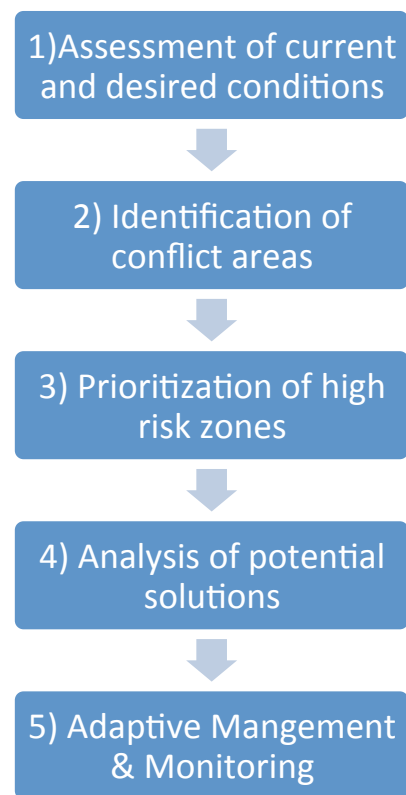
1. Planning

The State of Vermont's Agency of Transportation (VTTrans) must provide for adequate movement of fish and wildlife to uphold its overarching goals of effective, efficient and safe transportation of people and goods while minimizing impacts to the environment and costs to taxpayers. Wildlife on roads and other infrastructure present safety hazards resulting in vehicular crashes and injuries to drivers. Daily, monthly, and seasonal movement of species creates hazardous situations for humans and animals where movement corridors and

transportation corridors intersect. A low-impact transportation system depends on safe driving behavior, enhancements to existing infrastructure to make them wildlife friendly, and construction of crossing mechanisms such as specially designed overpasses, underpasses, and culverts.

In Vermont, bridge replacement presents an opportunity to improve wildlife movement conditions. For example, extending the beam of a bridge greatly improves mobility of many species of wildlife by providing stream bank walking paths. Preserving riparian habitat underneath bridge structures is a proven successful method for crossing wildlife. (See Figure 1.)¹ This simple solution has been incorporated into bridge designs on the Bennington Bypass and Route 12 in Middlesex. Modifying existing structures is not always sufficient. Under certain conditions, new structures may be needed.

Planning is a key component of effectively minimizing wildlife and vehicle conflicts. The primary tasks of planners include networking between wildlife and transportation experts, state agencies, regional planning commissions (RPC) and conservation NGOs; identifying high impact roadways; prioritizing projects in an efficient manner; and project effectiveness evaluation. Planners must communicate the findings of these analyses with



engineering and design, operations and maintenance, and safety staff.

Planning for connectivity is a complex multidisciplinary activity. It requires consideration of socio-economic, ecological, biological, and adaptive management factors. Figure 2 outlines a 5-step process to accurately assess the current status of wildlife movement, develop measurement and modeling tools, apply cost-benefit analyses, implementation of adaptive solutions.

Step 1: Assessment of fragmentation of movement corridors or habitat zones pertaining to species of interest. Species listed as threatened or endangered, or those that pose a significant risk to drivers, are of particular concern. Compare the findings to natural or reference conditions. There are multiple approaches to quantifying habitat loss and fragmentation requiring slightly different spatial or species data.²

Step 2: Identification of wildlife/transportation

Figure 2. The 4 step process to analyze wildlife movement in transportation planning.

¹ <http://www.wildlifeandroads.org/gallery/>

² See “Quantifying Terrestrial Habitat Loss and Fragmentation: A Protocol” for an overview of possible quantification methods. <http://bit.ly/NEzIzb>

conflict zones through various Geographic Information System (GIS) data sets and the model developed in Step 2.

Step 3: Prioritization of the high risk zones identified in Step 3 based on: 1) crash report data involving wildlife 2) large animal (such as deer, moose, and bear) movement potentially compromising public safety, and 3) significantly isolated animal populations resulting in genetic decay or migratory difficulties. A cost/benefit analysis at this stage would determine whether further action is needed.

Step 4: Analysis of actions to improve wildlife movement, genetic connectivity, and public safety. The benefits or potential drawbacks of any action or non-action should be evaluated using the connectivity³ model developed in Step 2.

Step 5: Site monitoring and evaluation to determine the success of the mitigation project. If mitigation efforts prove to be ineffective, the

1.1. Step 1: Assessment of Existing Connectivity

Assessment of existing habitat connectivity is a critical first step to inform planners and gather data critical to the decision-making process. This process should expose potential issues and concerns to be addressed and provide a baseline from which the success of projects may be evaluated. There are various methods of measuring the connectivity of landscapes for wildlife populations. Connectivity depends on environmental conditions such as habitat type, elevation, and proximity to food or water sources; human development conditions such as urbanization, resource extraction, transportation, and agriculture; and species' preferences regarding tolerance to human activity, and landscape groundcover variation. Use Table 2 and Table 3 to focus research efforts on threatened species within the particular bioregion of interest. Study previous research efforts on species or bioregions of interest.

Recommended methods of data collection will be discussed with an emphasis placed on minimization of uncertainties.

1.1.1. Data collection

1.1.1.1. Wildlife Observations

Observation of live or dead wildlife on or near roads and highways is an easy and cost-effective method of gathering data on wildlife location and preferences. The primary benefits of collecting observational data include low expenses, inclusion of multiple species, both live and dead wildlife, and a decent level of accuracy. The use of citizen-volunteers further lowers costs and expands the area of study.

³ Connectivity is the degree to which the landscape facilitates or impedes wildlife movement.

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. A wildlife observation database should include species type, location, time, date, qualifications of the observer, and the circumstances of the observation. By standardizing how data is collected and reported, both sets can be used in analyses. A combination of involved citizenry, robust surveying protocols, and easy-to-use reporting tools could make this a powerful approach.

Data Collection

Data may be collected through public participation or formal surveys undertaken by experts, or by VTrans staff reports. 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 might 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).

People from all walks of life observe live and dead wildlife while they are on roads. Most observations take place on roads because they cover large areas, however Vermont's large contingency of hunters contribute off-road data to the project. 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). 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.

A simple approach to adapt data collection to smart phones and online systems would encourage more people to report observations. Ensure that the web reporting services are usable on smart phones to allow in the field reporting. This would also avoid using resources on costly mobile application development. Maine's Wildlife Road Watch⁴ website is a good example of an effective reporting platform.

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 California⁵, it was found that species-level identification of road-killed animals was >95% accurate, with similar location accuracy (Shilling, unpublished observations). If data are to be used from citizen monitoring to support wildlife passage

⁴ <http://www.wildlifecrossing.net/maine>

⁵ <http://www.wildlifecrossing.net/california>

management actions, it would be appropriate for VFWD 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.

1.1.1.2. [Wildlife Monitoring](#)

Active monitoring and detection techniques provide the most detailed spatial and temporal data. This is especially useful to determine fine scale movements and habitat use. These measurements are usually expensive and often only focused on a single species.

A number of detection and monitoring methods exist which can help determine general movement corridors. Intersection of these movements and transportation infrastructure reveal the preferred crossing locations and the behavior of animals in response to the ROW. This data is useful for both the initial planning process and post-installation effectiveness monitoring.

Invasive Monitoring Methods

Invasive monitoring involves trapping an animal and applying a tracking, also known as tagging, device. Two tracking methods are used depending on the size of the animal. Small animals require pit or ear tags, while large animals use collars. Global Positioning System (GPS) or radio signals allow researchers to record location and time data. Data can be distributed in real time using satellite communication (expensive) or saved in the collar (less costly). This technology provides precise animal location data, but can be costly (GPS collars can cost \$2,000 to \$4,000). Tags allow specific animals to be re-trapped and their movements and habitat preferences tracked over long periods of time. Bellis (2008) monitored several species using tags in conjunction with cameras at the Bennington Bypass bridges.

Passive Monitoring Methods

Non-invasive methods include snow track plates; hair snares; fecal pellet, nest, hibernium, and bird surveys; aerial flight surveys, and camera monitoring. These types of monitoring can capture volume and frequency data on multiple species and volumes. For the needs of transportation planners, these passive methods with longer latent times to detection may prove to be as effective as invasive methods at considerably lower costs. More detail is provided in Appendix E: Detection and Monitoring Methods.

