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**Habitat Connectivity: Placement of Crossing Structures**

# CONSERVATION STRATEGIES IN THE FLORIDA KEYS: FORMULA FOR SUCCESS

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**Abstract**: The extensive and growing road network in the United States has substantial ecological, economic, and social impacts. In the case of the endangered Florida Key deer (Odocoileus virginianus clavium), nearly 50 percent of the total mortality is attributed to deer-vehicle collisions. Over half of the deer-vehicle collisions occur on U. S. Highway 1, the only highway linking the Keys to the mainland. Since the early 1990's, various agencies and stakeholders have been trying to address deer-vehicle collisions in the Florida Keys. Initially, underpasses in combination with fencing were chosen to address deer-vehicle collisions. An apparently simple solution, however, was complicated due to access management issues and environmental regulations related to urban development. The Florida Department of Transportation (FDOT) was instrumental in resolving many of these issues, and provided resources and expertise which served as a catalyst in this process. The FDOT's U. S. Highway 1 improvement project, testing of a bridge grating system, and a habitat conservation plan illustrate successful conservation strategies in the Florida Keys.

In the continental United States, roads and roadsides cover approximately 1 percent of the surface area, and impact 22 percent of it ecologically (Forman 2000). For species that readily cross roads, wildlife-vehicle collisions can have serious costs in several forms. For example, each year in the United States, deer-vehicle (*Odocoileus virginianus*) collisions cost $1.1 billion in property damage or losses, and cause an estimated 29,000 human injuries and 211 human fatalities (Conover et al. 1995). Continued urban sprawl and suburban development are likely to increase costs associated with deer-vehicle collisions.

Florida Key deer *(O. v. clavium)* occupy 20-25 islands in the lower Florida Keys and are the smallest sub-species of white-tailed deer in the United States (Hardin et al. 1984, Lopez 2001, fig. 1). Approximately 75 percent of the overall population is found on Big Pine and No Name keys (Lopez et al. 2003*a*). Since 1960, urban development and habitat fragmentation have threatened the Key deer (Lopez 2001, Lopez et al. 2003*c*). In addition to a loss of habitat, an increase in urban development is of particular concern because highway mortality accounts for the majority of the total deer mortality. Over half of the deer-vehicle collisions occur on U. S. Highway 1 (US 1), the only highway linking the Keys to the mainland (fig. 1, Lopez et al. 2003*c*). Since the late 1980's, U. S. Fish and Wildlife Service (USFWS), Florida Department of Transportation (FDOT), and local residents have been trying to address deer-vehicle collisions on Big Pine Key (Lopez et al. 2003*c*). In 1993, FDOT began efforts to reduce Key deer mortality along the US 1 corridor on Big Pine Key. This proactive effort resulted in the formation of the Key Deer Ad-Hoc Committee in 1993. Based on recommendations from the committee, the Key Deer/Motorist Conflict Concept Study was initiated in 1995 to evaluate viable solutions in reducing Key deer mortality along US 1 (Calvo 1996, Calvo and Silvy 1996).

## Key Deer Dilemma

Recommendations from the Key Deer/Motorist Conflict Concept Study proposed the construction of barriers (fences) with two wildlife crossings (underpasses) to prevent Key deer access onto US 1 (fig. 2, Calvo 1996, Calvo and Silvy 1996). Underpasses in combination with fencing have been successfully used to reduce wildlife- (Foster and Humphrey 1995, Clevenger and Waltho 2000) and deer- (Bellis and Graves 1971, Falk et al. 1978, Reed et al. 1975, Ford 1980, Reed et al. 1974, Reed et al. 1975) vehicle collisions in many parts of the country. Furthermore, FDOT has successfully reduced road mortality for other federally-listed species (e.g., Florida panther (*Puma concolor coryi*) and Florida black bear (*Ursus americanus floridanus*) with the use of wildlife crossings. At this point, an apparently simple solution was complicated due to access management issues and environmental regulations related to urban development.

First, access management is a critical factor in the success of fence/underpass-type wildlife crossings. For example, along the US 1 corridor there are a number of access points (e.g., side roads, driveways) making continuous fencing impossible (fig. 2). Previous studies (Reed et al. 1974, Reed et al. 1975, Sebesta 2000) proposed modified cattle guards or "deer guards" (defined as cattle guards adapted for deer) as a method to