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 cameras⁶, and can provide precise information on times of wildlife visits.

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. This makes cameras cost-effective for both pre and post project implementation.

1.1.1.3. Genetic Variation

Because roads and highways can bisect populations of individual species, 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. Well-mixed groups with easy movement allowing for cross breeding show similar marker gene composition. The magnitude of difference in marker genes correlates to the degree to which cross breeding, and hence movement, is occurring. Although expert assistance is required to implement this approach, it is a very cost-effective way to measure habitat connectivity with high certainty.

1.1.2. Integration of collected data

Each of these methods provides varying degrees of detail and type of wildlife movement information. Multiple data sources should be used to minimize uncertainties associated with connectivity measures. 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 base land and road conservation efforts on predictive GIS modeling. The next section (Step 2: Impact Assessment and Identification of Conflict Areas, below) discusses the role of GIS in impact assessment and data integration.

The following approaches are complementary and when taken together provide a complete picture of connectivity.

⁶ Reconyx and Bushnell Cameras (2011 Trophy Cam) are industry standards because of their proven reliability and accuracy. These cameras must be mounted and locked in protective boxes so they are not stolen, since they cost between \$200 and \$600.

- 1) GIS modeling validated through wildlife observations OR wildlife movement tracking (can examine the impacts of development before execution of plans)
- 2) Genetic connectivity AND wildlife movement (can measure extent to which adult and juvenile movement and dispersal contributes to gene flow or the extent to which transportation infrastructure inhibits movement)
- 3) Wildlife observations AND wildlife movement (can be used to understand population counts and shifts in particular areas.)

Only one of these approaches may be necessary depending on the needs of the project. Because the approaches provide and require different types of data, the following is a list of reasonable combinations of these practical approaches to support connectivity assessments and the practices to address wildlife movement:

1.1.3. Existing data sources

A number of databases are maintained by state agencies, regional planning commissions, and NGOs. A thorough examination of these sources should be pursued before new research projects begin.

VTrans maintains a road kill carcass database useful to determine wildlife-vehicle collision (WVC) hotspots for various species and bioregions. Statistical tools such as Getis-Ord or ArcGIS measure spatial autocorrelation to easily analyze the data for large regions. If the project is occurring in the Champlain Valley or along the spine of the green mountains, refer to the 'Critical Paths' documents for additional data on potential wildlife linkages. Lastly, consult with Vermont Fish and Wildlife (VFWD) 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 VCGI database for such studies.

1.2. Step 2: Impact Assessment and Identification of Conflict Areas

1.2.1. GIS Modeling

GIS modeling computes one, two, or three-dimensional connectivity values derived from multiple environmental and human factors. These may include habitat type, elevation, food or water sources, housing, roads, or natural resource extraction. Incorporating wildlife movement at the landscape scale into transportation planning is often accomplished using GIS. Predictive models of wildlife movement and the spatial components of genetic connectivity are overlaid on the transportation system to identify and prioritize wildlife crossing sites or impairments. 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 prediction of potential wildlife movement with an inherent statistical uncertainty necessitating verification using wildlife occurrence and movement data.

The Staying Connected Initiative undertook a Vermont Habitat Block and Wildlife Corridor Analysis, and similar projects around the US (Appendix B:), hypothesize about where wildlife might be moving based upon bio-physical landscape attributes (e.g., vegetation type, topography); see Figure 4 and Figure 5. 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.

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.

The value of a GIS model is dependent on scale and confirmation of accuracy from back-testing. Fine and large scale models may lead to very different conclusions. To ensure that the scale is appropriate, the model output should be compared to field data at a

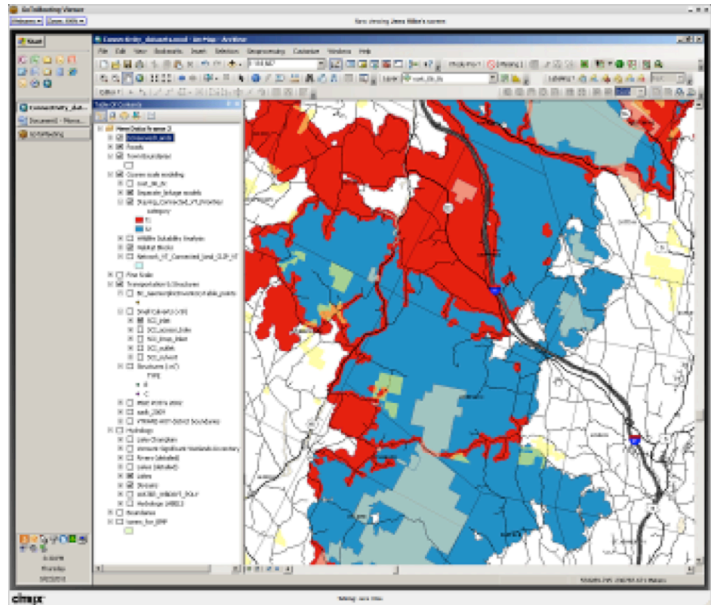


Figure 3: The Staying Connected Initiatives habitat and wildlife analysis output showing ‘core’ habitat and linkages. (Osborne and Sorenson, 2011).

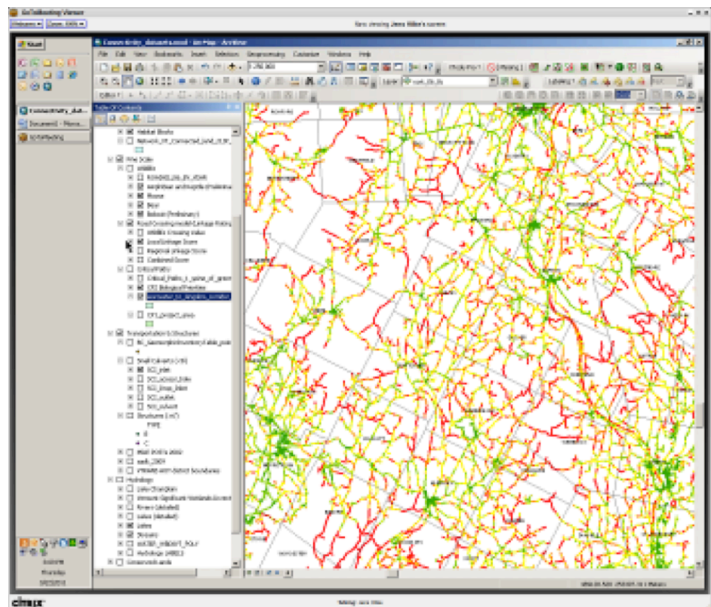


Figure 4: Map of the linkage ratings model output. This map shows ranks of the road and highways segments for their modeled connectivity value, with red being higher value and green lower value (Osborne and Sorenson, 2011)

similar scale and type to the project. This extends to evaluation of various types of species. Large ungulates⁷ will have significantly different modeling needs from amphibians. It is possible that even validated models of connectivity may not have sufficient resolution or certainty to correctly evaluate the magnitude of mitigation efforts or evaluate individual crossings intended to meet local, regional, or species needs.

1.3. Step 3: Prioritization of Projects

1.3.1. A Top-Down Approach for Regional-Scale Projects

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

Step 2: Determine the distribution of species of concern. GIS models can provide a broad overview of the distribution that can be further refined through field studies and consultation with wildlife experts. It is important to verify the findings of the GIS models before moving forward with a project. Follow the process below to gather and analyze any available data.

- a) Obtain maps and wildlife data pertaining to the project location from Vermont Fish and Wildlife's (VFWD) Conservation Planning Biologist.⁸
- b) Identify possible wildlife linkages occurring within the project boundaries
- c) Identify species at risk within the particular biophysical meeting using Table 2 and Table 3
- d) Seek information regarding species distribution from state, federal, The Nature Conservancy and NatureServe databases.

Step 3: Next, identify existing wildlife transportation corridors in proximity to the project. It is important to recognize that agriculture and lightly developed land may still provide wildlife movement corridors. Consult with a VFWD Conservation Planning Biologist⁹ to

⁷ Ungulates is a classification of animals that includes deer and moose

⁸ At the time of the final draft of this manual in early 2012, VFWD added the following concerning species' maps:

"The VFWD 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 VFWD at a date to be determined). VTrans planners should consult with VFWD conservation planning biologists or other wildlife biologists."