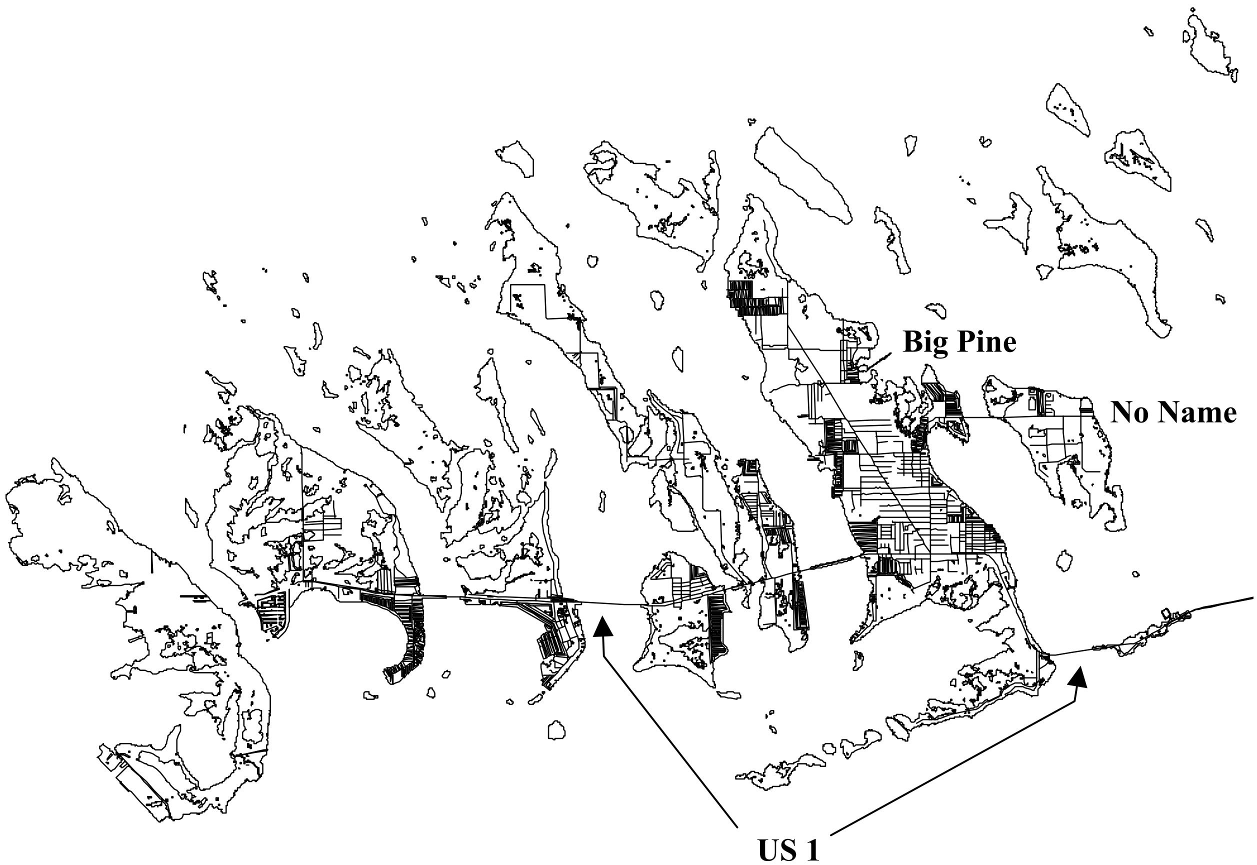


Fig. 1. Range of Florida Key deer, Monroe County, Florida.

allow unrestricted vehicle access while excluding deer. The use of traditional deer guards in preventing Key deer access into the corridor, however, were considered a hazard to pedestrians and cyclists, unproven in supporting heavy vehicular loads, and a skid hazard due to their required length (Rick Crooks, EAC Consulting, Project Engineer, personal communication). This required the development and testing of an effective and safe deer grate (defined as rectangular bridge grating material used to prevent deer crossing) that could be used in preventing Key deer access into the proposed project area (Peterson et al. 2003).

Second, environmental regulations prohibited road improvements on Big Pine and No Name keys without a habitat conservation plan (HCP). As previously mentioned, US 1 is the only highway linking the Keys to the mainland (Fig. 1). Safe and expedient evacuation during hurricanes depends on the US 1 level of service (Lopez et al. 2003*b*). In 1995, Monroe County authorities imposed a building moratorium due to the failure in level of service on the US 1 segment servicing Big Pine and No Name keys. Highway improvements, such as intersection widening and/or adding a third lane northbound (traffic direction towards mainland), were proposed that would improve the level of service and lift the building moratorium (Lopez 2001). Because additional traffic and development on Big Pine and No Name keys also might result in an incidental take of Key deer, however, highway improvements could only be permitted with the initiation and approval of a HCP (Endangered Species Act, Section 10a, 16 U.S.C. §1539a). In short, efforts to reduce Key deer mortality along the US 1 corridor could effectively increase Key deer mortality on other areas of the island, thus, our Key deer dilemma.

## Complex Problem, Multi-Dimensional Solution

Engineering constraints and environmental regulations complicated the solution in reducing Key deer mortality. Due to the complexity of the Key deer dilemma, multiple solutions were necessary in achieving the overall project objective – reducing Key deer mortality on Big Pine and No Name keys. Furthermore, solutions to reduce Key deer mortality required coordination with several agencies (e.g., USFWS, Florida Fish and Wildlife Conservation Commission, Florida Department of Community Affairs [DCA], and Monroe County), stakeholders (e.g., Key Deer Protection Alliance, Big Pine Key Chamber of Commerce, ), and the public. In 1998, efforts

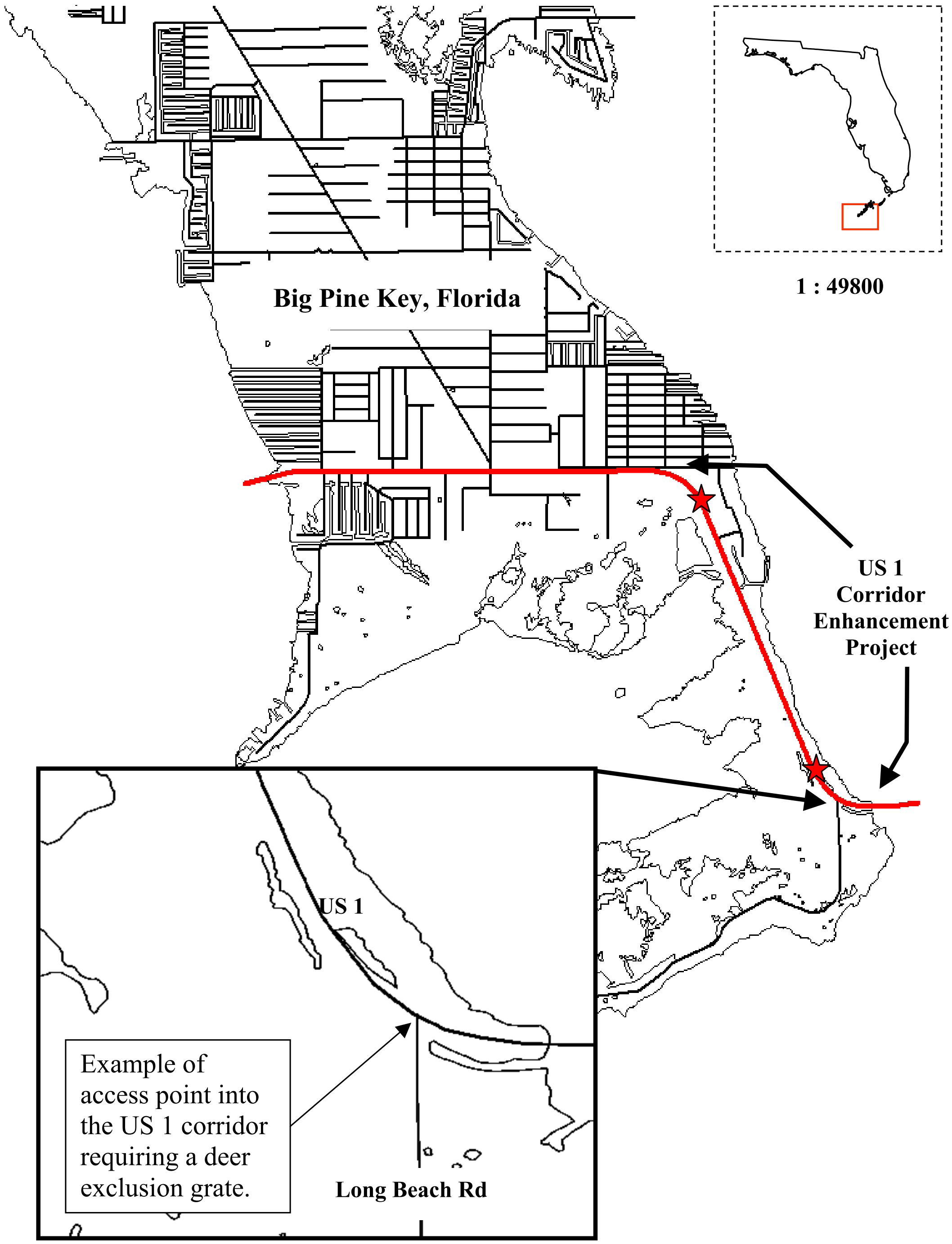


Fig. 2. U.S. Highway 1 corridor enhancement project, Big Pine Key, Florida. Arrows represent beginning and end points of fencing; star represent wildlife underpasses.

to address Key deer mortality began with (1) engineering design of improvements to US 1 (fencing and underpasses), (2) testing and implementation of a bridge grating system, and (3) the initiation of an HCP for Big Pine and No Name keys. Initial testing of a bridge grating system was completed in August 2002. Construction on the US 1 corridor was completed in February 2003. An HCP draft was submitted in May 2003 to USFWS for final review and approval. At this point, we will present and discuss preliminary results for actions implemented in resolving the Key deer dilemma separately, though in reality these solutions were not mutually exclusive.

**US 1 Improvement Project**

In June 2002, road construction along the "undeveloped" segment of US 1 between mile markers 31-33 consisted of two underpasses placed one mile apart in areas of high road mortality (mile markers 31.5 and 32.5), and fencing along the corridor to prevent Key deer access onto US 1 and to help direct deer toward underpasses (fig. 2). Underpasses consisted of concrete bridge structures with an effective crossing width of 25 feet and height of 8 feet, and were designed to provide safe crossing opportunities for Key deer. A vinyl-covered, chain link fence (8 feet in height ) was installed, with four inches of ground clearance to allow movement of the Federally-endangered Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*) but restrict Key deer movement into the project area. The fencing was continuous except for five access points where deer guards were used. FDOT also created a travel corridor parallel to the fencing between mile markers 31 and 33 to promote Key deer use of underpasses. The corridor was created through selective trimming of mangrove wetland vegetation along the outside (not on the roadway side) of the fencing.

**Bridge Grating System**

In May 2001, Peterson et al. (2003) evaluated 3 types of bridge grating material for Key deer-exclusion efficiency that were deemed safe for pedestrians, cyclists, and motorists by FDOT engineers. Each grate consisted of 20-ft x 20-ft bridge grating material (L. B. Foster, Pittsburgh, Pennsylvania) each with a different grate pattern: deer grate 1 had 4-in x 5-in openings with a diagonal cross member; deer grate 2 had 4-in x 3-in openings with no diagonal; deer grate 3 had 3-in x 4-in openings with no diagonal (Peterson et al. 2003). Peterson et al. (2003) reported deer grate 1 excluded less than 99 percent of Key deer crossing attempts, while deer grates 2 and 3 were greater than 75 percent effective. Thus, in addition to aforementioned use of fencing and underpasses, 5 Key deer grates were installed along the US 1 corridor (4 side roads, 1 at project terminus on US 1). Each Key deer guard consisted of bridge grating tailored to the width of the roadway and having a standard length of 25 feet.

**Habitat Conservation Plan**

In 1998, a planning process began with FDOT, Monroe County, and Florida Department of Community Affairs (DCA) representatives to draft and submit a regional Key deer HCP to USFWS biologists. The HCP applicants (i.e., FDOT, DCA, and Monroe County) employed a population viability analysis (PVA) to determine the effects of development (roadway improvement and houses) on the Key deer population. A PVA is a method or a collection of methods used to evaluate the viability of threatened or endangered species using computer simulation models (Boyce 1992, Burgman et al. 1993). Species viability is often expressed as the risk or probability of extinction, population decline, expected time to extinction, or expected chance of recovery (Akçakaya and Sjogren-Gulve 2000). PVA models attempt to predict such measures based on demographic and habitat data, and provide outputs or predictions that are relevant to conservation goals (Akçakaya and Sjogren-Gulve 2000). A demographic and spatially-structured Key deer model was developed for this purpose (Lopez 2001, Lopez et al. 2003*b*, Fig. 3), and was used in evaluating proposed development scenarios *a priori* in the final HCP draft submitted to USFWS in May 2003. Proposed development included limited residential and commercial building, improvement to public facilities (e.g., parks, fire station), and road improvements (e.g., three-laning US1, paving of unimproved roads). Currently, the Key deer HCP is being reviewed by USFWS.

## Formual for Success

Although many wildlife crossing projects have been implemented throughout the country, this project was unique in several ways. First, although every aspect of the project was based on the expertise of Key deer biologists, there was no precedent project elsewhere; thus, the probability of success was somewhat uncertain. This did not deter FDOT as it collaborated and used best science to keep the project moving forward. In resolving the Key deer dilemma, FDOT was proactive, and preliminary results from the US 1 project indicate 100 percent efficiency in the first six months of the project. The HCP also is unique in that a spatially-structured population model was used to evaluate development scenarios *a priori* and as a conservation-planning tool in making conservation decisions for the next 20 years on Big Pine and No Name keys. The Key deer model promises to serve this island community by providing some relief from building restrictions and traffic congestion without seriously impairing the viability of the Key deer population.