⁹ (802)338-4862 or (802)476-0199

determine whether or not wildlife movement plans must be incorporated into the project. In heavily developed or urbanized settings, there may be no need for wildlife considerations.

Step 4: Reference the data and methodology used to make the decision in Step 3 in the project documentation. Note the impacts of the projects on wildlife movement and mitigation actions or project location to avoid or minimize these effects.

1.3.2. A Bottom-Up Approach for the Local or Fine Scale

A bottom-up prioritization approach examines road segments of local interest or concern. If the road is negatively impacting species, especially those of state or federal concern, mitigation efforts would then be examined. For this purpose, wildlife observations and tracking is critical to reveal detailed distributions and movement patterns in close proximity to the road of interest. Local town-personnel or experts can provide subjective descriptions of the primary issues and valuable information resources.

In this stage planning will: a) identify stretches of road with animal-vehicle collision data, b) contact VFWD personnel for species of concern, c) check Wildlife Infrastructure Enhancements Recording System (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 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.”*

“Conserving Vermont’s Natural Heritage”¹⁰ is a guide to help planners interpret biological data for land use and transportation planning purposes.

1.4. Step 4: Analysis of potential mitigation options

Analysis of potential mitigation options requires assessment of need and feasibility. Planners must determine the risks associated with crossing wildlife to both driver and animal. Regardless of the results

¹⁰ http://www.vtfishandwildlife.com/library.cfm?libbase =Reports_and_Documents

from the impact assessment in Step 2, highways should be designed to be wildlife permeable. Network wide permeability ensures that future changes to wildlife movement patterns will not cause adverse impacts to drivers or wildlife. Shifting movement will become increasingly likely as climate changes increases temperatures in the Vermont region.

It is important to consider other conservation or restoration activities occurring near a road. If the road severs a potential landscape linkage, every feasible effort should be made to restore connectivity. Contact appropriate personnel¹¹ within VTrans about planning for these wildlife species and about the specific locations; such as: and colleagues, archeological resources, geology personnel, engineers, to learn of the feasibility of the potential mitigation. Decide if the project is a retrofit or new mitigation. This is based on a field visit to the site with the PAS (below), which helps determine the retrofit enhancement potential of existing structures along the road of interest.

1.4.1. Types of Wildlife Crossing Mitigation

There are two types of wildlife mitigation that have been proven to efficiently enable wildlife to cross roads: wildlife passes (over- or under-) in conjunction with fencing (Hedlund et al. 2004) and wildlife crosswalks in conjunction with driver warning systems. Unlike wildlife crosswalks, funneling in combination with passes has been extensively used and studied. Crosswalks are characterized by the use of fencing to allow crossing at designated locations and driver warning systems. These two general categories of mitigation options are listed in Table 1.

Table 1: Types of wildlife mitigation and their purpose and efficacy.

Type of Mitigation	Purpose, efficacy
<p>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)</p> <p>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.</p>	<p>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.</p>
<p>Wildlife crosswalks – made with fencing and driver warning systems</p>	<p>Funnel larger wildlife to specific zone across a two-lane road where drivers are warned when wildlife are detected in the crosswalk. See Appendix C: for further photo examples.</p>
<p>Retrofits or enhancements to existing structures</p>	<p>See Section 2 for a description of these</p>

¹¹ Chris Slesar

Identifying the target species is the initial step in identifying the optimal mitigation option. With the species identified, use the Species Movement Guilds matrix (Table 2) and the Structure Function Classes (Table 4) to determine the appropriate structure. Consider physical and ecological features in addition to species type. Water movement and topography may play an important role in the effectiveness and cost of a crossing structure.

1.5. Step 5: Monitoring and Adaptive Management

Monitoring wildlife movement and habitat occupancy is critical for good planning of wildlife crossing practices and to understand the effectiveness of those practices. The assumption in the guidance document is that VTrans' 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 a critical component of adaptive management and is a recommended practice. Additional detailed monitoring information is provided in Section 2.2.7 and Appendix E: Detection and Monitoring Methods

1.6. Local, Regional, State, National, and International Partnerships

This section describes the critical role of partnership formation in designing, funding, implementing, and monitoring wildlife movement strategies. Although VTrans could carry out many of these functions alone, inclusion of towns, RPCs, conservation groups, resource agencies, and others in planning and implementation efforts is more likely to result in effective action 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 include land conservation and planning in addition to infrastructure considerations.

Box 1: 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.

To meet this need, wildlife movement conservation partnerships have emerged all over the country. For example, the Utah US 6 Wildlife Coordination Committee, comprised of federal, state, and academic resources, addresses wildlife issues on Utah's portion of US highway 6.¹² (See Box 1) A grassroots project in Monkton, Vermont provides amphibian passage across a local road (see Box 2). The Monkton project utilized public involvement to assess the impact of Vergennes Road on amphibian populations before obtaining Federal transportation funding to install amphibian friendly culverts.

Other local efforts are underway to monitor wildlife movement. The *Keeping Track*¹³ program provides technical training to Vermont professional biologists, citizen scientist volunteers, VTrans personnel, land trust officials, and conservation planners. It assists groups to establish local wildlife habitat monitoring programs. The *Staying Connected*

¹² 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.

¹³ <http://www.keepingtrack.org>

Initiative (SCI)¹⁴ is a partnership between *The Nature Conservancy*, State wildlife and transportation agencies, and 11 other organizations. The initiative received a \$1 million US Fish and Wildlife Service grant to ‘restore, maintain and enhance large blocks of wildlife habitat and the connections between them.’

Volunteers and others involved with the initiative have expressed interest in monitoring specific stretches of roadway during the 2011/2012 season, and SCI is coordinating projects in at least two locales in the Northern Greens. SCI is also supporting similar “citizen science” monitoring efforts in the Adirondacks-Greens linkage.

Box 2: ***Lessons from the Vermont Monkton Crossing***

The following was the process used to achieve favorable outcomes addressing the issues of salamander and other amphibian mortality on Vergennes Road, Monkton, Vermont:

- 1) Identify the problem:** Collect robust and thorough data over a significant time span and take into account seasonal variation. Relevant information of interest includes: quantified and parameterized movement paths, location and quantity of roadkill, and ecological or seasonal triggers of movement (temperature, rain/snow cover etc). Quantification of these variables is critical to document the effectiveness of any actions (or non-actions) undertaken.
- 2) Determine whether the impact on species justifies further action:** Three major factors justified action in Monkton: high species diversity and volume, species of concern (*rare or endangered*), and high mortality
- 3) Compile an effective team:** Many people contributed to the success of Monkton’s Conservation Commission: an effective writer to research and draft grant funding proposals, a science advisor, an individual with connections to the state’s agency of transportation, and a networking specialist to make connections between various interest groups and aid fundraising endeavors.
- 4) Go to the local community for support:** Many people in the local community were receptive to the goals of the Monkton Crossing project. An email listserv allowed for volunteers, the press, and interested parties to collaborate and contribute.
- 5) Research funding and identify funding sources:** Various funding mechanisms exist at the town, regional, state, and federal levels. For example, this project was eligible for Transportation Enhancement Grants and State Wildlife Grant Program.
- 6) 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, maintenance, and deterioration rate? Can normal road treatments, such as salt, be applied in the area of the mitigation?); B. regulatory issues (constituent pushback, permitting at town and county, state, federal level).
- 7) Partner and collaborate with local NGOs:** Local NGOs commonly have political,

¹⁴ <http://www.stayingconnectedinitiative.org/>

social, and economic networks of support.

8) Apply for funding: Craft a proposal that meets the criteria of the funding agency. Frame the benefits of the project in light of the goals of possible funding sources such as corporations or state agencies.

9) Post project monitoring is important to document the success of the project: Assess the effectiveness of the actions taken to mitigate the problem identified in step one. Modify policies or infrastructure based on this feedback if necessary.