Second, collectively these efforts were conducted for the purpose of benefiting an endangered species; there was no regulatory requirement to implement the project. The Key deer project represents FDOT's dedication to work with the local community, regulatory agencies, and USFWS to implement a plan that maintains the continuity of vehicular traffic, while achieving the objectives of reducing Key deer mortality. The FDOT formed a collaborative partnership with several agencies, stakeholders, and the public in this process. FDOT's initiative resulted in improved trust and strengthened the relationship between all stakeholders. This partnership also illustrates the successful balancing of the (often competing) needs of the motoring public, businesses, residents, and the environment.

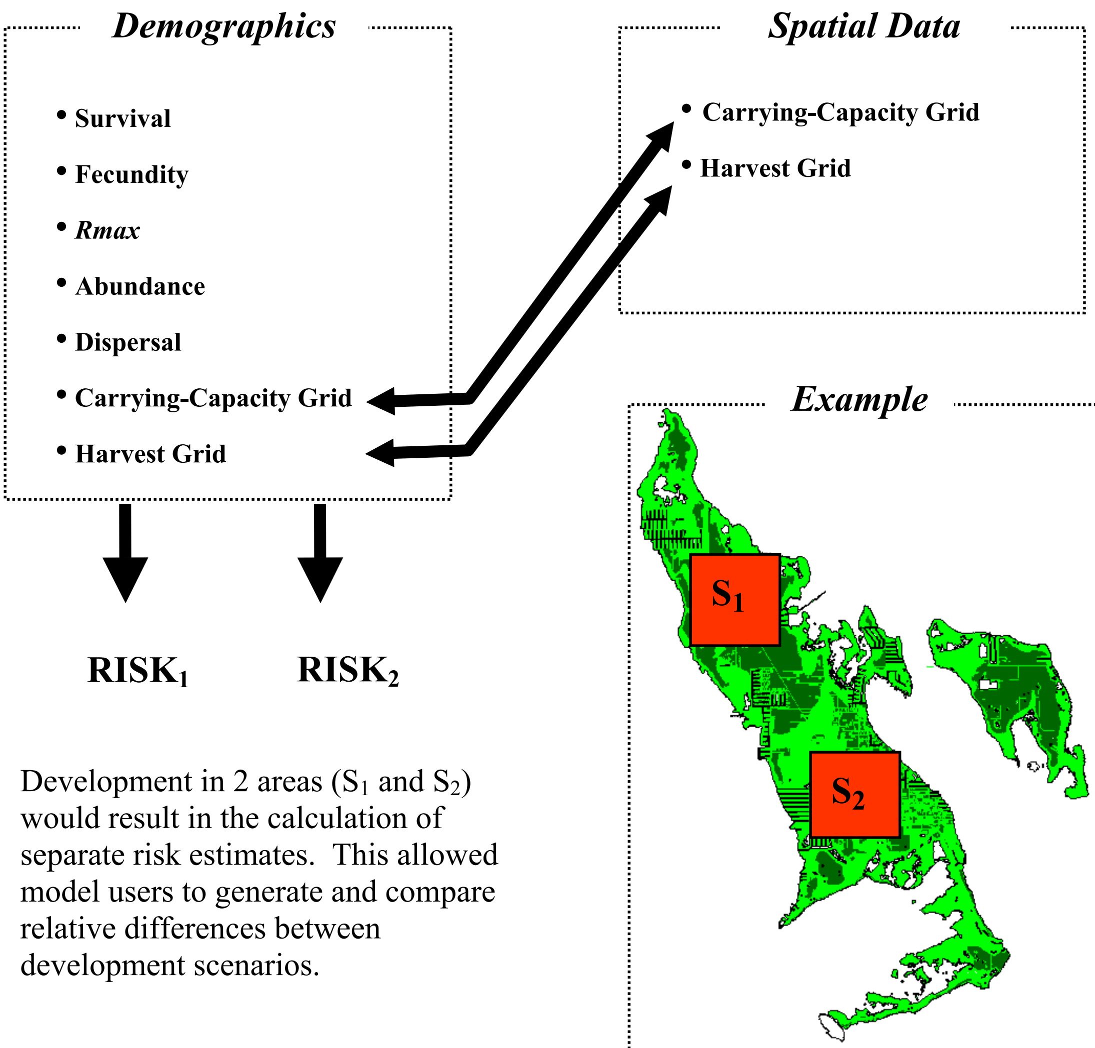


Fig. 3. Conceptual model used in the Key deer population viability analysis, Big Pine and No Name Keys, Florida.

Finally, what best illustrates the unique nature of this project was that environmental needs led the project, and that aspects of traditional engineering had to be adjusted in order to accomplish these needs. There was no truly defined engineering goal at the start of the project, rather, an environmental goal achieved through engineering design. Currently (August 2003), no Key deer mortalities have been recorded within the project area.

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## References


Akçakaya, H. R. and P. Sjogren-Gulve. 2000. Population viability analyses in conservation planning: an overview. *Ecological Bulletins* 48:9-21.

Bellis, E. D., and H. B. Graves. 1971. Deer mortality on a Pennsylvania interstate highway. *Journal of Wildlife Management* 35:232–237.

Boyce, M. S. 1992. Population viability analysis. *Annual Reviews Ecology and Systematics*. 23:481-506.

Burgman, M. A., S. Ferson, and H. R. Akçakaya. 1993. Risk assessment in conservation biology. Chapman and Hall, London, England.

Calvo, R. 1996. US-1/SR 5 Key deer/motorist conflict study concept report. Dames and Moore, Miami, Florida, USA. and N. J. Silvy. 1996. Key deer mortality, U.S. 1 in the Florida Keys. Paper 23, Pages 1-10 G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. *Trends in addressing transportation related wildlife mortality. Proceeding of Transportation Related Wildlife Mortality Seminar.* Florida Department of Transportation, Tallahassee, Florida, USA.

Clevenger, A. P., and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. *Conservation Biology* 14:47–56.

Conover, M. R., W. C. Pitt, K. K. Kessler, T. J. DuBow, and W. A. Sanborn. 1995. Review of human injuries, illnesses, and economic losses caused by wildlife in the United States. *Wildlife Society Bulletin* 23: 407–414.

Falk, N. W., H. B. Graves, and E. D. Bellis. 1978. Highway right-of-way fences as deer deterrents. *Journal of Wildlife Management* 42:646–650.

Ford, S. G. 1980. Evaluation of highway deer kill mitigation in SIE/LAS-395. Report Number FHWA/CA/TP-80-01. California Department of Transportation, Sacramento, California, USA.

Forman, R. T. 2000. Estimate of the area affected ecologically by the road system in the United States. *Conservation Biology* 14:31–35.

Foster, M. L., and S. R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. *Wildlife Society Bulletin* 23:95–100.

Hardin, J. W., W. D. Klimstra, and N. J. Silvy. 1984. Florida Keys. Pages 381-390 L.K. Halls, editor. *White-tailed deer: ecology and management*. Stackpole Books, Harrisburg, Pennsylvania, USA.

Lopez, R. R. 2001. Population ecology of Florida Key deer. Dissertation, Texas A&M University, College Station, Texas, USA.

B. L. Pierce, P. A. Frank, M. T. Wilson, and K. M. Burke. 2003*a*. Population density of the endangered Florida Key deer. *Journal of Wildlife Management.* In revision.

R. N. Calvo, P. A. Frank, P. M. Harveson, N. M. Peterson, and C. B. Owen. 2003*b*. A demographic and spatially-structured population model for Florida Key deer. *Journal of Wildlife Management.* In review.

M. E. P. Vieira, N. J. Silvy, P. A. Frank, S. W. Whisenant, and D. A. Jones. 2003*c*. Survival, mortality, and life expectancy of Florida Key deer. *Journal of Wildlife Management.* 67:34-45.

Peterson, M. N., R. R. Lopez, N. J. Silvy, C. B. Owen, P. A. Frank, and A. W. Braden. 2003. Evaluation of deer exclusion grates in urban areas. *Wildlife Society Bulletin*. In revision.

Reed, D. F., T. M. Pojar, and T. N. Woodard. 1974. Mule deer response to deer guards. *Journal of Range Management* 27:111–113.

Woodard, T. N., and T. M. Pojar. 1975. Behavioral response of mule deer to a highway underpass. *Journal of Wildlife Management* 39:361–367.

Sebesta, J. D. 2000. Design and evaluation of deer guards for Florida Key deer. Thesis, Texas A&M University, College Station, USA.

# IDENTIFYING THE BEST LOCATIONS TO PROVIDE SAFE HIGHWAY CROSSING OPPORTUNITIES FOR WILDLIFE

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**Abstract**: Providing mid- and large-sized mammals with safe opportunities to cross roadways can reduce the impacts of highways on wildlife. To maximize effectiveness, this type of mitigation must be placed in locations where animals naturally approach and cross the highway. Results of a study funded by the Colorado Department of Transportation indicate that mid- and large-sized mammals focus crossing activity at specific locations that are correlated to features of the surrounding habitat and the roadway itself. Therefore, both the design of a highway and its placement in the landscape should be considered when creating mitigation projects to help wildlife safely cross a highway. It is important to note that no single set of variables identifies all preferred crossing locations.

Because every landscape and every highway is unique, identifying the best location for each mitigation project must be approached individually. However, the study results suggest a set of guidelines, comprising the following: (1) use habitat suitability as the primary indicator of crossing activity; (2) consider how landscape structure interacts with habitat suitability to either increase or decrease the level of use an area of suitable habitat receives by a particular species; (3) consider how the design of the existing highway interacts with habitat suitability and landscape structure to influence crossing behavior; (4) synthesize this information by mapping the landscape and roadway features/conditions likely to be associated with crossing or that are attractive/repellant to the species present. Use these maps to identify the most likely crossing locations. Finally, because the preferred habitat and behavior of a given species can vary across its range, it is important to employ professionals familiar with the landscapes and species of concern on the analysis team.

## Introduction

Results of a study (No. 32.40) funded by the Colorado Department of Transportation (CDOT) investigated whether mid- and large-sized mammals cross highways randomly, or whether they instead focus crossing activity in locations that can be correlated to characteristics of the surrounding habitat and/or the roadway itself. The study recorded the locations where wildlife crossed two Colorado highways for two years, then compared the characteristics of crossing locations to random locations along the roadside.

The study results apply directly to Colorado's mountain environments and the common species that live there. However, they also provide insight into identifying the best locations to provide safe crossing opportunities for other mid- to large-sized mammal species in a variety of habitats. A brief description of the methods is presented below, followed by a summary of the primary findings. Strategies to identify the crossing locations for mitigation, based on the study results, are then discussed. A complete description of the study areas, methods, and results is available at http://dot.state.co.us/publications/PDFFiles/wildllifecrossing.pdf (note the double l in "wildllife"). This web document also includes a detailed discussion of project planning practices that will help to foster highway projects that reduce wildlife/highway conflicts.

## Methods

### Study Site Descriptions

One study area was located in the Trout Creek Pass area along US 24 (MP 116.0 – 126.0), a low-volume, two-lane highway. The northern part of this study area was rolling, and cover type consisted of grasslands communities west of US 24, and mixed coniferous forests to the east. The terrain in the south end of the study area was rugged and highly dissected by dry washes and rocky outcroppings. Elevations in the study area range from 2,830m at the Pass to 2,420m at MP 216.0, and the main source of human disturbance, apart from the highway itself, was about 20 homes located mainly in the southern end of the study area. US 24 intersected six major drainages in the study area that were bridged by large, three-chambered concrete box culverts with concrete floors or by smaller bridge structures with natural floors. This area acted as both summer and winter range for mule deer and elk. Other common terrestrial species included red fox (*Vulpes vulpes*), gray fox *(Urocyon cinereoargenteus*), coyote (*Canis latrans*), mountain lion, bobcat, long-tailed and short-tailed weasel (*Mustela frenata, M. erminea*), and mountain cottontail (*Sylvilagus nuttallii*).