(Steve Parren and Laura Farrell)

1.7. Status of Connectivity Research in the Northeast Kingdom

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, Staying Connected Initiative (SCI)¹⁵ and Two Countries One Forest(2C1Forest)¹⁶ reveal that this eco-region is increasingly at risk of fragmentation by development and roads¹⁷. These assessments identify a handful of high priority habitat “linkages”¹⁸ – areas that are thought to be critical for maintaining healthy wildlife movement within the Northern Appalachians eco-region. Maintaining, restoring, and enhancing connectivity among areas of less-disturbed habitat has emerged as a top conservation priority for the region in recent years. Vermont plays a critical part in this role due to its geographic location.

Vermont stands at a 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); a second linkage connects the Taconic Mountains across the Valley of Vermont to the southern Greens(B); a third links the Sutton Mountains of Québec through the Green Mountains of Vermont to the Berkshires of Massachusetts (C); a fourth

¹⁵ 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.

¹⁶ 2C1Forest is a Canadian-U.S. collaborative of conservation organizations, researchers, foundations

¹⁷ Anderson et al. 2006, Reining et al. 2006, Trombulak et al. 2008, Beier et al. 2011

¹⁸ The term “linkage” is used here as it used in conservation planning, with the recognition that its ecological meaning or validity can vary substantially depending on context.

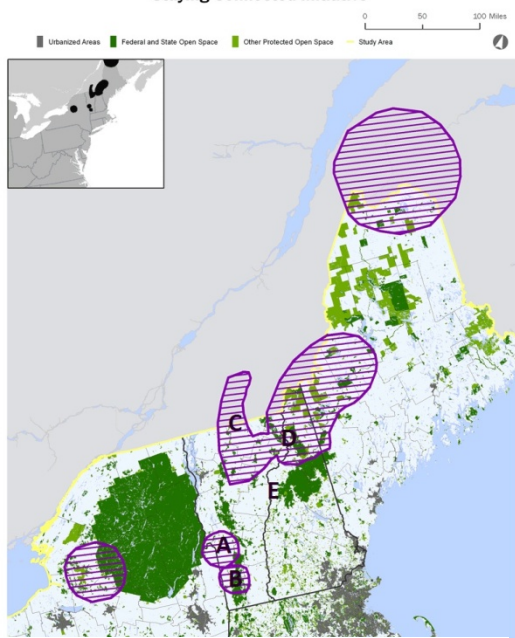


Figure 5. Critical habitat linkages in Vermont; the purple areas are being actively studied by the Staying Connected Initiative organization.

runs from the Worcester Range through the Northeast Kingdom of Vermont to the Connecticut Lakes region of northern New Hampshire(D); and a fifth ties the central Green Mountains to the White Mountains of New Hampshire(E). See Figure 5¹⁹.

This regional scale puts conservation efforts into a larger context but does not provide planners with sufficient detail to be applicable to individual projects. Several organizations provide higher resolution analyses of habitat blocks and connectivity. Efforts are underway to downscale the regional models and analyses.

In 2006, VTrans and VFWD developed a GIS-based, landscape-level model designed to predict the location of wildlife linkage habitats in proximity of state highways (Austin et al. 2006). The project assigned Wildlife Habitat Suitability (WHS) values to land based on social economic (housing density, land use/ land cover) and biological factors (habitat type). GIS analysis identified sections of roadway in, or close to, high WHS value areas.

A more recent collaboration between VFWD 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 and vulnerability of habitat blocks for their biological/conservation value
3. Identify potential wildlife corridors between habitat blocks using “least-cost-path” analysis.
4. Rank the relative importance of potential wildlife road crossings statewide.
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 Agency of Natural Resources (ANR) is actively mapping the state’s natural resources through its Natural Resource Mapping Project (NRMP). The map and accompanying database will allow planners to identify high priority ecosystems and habitats for conservation efforts. The project is scheduled to be completed in December 2012. The statewide data developed by Sorenson and Osborne have been used to refine connectivity analyses for subregions of the state. For example, VFWD (Hilke, unpublished) has

¹⁹ <http://www.rpa.org/northeastlandscapes/2011/05/habitat.html>

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”²⁰ within the 61-town region where the Initiative is active. These structural pathways are relatively small – a few hundred to a few thousand acres, have clear boundaries and encompass specific road segments.

Another project, called Critical Paths, surveyed 38 road sites along the spine of the Green Mountains. State biologists and conservation organizations assessed the physical features of crossing locations adjacent landscapes and tracked and monitored wildlife at the sites. The project revealed 11 essential north-south "Priority Crossing Zones." Comprehensive plans are now being developed for enhanced wildlife crossing capabilities, land use conservation and planning, and other improvements.

Comprehensive plans are now being developed for enhanced wildlife crossing capabilities, land use conservation and planning, and other improvements. Both SCI and Critical Paths found impassable sections of road in wildlife movement corridors. Alleviatory structural enhancements or additions are recommended in these areas.

SCI and Critical Paths provide valuable information to guide transportation decision making and project prioritization. VFWD and the VTrans-VFWD Wildlife Steering Committee are available to provide technical support for VTrans.

1.7.1. Movement Guilds for Vermont’s Biophysical Regions

Transportation planning can more efficiently plan for habitat connectivity by cross-referencing geographic, biological, and species data. The *Species Movement Guild*, in concert with *Vermont’s Biophysical Regions* map cross-reference geographic, biological, and species data to enable planners to make better decisions.

The *Species Movement Guild* (Cramer et al. 2011) is a compilation of previous wildlife research. Species are categorized by locomotion and crossing structure preference attributes. This unique classification system is designed to determine the BMP for individual or taxonomic²¹ groups of animals. The Guilds facilitate an understanding of the movement needs and preferences of certain species within a larger context of their guild classification.

²⁰ SCI defines a structural pathway as an “area with sufficient structural connectivity to function as a habitat corridor.” Where, habitat corridors are “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.”

²¹ animals that have similar characteristics

Eight Species Movement Guilds are defined (Table 2): 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. The Guild allows for generalizations as to which mitigation solution is most appropriate for any given species. 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.

To effectively utilize these documents, place the project in its respective *Biophysical Region*²² (Table 3) and consult with VFWD concerning presence of species listed in the *Wildlife Action Plan of Species of Greatest Conservation Need (SGCN)*²³. If species are found, categorize them in the Species Movement Guild (Table 2) to determine the most suitable crossing structures or methods. The information will be part of a larger document that helps users to create statewide practices for wildlife and transportation.

²² 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.

²³ Vermont's Wildlife Action Plan aims to protect species across the spectrum of need of protection and conservation. SGCN includes 144 vertebrate species of the 470 in the state. http://www.vtfishandwildlife.com/SWG_list.cfm

Table 2: 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 cover to hide. 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 > 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 structure to the other.	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 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.

Table 3: 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	
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

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
Woodland vole		X	X		X		X	
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?								

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
Arboreal Fauna								
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					
<p>* 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</p> <p>** = 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.</p>								

2. Design and Construction

2.1. Enhancement of Existing Structures

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 recommendations described here are complementary to the planning recommendations in that good planning is often a necessary precursor to retrofitting roadways for wildlife movement.

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 the understanding of wildlife preferences for different structure types and how to determine actual use of these structures and plan for improvements to existing structures.

Many existing structures may not be used by wildlife, but if they were enhanced or retrofitted, they could become useful crossing structures. Enhancements include, but are not limited to, wildlife sidewalks, culvert enlargement, culvert ledges, and benches under bridges. 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.

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. removal of obstacles,
2. facilitation of movement and creation of pathways,
3. reduction of intimidation,
4. enhancement of structure approaches,
5. improvement or redesign of fencing and barriers, and
6. adjustment structural features.

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 completed for Washington DOT (WSDOT)²⁴ created protocols for evaluating existing structures – bridges and culverts – with regards to their

²⁴ <http://www.wsdot.wa.gov/research/reports/fullreports/777.1.pdf>

potential to pass different types of wildlife. The Passage Assessment System (PAS) created from this work provided an assessment process that differentiates possible structure enhancement projects and those functioning sufficiently. In this manner, the system enables transportation agencies to evaluate infrastructure in a standardized manner, and prioritize these enhancement opportunities.

2.1.1. 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.

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 habitat 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 PAS 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 D: details the various elements of PAS. 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. See Table 3: Biophysical regions of Vermont and potential target species. (pg21)
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 C: Structure Retrofits. (pg. 65)

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.

2.1.2. Factors Affecting 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. Designers must consider both of these components for every project.

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.

2.1.3. Classification of Existing Structures

In order for a standard to work across a state and other areas, there needs to be common understandings of types of transportation infrastructure such as culvert sizes, and wildlife such as taxonomic groups. Table 4 presents a quick guide to structure classification within a wildlife movement context. In developing the PAS, it was necessary to refine our understanding of how landscape and structure characteristics affect a species' willingness to pass through a structure.

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. 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.

Table 4: Crossing structure classes from the wildlife perspective²⁵

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	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 (i.e., deer can use smaller structures than elk or moose) although pronghorn require larger structures (minimum 18.3 m span x

²⁵ 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

Crossing Structure Category	Function	Approximate Dimension Range (Span x Rise)	Passage Examples	Species Examples
	some natural processes including vegetation growth and stream processes.			5.5 m rise). Large carnivores (wolf, grizzly bear, black bear, puma).
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.

2.1.4. Culverts

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 allow water and sediment to pass through the transportation network without significant impact. 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 so many 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 the entire water system composed of sediment, wood debris, aquatic organisms, and wildlife (Figure 6).

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 [Box 3: Enlarging a fish passage structure for wildlife](#), below).

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.



Figure 6: Bobcat crossing under California interstate via a 60" diameter concrete culvert

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).

2.1.5. 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 7A). 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 7B) may provide a pathway for wildlife.

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.

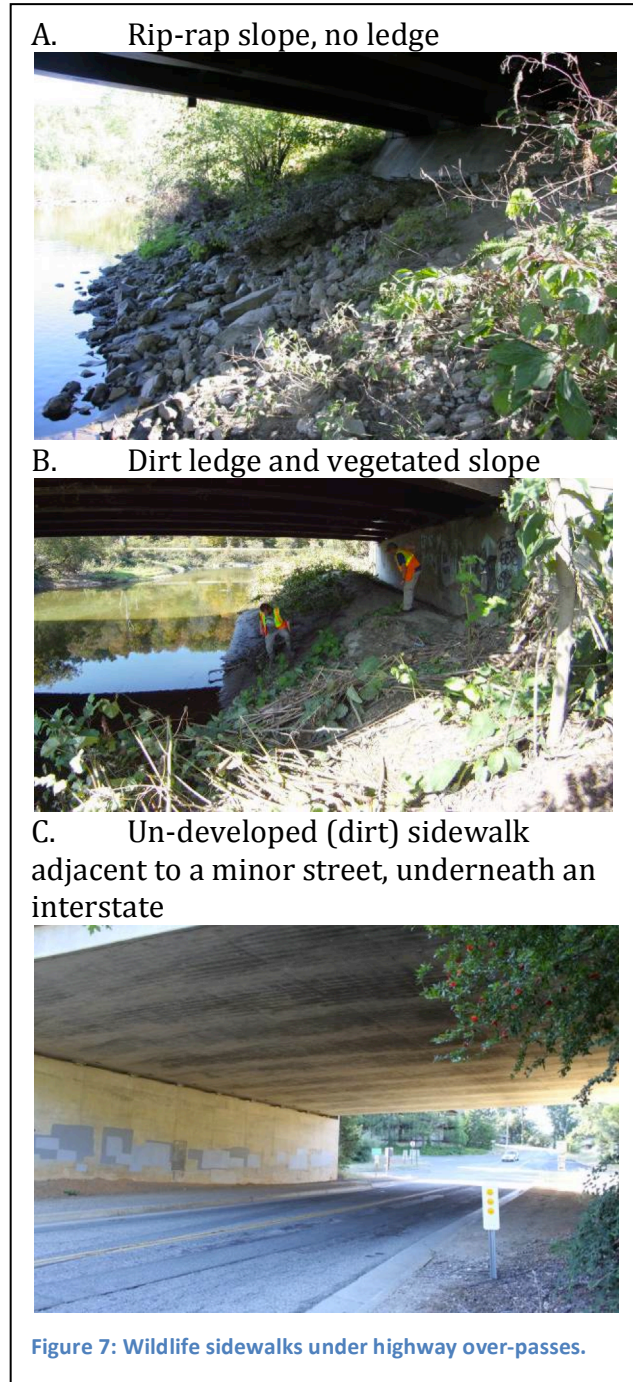


Figure 7: Wildlife sidewalks under highway over-passes.

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 7C).

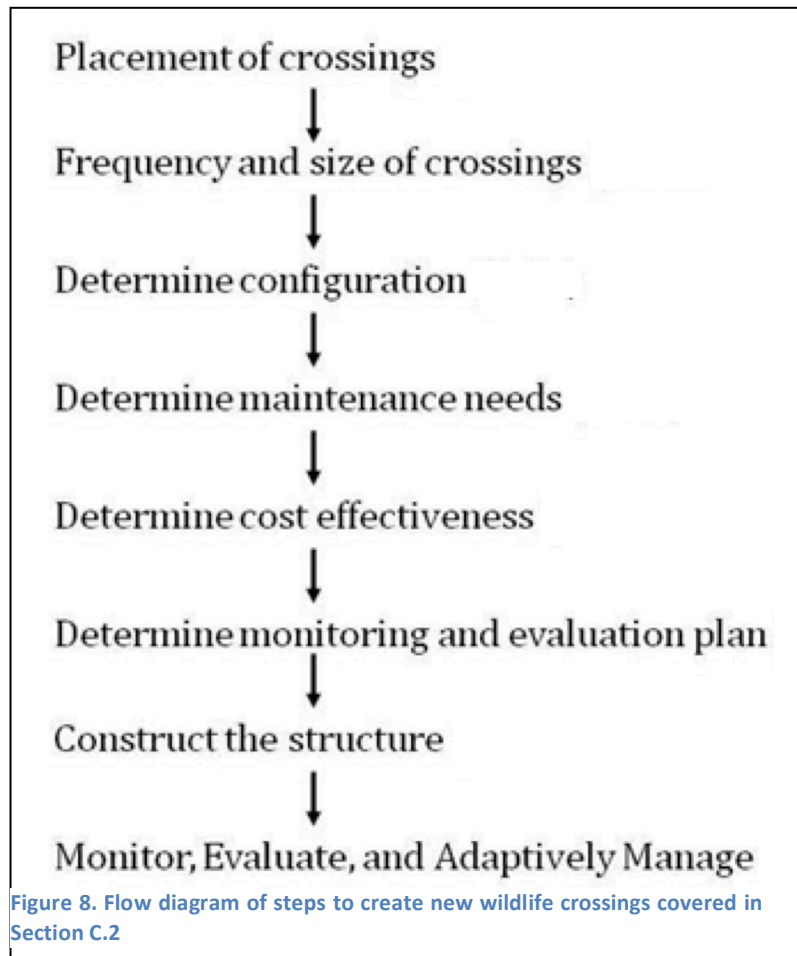
2.2. Wildlife Specific Structures

This section gives guidance in creating new structures to promote habitat 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. Modification of existing road infrastructure described in 2.1 Enhancement of Existing Structures is the first choice in states that are not rapidly expanding their road network. The Irene flooding created a unique opportunity to redesign many bridges and culverts to be wildlife movement friendly.

This section reviews the steps to implementing habitat connectivity mitigation. The process is described in Figure 8. Several of the points covered in this section are interwoven with other areas of the report.



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.