The other study area was located in the Vail Pass area along I-70 (MP 183.0 – 195.0), a moderate- to high-volume, four-lane highway. Along this section of I-70, the alignments of the east- and westbound lanes were independently sited and varied in location and elevation. Vail Pass, located at approximately MP 190, divided the study area into an east side and a west side. The median separating the east- and westbound lanes varied in width from less than a meter in some places on the west side of the Pass, up to 260m on the east side. To a large extent, the natural cover and topography was maintained within the wide median area on the east side. On the west side, Jersey barriers separated the east and westbound lanes in locations where they were at the same elevation. Stepped retaining walls were used to separate the lanes in locations where one lane was at a higher elevation than the other.

The primary cover type in this study area was mixed coniferous forest interspersed with aspen stands, sub-alpine meadows, and willow carrs. The elevation of the study site ranged from 2,730 to 3,165m, and sources of human-induced disturbance, aside from the highway itself, included a rest area, truck turn out and maintenance shed at the summit and the Copper Mountain Resort at the base of the east side. I-70 intersected 18 large drainages in the study area, and bridges spanned 11 of them. These bridges provided high quality highway crossing opportunities for wildlife as the drainages they spanned are wide (up to 230m), and the natural cover below most was largely undisturbed. Common terrestrial wildlife species in this study area included red fox, bobcat, mule deer, elk, and mountain lion during the snow-free months. Snowshoe hare *(Lepus americanus*), coyote, long-tailed and short-tailed weasels, and American marten (*Martes americana*) were present year-round.

**Tracking**

I recorded locations throughout both study areas where medium- and large-sized mammals (mule deer, elk, coyote, fox, bobcat, mountain lion) crossed the highway, as indicated by their tracks. At TCP and VP I checked 10 roadside transects 200m in length for tracks during each field session. To ensure transects were distributed throughout a study area and did not overlap, I used a stratified random selection approach, varying transect location for each data collection session. At each transect, a field assistant or I walked along the highway at the pavement's edge and looked for animal tracks left in the unpaved shoulder. At TCP, traffic was light, and I crossed the highway to walk along both sides of it, recording tracks from both sides. At VP, however, I only walked along the outer edges of the west- and east-bound lanes. Due to high traffic volumes and speeds, I considered crossing the highway to access the median-side roadside unsafe.

I recorded track locations using a hand-held GPS device\data logger (Geo Explorer II, Trimble) that automatically recorded location while I entered information through a menu-driven interface. All tracks of the same species observed within a five-meter stretch were recorded as a single track record (TR). Each TR included species of animal, number of animals, location (UTM coordinates) and date. I downloaded data files from the data logger and used Trimble's proprietary software to convert them to Excel spreadsheet and ArcView shapefile formats for analysis.

Snow tracking was conducted at VPS December through March during both 2000/2001 and 2001/2002. I did not implement snow-tracking protocols at TCP because sufficient snow cover at this site was infrequent, unpredictable, and ephemeral. Thus, even on the few occasions when there was snow on the ground at TCP, the standard tracking procedures described above were followed. Using snow-tracking methods, I observed the entire VPS study area, as opposed to a subset of transects, for tracks. Far fewer animals are present in the Vail Pass area during winter than during the summer, and finding and recording all trails present was a reasonable task. I located all animal trails that entered the roadway within the study area by driving slowly (<25km/h) along the shoulder. When a trail was observed it was identified by species, and crossing success determined. Using the GPS device/data logger, I recorded species, number of individuals, date, and the UTM coordinates of the trail's intersection with the highway.

**Underpass Monitoring**

In addition to monitoring the roadside for tracks, I monitored some highway structures (bridges, oversized concrete box-culverts) at both study sites for use by animals to cross under the highway. Although only one of the monitored structures was constructed specifically to act as a highway underpass for wildlife, I will refer to all these structures as "underpasses." All underpasses monitored spanned either narrow, perennial streams or intermittent drainages that only carried water during spring run-off or during storm events, and offered plenty of dry substrate for animals to use when they passed through. I created track beds from locally available sand and soil at both ends of each monitored structure. An animal was recorded as passing through a structure only when I observed a matched set of tracks at both ends.

**Habitat Measurements**

I made all measurements of landscape structure for landscape-scale comparisons from digital data layers, using the ArcView software package. At both study sites, the landscape I measured was the area encompassed by the ridgelines that provided visual boundaries surrounding the highway. I derived the vegetation patterns of these landscapes from the National Land Cover Data (NLCD) vegetation maps and the topographic patterns from the USGS' Digital Elevation Models (DEMs).

I collected the locations of roadway features, including bridges (representing the locations of both underpasses and drainages) and roadside barriers (cliffs, walls, guardrails, Jersey barriers) in the field. I collected these data using the GPS device's setting for recording continuous data along a line. Using a roof-mounted antenna, I drove slowly (20-25km/h) along each feature of interest and collected positions for the entire length of each feature, then converted the positions into ArcView shapefiles using Trimble's proprietary software package.

In addition to making field measurements of the roadside habitat, I also used aerial photos and existing digital data layers to make some local-scale measurements. I digitized lines representing the forest boundaries from aerial photos, then used that data layer to measure the distance of crossing location to the nearest forest edge with ArcView. Additionally, I used the digital vegetation and topographic data layers described above to compare the cover, slope and aspect classes associated with crossing locations to what was available along the entire roadside.

**Analysis**
I defined concentrated crossing areas as those areas along the highway where tracks were more clustered than expected by chance. I determined the expected distribution of tracks using a GIS-based Monte Carlo simulation. A complete description of the analysis is available at http://dot.state.co.us/publications/PDFFiles/wildllifecrossing.pdf. Concentrated crossing areas were correlated to features from the landscape and the roadside using Monte Carlo simulations as well as simple statistical comparisons (e.g., chi-square tests, t-tests). A complete description of the comparisons made, the tests applied, and the statistical significance of the results is also available at the above-referenced Web site.