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

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/>

Box 3: Enlarging a fish passage structure for wildlife

2.2.1. Placement of Crossings

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 WVCs, or where protected lands exist on both sides), and then more specifically placed with finer scale methods (Section 1.3.2). These methods should 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)

2.2.2. Frequency and Sizing of Crossings

The size and frequency of wildlife crossings should be determined by the size, population density, and range of the target species. 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

Designing crossings for multiple wildlife species is a cost-efficient alternative to multiple single species crossing infrastructure. This can be done first by grouping wildlife species according to wildlife species movement guilds (Table 2), and by grouping types of structures based on their size and type (Table 4). 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

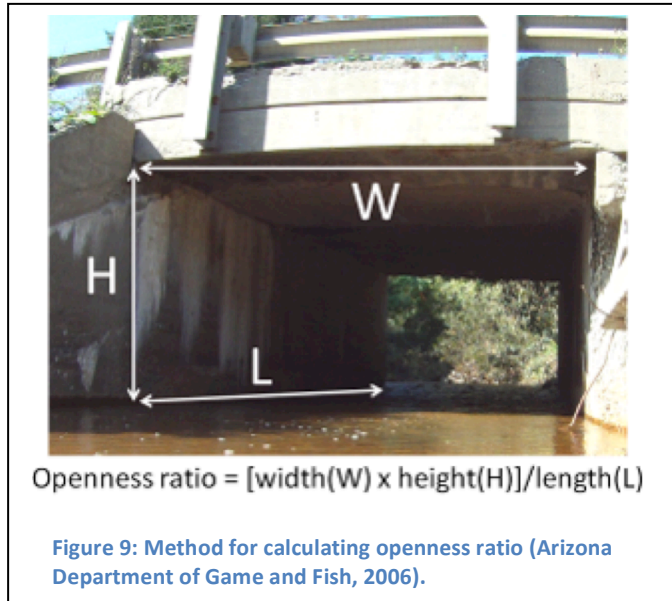
Sufficient size (combination of cross-sectional area and length) and frequency (number of crossings per unit length of highway) of wildlife crossings can be calculated for groups of species found in a particular area. Although large crossings can accommodate small animal

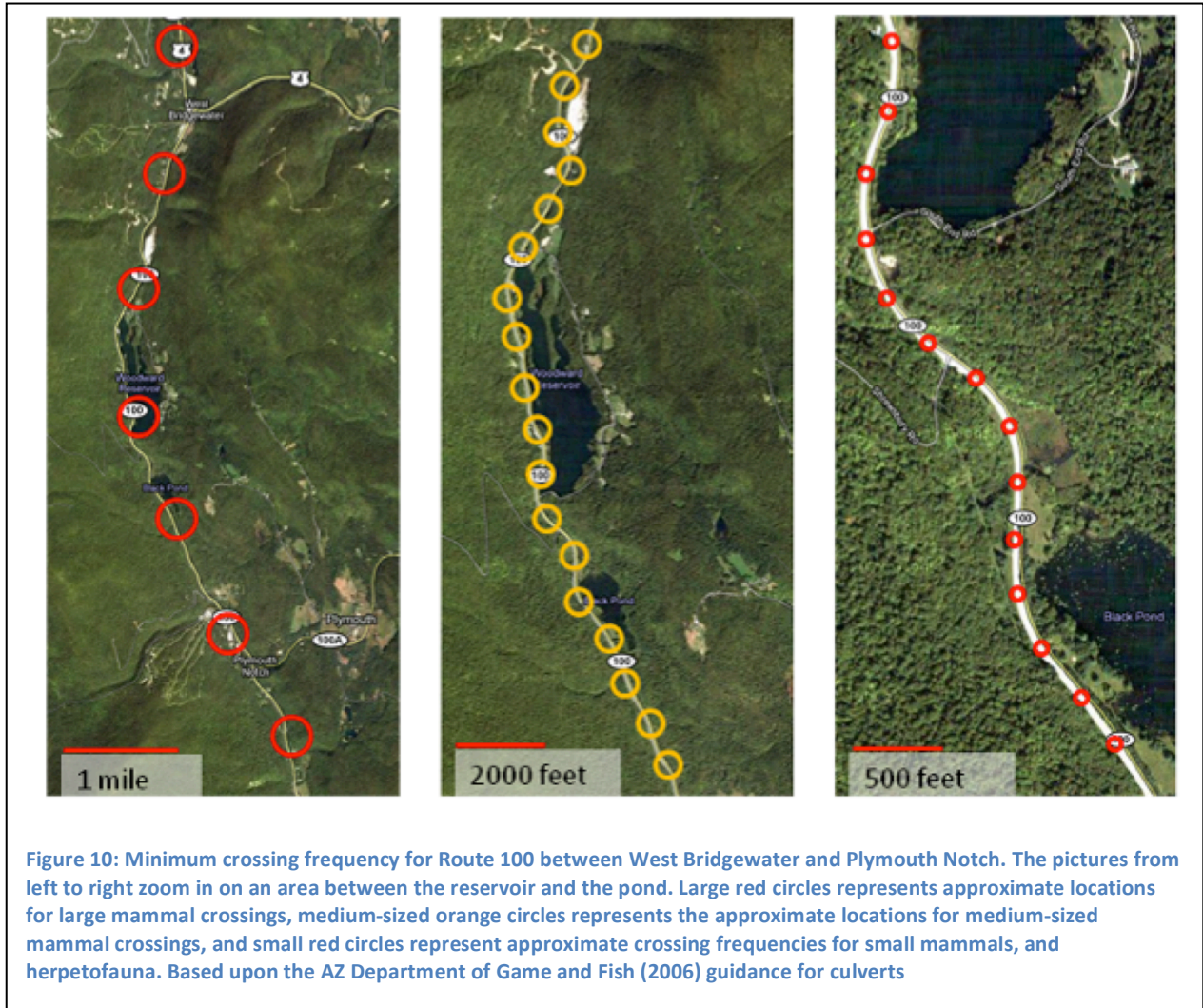
movement, small crossings are typically only used by small animals. The openness ratio (Figure 9) is one way that the potential adequacy of a structure for wildlife passage can be assessed. Larger animals will tend to tolerate only greater openness ratios, meaning a combination of larger cross-sectional 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.

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 planners to meet the needs of fish and wildlife movement (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 WVC hotspots and dozens to hundreds of yards for smaller fauna such as reptiles.





Limitations

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'

2.2.3. Optimal Crossing Type and Configuration

Vegetation-choked culverts don't pass water or wildlife. Although most wildlife likes some vegetation-cover on the approach to a culvert or bridge, it can also act as a barrier if there is a significant loss of visibility. Figure 11 displays proper vegetative cover leading to crossings but not impeding animal movement. The appropriate plant species may encourage species of interest to use the structures. Consult VFWD to determine the appropriate plant species.

A smooth, at-grade transition from the natural landscape to the inside of a culvert helps manage storm-water and increases the effectiveness of the crossing infrastructure. Conversely, a fenced-off, overgrown, or flooded approach may inhibit use. If the infrastructure is designed to suit the target species mode of locomotion (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. Skylights or sufficiently large culverts will pass light and make the structure more conducive to animal movement.

Use rail fencing, in place of traditional field fencing, at the entrances to bridges and culverts so 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 smaller animals access. See Appendix C: for photographs.

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

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. The approach generalizes both wildlife and structures to give insight into the preferences of various species. Table 2: Species movement guilds adapted from Cramer et al., 2011 and Table 4: Crossing structure classes from the wildlife perspective will give planners a better idea of what structural

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 11: Culvert attributes appropriate for wildlife.

configurations will pass specific wildlife types.

2.2.4. Maintenance Needs

Wildlife crossing structures and their accompanying fences often need annual maintenance. It is essential to involve the stakeholders involved in daily operations and maintenance in the planning process. 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 environmental forces and human tampering. To ensure this occurs, funding should be appropriated for repair. Planners are advised to work with stakeholders on estimating the maintenance needs, costs and schedules of mitigation. Further recommendations are made in Section 3: Operations and Maintenance Operations and Maintenance.

2.2.5. Cost/Benefit Evaluation

Although most ecological mitigation enables ecosystem services such as flood control and wildlife movement, there are few methods to calculate the value of those services. The typical method to evaluate the cost-effectiveness of wildlife mitigation is to calculate the yearly cost of animal-vehicle collisions from the predicted number of collisions and average cost per incident. (Clevenger and Huijser 2009 or Bissonette et al. 2008) The cost of the mitigation is estimated and amortized over the projected life time of the structure. These costs are then compared in a cost/benefit analysis

Potential Planning and Structural Costs

The cost of carrying out the assessment and planning for this practice are primarily associated with spatial analysis involving field analysis. The field component is primarily assessment of the capacity of existing culverts, bridges, and road sections to meet the needs of wildlife movement. Simultaneous calculation of crossing-size and frequency, GIS assessment of connectivity, and assessment of the existing system is cost-effective.