## Results: The Habitat and Roadway Features Correlated with Crossing

**At-Grade Crossing**
Study results indicate that mid- and large-sized mammals select road-crossing locations based on features from both the landscape scale and the local (roadside) scale. Concentrated crossing activity by these species was evident at both scales. At the landscape scale, there were long (>2km) segments of roadway that were crossed more often than other segments. This pattern occurred even where the highway was entirely surrounded by suitable habitat. These landscape-scale highway segments that were crossed most often can be thought of as *conflict zones*, because animals on the roadway risk being hit by vehicles, and they create a safety hazard for highway users. At the local scale, there were crossing hotspots, i.e., the locations within a highway segment that had the highest rates of crossing, relative to the rest of the segment. Hotspots occurred both within conflict zones and in segments with lower crossing rates, but there were more hotspots within conflict zones. Because hotspots varied in length from about 30 up to 600m in length, it is best to think of them as *crossing zones*, rather than point locations. The features correlated to crossing activity within both types of zone are discussed below.

**Landscape-Scale Features Correlated with Conflict Zones**
The study indicated that certain qualities of the landscape were correlated with conflict zones. They include suitable habitat, linear guideways, and slope steepness and complexity. These qualities are discussed in detail below.

*Suitable Habitat.* The presence of suitable habitat on both sides of the road was the baseline condition required for animals to cross the roadway on a regular basis. The better the habitat, the higher the rates of crossing. This may be the single most important factor for species that have narrow habitat preferences. Species that have broad habitat preferences (e.g., deer, elk, coyotes) have a greater opportunity to be affected by other factors.

*Linear Guideways.* Linear guideways can either encourage or discourage crossing, depending on their orientation to the roadway. Highway segments located in landscapes that contain guideways oriented perpendicular to the roadway had higher rates of crossing than segments located in landscapes where guideways ran parallel to the roadway. Guideways that lead animals through the landscape included drainages, ridgelines, and sharp breaks in cover type. Other potential guideways include fence lines, sharp changes in land use, and side roads that receive low rates of human use.

*Slope Steepness/Complexity.* Highway segments located in landscapes comprising relatively moderate slopes with low complexity (i.e., landforms are not too rugged) adjacent to the roadway had higher crossing rates. This effect was most pronounced in large areas of suitable habitat where animals had the opportunity to pick the easiest travel routes. If a species preferred rugged terrain (e.g., bighorn sheep, mountain goats) the opposite effect would be expected

**Local-Scale Features Correlated with Crossing Zones**
Results of the study indicate that features from the roadway itself and the habitat immediately surrounding the roadway were correlated to crossing zones. They include barriers, the distance to cover, and linear guideways and are discussed in detail below.

*Barriers.* Deer, elk, and coyotes avoided jumping over barriers (Jersey barrier, guardrails, walls, and steep road cuts) to enter a roadway, although they readily jumped Jersey barrier and guardrails to exit. Animals commonly entered the roadway at the ends of barriers, and rarely wandered along between the barrier and the road before crossing, if the space was narrow. However, animals sometimes walked hundreds of meters along roadsides before crossing if a barrier did not confine them. Other researchers report similar results (Carbaugh et al. 1975).

*Distance to Cover.* The species that commonly crossed the road in this study were most likely to approach the roadside in areas where a moderate amount of cover (i.e., suitable habitat) was present. However, they did not require cover up to the road's edge in order to approach the roadside. The amount cover within 90m of the roadside was not correlated with the location of crossing zones. Instead, crossing zones tended to be located along highway segments that had smaller average distances from the roadside to the cover's edge throughout the segment. The characteristics of crossing locations of species that prefer dense cover or no cover at all are expected to vary accordingly.

*Linear Guideways.* The intersection of linear guideway with a roadway often created a well defined, intensely used crossing zone. This effect is most pronounced for drainages, because drainages tend to be well defined. Ridgelines also guided animals to the roadside, but tended to create more diffuse crossing zones, as the ridgelines themselves are less discrete. In addition, when a ridgeline and a roadway intersect, extensive cutting is often required, and the slopes that are created may be steep, further diffusing the crossing activity at that location.

**Below-Grade Crossing**

In addition to at-grade crossing, below-grade crossing opportunities were monitored for use by all wildlife during the study. Monitored structures included large concrete box culverts (CBCs) and bridges. Dimensions of the structures varied widely, but dry footing was present in all. Roadside barriers did not force animals to use any of the monitored underpasses; at all locations, animals had the option of crossing at-grade if they preferred. Although the study design precluded quantitative evaluation of the underpass date, a qualitative assessment indicated the following:

- A wide variety of culvert and bridge designs were used frequently by a wide variety of species, including mule deer, coyotes, mountain lion, bobcat, fox, American marten, rabbits, and small mammals.
- Deer were most likely to use underpasses at least 2.5m in height and with a natural bottom.
- The surrounding habitat, as well as the design of the structure, played a role in which underpasses were used most frequently.
- The evidence suggests that mid- and large-sized mammals species may prefer to use high quality below-grade crossing opportunities instead of crossing at-grade, in locations where they have a choice.

For all species, both the characteristics of a structure itself and the surrounding habitat appeared to play a role in the level of use it received. For example, at Trout Creek Pass, underpasses varied in design, including single chamber CBCs, multi-chamber CBCs, and single span bridges with natural floors. One of the bridges was the most open (height x width/length) structure checked for tracks, and it received the most consistent levels of use, including large numbers of deer, as well as some bobcats and coyotes. However, a high openness value and a natural floor did not guarantee use. A single span bridge located in the north end of the study received lower rates of use than any of the CBCs. Habitat suitability factors limited at-grade crossing at north end of Trout Creek Pass and probably had a similar effect on underpass use.

The underpasses at the Vail Pass study area were all over-sized bridge structures and provided exceptionally high-quality, below-grade crossing opportunities for wildlife. They ranged from 3.9 to 13.5m in height and from 21.9 to 218.0 m in width. Because of these generous dimensions, the natural ground cover, including trees, grew underneath many of them. The use of these structures appeared to be most heavily influenced by the pairing of underpasses that allowed animals to cross under both the east- and the westbound lanes of traffic with ease. The two most heavily used underpasses differed greatly in dimension but were both located on the west side of the pass, where the east- and westbound alignments were side-by-side. On the east side of the pass, the alignments were separated by a wide (>200m) median, and the underpasses along the eastbound lanes were not mirrored in the westbound lanes. The underpasses on the east side of the pass were otherwise similar in construction and dimension to the west side underpasses. Therefore, the ease of crossing the entire highway, rather than an underpass' design and dimensions appeared to play the major role in regulating an underpass' rate of use.