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 effective under-passes. (Huijser et al. 2007). In 2009, 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, \$30,000 for three deer escape ramps and \$50,100 for fencing. 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 6 below.

Table 6: Crossing structure material costs²⁶

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 do not include maintenance and operations. Collaboration between environmental planners, design engineers, and project manager are essential in understanding the design and costs associated with proposed structural improvements or installation.

2.2.6. Construction or Implementation

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 2.2.7, below), and that monetary payments are tied to fulfilling these requirements.

2.2.7. Monitoring, Post-Implementation Evaluation, and Adaptive Management

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 to promote transparency and dissemination of results. Monitoring wildlife

²⁶ Derived from the 2003 Caltrans Contract Cost Data book, available at: <http://www.dot.ca.gov/hq/esc/oe/awards/2003CCDB/2003ccdb.pdf>.

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 to pass the knowledge onto 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 repellence and usage rate for each structure. The cameras in use today are powered by batteries (rechargeable NiMH batteries) and store photos on a retrievable memory card. Cameras are checked every month to two months depending on the battery life of the camera, resolution of the camera, and site activity level. Vegetation that grows up near the cameras is cleared. Data is entered into spreadsheets for later analyses. 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. 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.

Wildlife can also be monitored by other methods, described in Appendix E: . 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 WVC 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.

Measuring the effectiveness of actions has 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 strategies for improved wildlife movement can also be used to measure their performance. The table below (Table 7) provides examples of suitable metrics/indicators and monitoring methods for wildlife and transportation performance measurement.

Table 7: Wildlife crossing performance measures/indicators and methods.

BMP	Performance measure/indicator (desired target/direction)	Monitoring method
Speed control	<ul style="list-style-type: none"> ➤ Density of carcasses from WVC (decrease) ➤ Injuries and death from collisions (decrease) 	Standardized survey (>1/week) Existing collision reports
Wildlife fencing	<ul style="list-style-type: none"> ➤ Density of carcasses from WVC (decrease) ➤ Injuries and death from collisions (decrease) 	Standardized survey (>1/week) Existing collision reports
Under-crossing enhancement	<ul style="list-style-type: none"> ➤ 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	<ul style="list-style-type: none"> ➤ Density of carcasses from WVC (decrease) ➤ Number of target wildlife passage events (\geq 1/day) ➤ Diversity of wildlife species, Shannon Diversity Index (> 1.5) ➤ Injuries and death from collisions (decrease) 	Wildlife camera traps Track plates/beds

2.3. Right of Way Access Control Structures

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 fiscally infeasible and severely reduce genetic connectivity, wildlife movement, and other important ecological functions. 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.

2.3.1. 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 12). They function only when they are extensive and intact.

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, animals may become trapped within the ROW.

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



Figure 12: An eight-foot-tall fence-line suitable for excluding ungulates.

intended to keep off the road and guide to crossing locations. The most common fencing is created to deter ungulate species such as deer and moose. The requirements for this type of fencing have been summarized by California and Washington DOTs²⁷. They include basic guidelines for fencing in snowy environments:

- 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

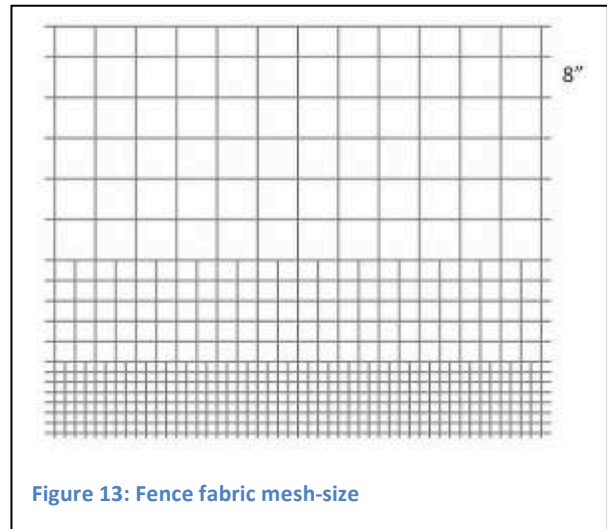


Figure 13: Fence fabric mesh-size

An important possibility to consider is varying the mesh-size of the fence fabric vertically (Figure 13). This acts to inhibit small animal movement low to the ground, while remaining effective in inhibiting large animal movement at all heights.

Location

Wildlife fencing is effective at keeping wildlife of the road and alive when it is associated with crossing structures (Figure 14). 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



Figure 14: Fence anchored at bridge abutment, over riparian wildlife-crossing

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 include

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

²⁷ <http://transwildalliance.org/resources/2009415101329.pdf>

- direct evidence (e.g., radio-collared animal movement, wildlife pictures) of wildlife movement along the stretch of road/highway.
- 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 weather

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 14). 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 (to inhibit wildlife from crossing the roadway except through structures), fence line length adequacy (to ensure 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 animal and public safety on the 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 western states). Electrified fence strands may be more cost-effective in some cases than standard fencing because of its deterrent effect on 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 fence lines are often planned for the edge of the legal right-of-way, adjacent landowners should be consulted about how the fence lines may impact them. Wildlife agencies should be consulted because of possible negative and positive impacts on movement of legally-protected and other animals.

2.3.2. 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 15). 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



Figure 15: Elk using escape ramp along US 93 in Montana to access wild area.

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).

2.3.3. 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.

2.3.4. Guard Rails

Concerns about driver safety on windy roads with steep drop-offs have 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 16A). An animal that does not exit the roadway may move erratically until it eventually collides with a vehicle.



Figure 16: 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).

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 16B). 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.

3. Operations and 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 based upon the results of effectiveness monitoring.

3.1. Driver Based Solutions

Driver based solutions are potentially less-expensive than infrastructure modification to improve wildlife movement. Driver education and traffic control has the potential for reducing WVCs 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.

3.1.1. 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 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 (Figure 17), 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 than a sign flashing "speed limit 45". In addition, it appears that dynamic signs may result in the

highest percentage speed reduction among 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 periodically moved to avoid driver complacency.

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). Further cost/benefit analyses of these active systems are required due to relatively high costs and maintenance concerns



Figure 17: “Moose” sign on I-89

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

Public campaigns have been effectively carried out to change particular behaviors that are seen as environmentally damaging (e.g., littering, dumping chemicals in drains). Similar efforts may be applied to reduce WVC rates. VTrans might consider developing 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 provided 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 to reflect the maximum safe speed under favorable conditions. (Donald, 1994) Frequency of wildlife crossings should be considered when setting speed limits.

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.

In Colorado, wildlife crossing zones have been established in areas with high WVC rates (Figure 18). 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.

3.1.3. Physical controls (e.g., rumble strips)

Drivers are familiar with road features that are intended to slow vehicles (e.g., speed



Figure 18: Speed enforcement in Colorado's Wildlife Zones. These are areas where speeding fines are doubled during specific hours and months of the year.

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 ROW. These methods have been used to reduce driver speed, rates of WVC, and impact on threatened species (Jones, 2000).

3.2. Inventory 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 the ground are situated in a way to promote habitat connectivity. As Tropical Storm Irene infrastructure replacements are planned and installed, additional data concerning wildlife related enhancements could be added to the current bridge and culvert database. 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 habitat 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. In some western states, maintenance personnel will dump WVC carcasses at bridge and culvert locations to facilitate removal at a later time. This could inadvertently discourage wildlife from using these structures as crossing points leading to a greater number of animals on the ROW. A database of wildlife crossing enhancements would help maintenance, operations, and consultant personnel understand the potential consequences of these actions.

The second step to this system would be to have the culvert and bridge database in the computers of the maintenance vehicles or smartphone. 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. From the database, the user could select the culvert of interest, see the date of construction, wildlife enhancements, and maintenance concerns and schedules. Permitted users could also add data remotely. 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 access and updates.

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 by CD or department website. 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.

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4. Technical Appendices

Appendix A: Acronym Definitions

GIS	Geographic Information Systems
VTrans	Vermont Agency of Transportation
ANR	Vermont Agency of Natural Resources
VFWD	Vermont Fish and Wildlife Department
RPC	Regional Planning Commission
NGO	Non-Governmental Organization
GPS	Global Positioning System
WIERS	Wildlife Infrastructure

	Enhancements Recording System
PAS	Passage Assessment System
VCGI	Vermont Center for Geographic Information
2C1Forest	Two Countries, One Forest
SCI	The Staying Connected Initiative
WHS	Wildlife Habitat Suitability
WVC	WVCs
NRMP	Natural Resources Mapping Program
STIP	State Transportation Improvement Plan

ROW	Right-Of-Way
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Appendix B: State and Federal Government Reports, Studies, and Resources

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 Cooperative Fish and Wildlife Research Unit (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 WVCs, 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 C: Structure Retrofits

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.

<p>Add a dry, natural pathway through structure, on both sides of waterway if a stream or river is present.</p> <p>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</p>		<p>Forman, R. T., Sperling, D., Bissonette, J. A., Clevenger, A. P., Cutshall, C. D., Dale, V. H., et al. 2003.</p> <p>AND OR – MNDOT BMP manual</p>
<p>Minimize or cover riprap on side slopes with dirt to create a dry, smooth pathway.</p> <p>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</p>		<p>MNDOT BMP manual – Leete 2010</p>
<p>Install interlocking brick to support slopes instead of riprap</p>		

<p>to open up a pathway and facilitate wildlife passage.</p>		
<p>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.</p> <p>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</p>		<p>Raccoon uses shelf in MT US 93 culvert. Photo credit: K. Foresman.</p> 
<p>Add baffles to culvert floor to retain sediment on artificial culvert floor (where water flows occasionally through the culvert).</p>		

<p>Install woody debris (e. g., down logs) through a structure for small species requiring cover from predators.</p> <p>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.</p> <p>Photo credit: P.Cramer</p>		<p>Ehinger, W., P. Garvey-Darda, R. Gersib, K. Halupka, P. McQueary, W. Meyer, R. Schanz and P. Wagner. 2006.</p>
<p>Maintain natural stream banks through the structure.</p>		
<p>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.</p>		


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.		


Reduce Intimidation

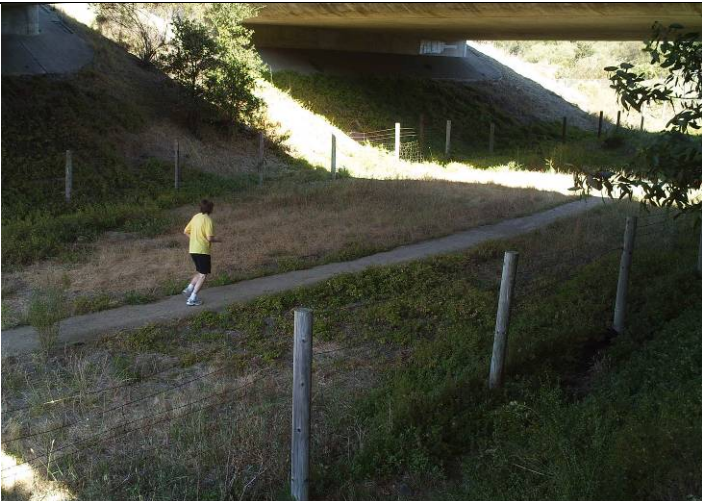
These types of actions enhance structure attributes so prey species are less apprehensive about entering an area for fear of a predator hiding inside or near the structure, to reduce light and sounds associated with roads and vehicular traffic, and to minimize human use of structures intended to pass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

Action		References
Replace steep abutment slopes or walls with natural 2:1 slopes for Adaptive Ungulates,		Dodd, N.L., J.W. Gagnon, A.L. Manzo, and R.E. Scheinsburg. 2007.

<p>Vermont's white-tailed deer and moose.</p>		
<p>Remove fill predator perches - ledges or places where prey species may be fearful of unseen predators.</p>		<p>Little, S.J., R.G. Harcour, A.P. Clevenger. 2002.</p>
<p>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.</p>		<p>Reed, D.F., T.N.Woodard, T.M. Pojar. 1975.</p>


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



<p>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</p>		
<p>Implement measures to reduce traffic noise inside culvert and/or at structure entrances (e.g., concrete shoulder barriers placed above the structure)</p>		<p>Jackson, S. D. (2000).</p>

<p>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.</p>		<p>Hartmann, M. (2003). Evaluation of Wildlife Crossing Structures: Their Use and Effectiveness.?</p>
<p>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]</p>		<p>Clevenger, A. and N. Waltho. 2005</p>
<p>Install barriers (e.g., large boulders) to prevent motorized travel through crossing structures.</p>		

Enhance Structure Approaches

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
<p>Enhance/maintain native vegetation cover in front of structure entrances.</p> <p>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</p>		<p>Ng, S., J. Dole, R. Sauvajot, S. Riley, and T. Valone. 2004.</p>
<p>Thin heavy vegetation that may obstruct wildlife passage at structure entrances.</p>		<p>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.</p>
<p>Avoid the use of herbicides around structure entrances.</p>		<p>Vegetation amounts and heights similar to the surrounding</p>

		<p>landscape are important, as is the absence of herbicides.</p>
<p>Plant shrubs and trees in the median to provide better cover and insulation from highway traffic noise and lights.</p> <p>Photo example: Arizona DOT planted trees along median at a newly established wildlife crossing bridge. The new construction eliminated all natural vegetation. Note: trees are protected from grazing ungulates. Photo credit: P. Cramer</p>		
<p>Avoid the use of erosion netting in landscaping around crossing structures, which may ensnare snakes.</p> <p>Photo example: garter 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.</p>		<p>Leete 2010. and VTRANS practices manual</p>

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 ROW.

Action		Reference
<p>Add wildlife fencing and/or guide walls to existing suitable structures - do not install extensive fencing where there are no suitable crossing structures.</p> <p>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 WVC 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</p>		<p>For guidance on different types of wildlife fencing, see:</p> <p>http://www.azdot.gov/highways/EPG/EPG_Common/PDF/Technical/Wildlife_Connectivity/Wildlife_Funnel_Fencing/Wildlife_Funnel_Fencing_Summary.pdf</p>

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

<p>Install wildlife fencing across a median to adjacent structures.</p> <p>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.</p>		
<p>Install escape ramps along fenced sections.</p> <p>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</p>		<p>Bissonette, J.A. and M. Hammer. 2000.</p>

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 ROW. 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, Electrobraided fencing, 8-foot fence and solar collector on N.M. 333.



Sprague, K. Ogren, and R.E. Schweinsburg. 2010.

<p>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.</p>		<p>Clevenger, A.P. and A.V. Kociolek. 2006.</p>
<p>Arrange shoulder or median barriers with intermittent gaps to facilitate wildlife passage at grade.</p>		<p>Same as above</p>
<p>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].</p> <p>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 are 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.</p>		<p>Same as above. Also common practice is specific regions within specific DOT's.</p>

		
<p>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.</p>		<p>Hardy, A.R., J. Fuller, M.P. Huijser, A. Kociolek and M. Evans. 2006. Allen 2011</p>
<p>Avoid gaps in wildlife fencing or walls.</p>		

Add or Adjust Structural Features

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

Action		Reference
<p>Fix perched outlets to allow access into culvert, for both aquatic and terrestrial wildlife.</p>		
<p>Add a gutter pipe for small mammals.</p>		<p>Foresman, K.R. 2004.</p>
<p>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 abrupt curb so turtles, and other animals can escape road bed.</p> <p>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.</p>	 <p><small>Photo courtesy of MNDOT – Peter Leete</small></p>	<p><u>Leete 2010.</u></p>

Bore new dry culverts adjacent to inundated culverts to promote wildlife passage through drainages.		<u>Anne Burrows work and diagram from NCDOT</u>
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 D: Passage Assessment System (PAS)

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 function 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.



Raccoon 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 PASEvaluation 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.

PASSummary 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 habitat connectivity.

Appendix E: Detection and Monitoring Methods

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, hibernium, 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 ROW 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 WVCs.

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 snares 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 hibernation, 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.