On the east side of the pass, the uneven distribution of underpasses also appeared to influence the rate and location of at-grade crossing. Exactly twice as many at-grade crossing events were recorded in the westbound lanes, which had only a single underpass, as compared to the eastbound lanes, which had four underpasses. Further, the crossing zones in the westbound lanes were roughly aligned with underpasses in the eastbound lanes. These patterns suggest that mid- to large-sized mammals prefer to use high-quality below-grade crossing opportunities when they have a choice.

## Applying the Results: A Framework for Identifying Crossing Locations for Mitigation

### Identifying Conflict Zones

As described above, the relative importance of different landscape features in creating conflict zones varies from location to location. For example, deer and elk will travel through steep, rugged terrain that they might otherwise avoid if that area has the most suitable habitat, compared to adjacent areas. However, if they have a choice within the area of suitable habitat, they are likely to choose the easiest travel route. The effect of landscape composition on crossing behavior is also influenced by roadside and roadway features of existing highways. For example, the presence of extensive roadside retaining walls will prevent animals from crossing in locations where landscape structure might otherwise induce them to do so. Finally, local habitat preferences and behavior can play a significant role in how a species responds to landscape structure. For example, the habitat preferences of elk vary across their range and some populations of elk are sensitive to human disturbance, while other populations are not. Determining the effect of recreational activities on habitat suitability near a highway, and the consequent likelihood of elk approaching the roadside in that area, requires local knowledge about both the habitat preferences and the behavior of that population. Thus, understanding how landscape composition and habitat preferences affect crossing locations requires familiarity with the landscape in question and the species likely to be present.

The information discussed above indicates the following strategy for identifying areas with a high potential to be conflict zones:

- Employ professionals familiar with the landscapes and species of concern.
- Use habitat suitability as the primary indicator of a potential conflict zone.
- Consider how landscape structure may interact with habitat suitability and either increase or decrease the level of use an area receives by a particular species.
- Consider how design of the existing highway affects the expression of habitat preference at the roadside.
- Consider accident data as an auxiliary source of information.

Methodology Note: A variety of commercial digital data products are available to assist with landscape level analyses. These include digital elevation models (DEMs) and national land cover data (NLCD) from the U.S. Geological Survey. Other products, such as digital aerial photography and local or statewide land cover data, are also available from local agencies and commercial sources, or can be commissioned through contractors.

### Identifying Crossing Zones

Crossing zones are relatively short stretches of highway that have the highest probability of being crossed by wild animals. As discussed in above, features from both the surrounding habitat and the existing highway focus crossing activity, creating a crossing zone. However, as with conflict zones, there is no single suite of variables associated with all crossing zones. Local conditions and interactions between variables mediated the influence a variable exerted at a particular study site.

An important local condition that regulates whether a feature may be useful for identifying crossing zones is the amount of variability in that feature. For example, crossing zones at four out of the six sub-areas studied were positively associated with highway segments that were closer than expected to the cover's edge. In contrast, on the west side of Vail Pass, the design and construction of the roadway resulted in a very consistent distance between the pavement and the forest edge. Consequently, there was little variability that animals could cue on, and distance to forest edge was not correlated with crossing zone locations in this sub-area.

Unique local conditions can also play a key role in determining the influence a feature has on crossing zones. For example, at five of the six study site sub-areas, the locations where drainages intersected the roadway were strongly correlated with crossing zones. However, at the north end of the Trout Creek Pass the positive association of crossing zones with the forest edge was so strong that it created a negative association with drainages. Reasons for the strength of the relationship with the forest edge include the following: the cover type along the roadside was mostly open grasslands at this site, creating a relatively narrow tongue of forest leading to the roadside; the forest edge was generally a long distance from the roadside in this sub-area, magnifying its effect where it came close to the roadway; there were few other well-defined features, such as drainages or barriers, which could also act to focus crossing activity. Those that were present were far away from the highway segment near the forest edge. None of these three conditions existed at any of the other five sub-areas.

Another example of a unique local condition overriding other variables that might otherwise act as cues to crossing is the presence of the Copper Mountain ski area at the foot of Vail Pass. In wintertime, the lure of food sources associated with the resort and easy travel on the compacted snow of the ski runs was a strong attractant for coyotes in the area. As a result, neither the locations of barriers nor the distance to the forest edge was important to them when they crossed the road, and they showed a weak negative association with drainages. Additionally, coyotes crossing I-70 near Copper Mountain used all slope classes consistent with their availability, even though animals crossing I-70 in the rest of the Vail Pass study area in winter showed a strong preference for shallow slopes.

As with landscape-scale variables and conflict zones, the relationships of the local-scale variables to crossing zones differed by location. However, they made sense to someone familiar with the resources available in the landscapes in question, as well as the habitat preferences and behavior of the species under consideration. In summary, the information discussed above suggests the following strategy for identifying locations with a high potential to be crossing zones:

- Employ professionals familiar with the landscapes and species of concern.
- Locate and map features likely to be associated with crossing zones and known to be important to the species present. Pay special attention to the location of drainages, barriers, special habitat features (e.g., food sources), and the distance to cover (for species that use cover).
- Using these maps, determine the relative abundance of each feature, and how much variation it exhibits along the roadside.
- Place greater reliance on features that are highly attractive to resident species, especially if those features are rare, and to features that are relatively variable.

Methodology Note: Maps of roadside and roadway features are easy to create by driving slowly along a roadside and identifying features of interest. A handheld GPS devise/data logger and a laser range-finder can be used to collect positional information about these features (Carson et al. 2001; Barnum 2003). These data can then be displayed and analyzed in the office using standard GIS software.

### Animal/Vehicle Collisions and Crossing Locations

Because conflict zones are crossed more often by wildlife than surrounding highway segments, they may also have higher-than-average rates of reported animal/vehicle collisions (AVCs) than surrounding segments. However, because AVC rates are dependent on traffic volume as well as the number of animals crossing the roadway (Roof and Woodling 1996; Barnum 2000), this effect may not be apparent for low-volume roads. Therefore, although AVC data can help identify conflict zones, they cannot replace incorporating information about the surrounding habitat and landscape structure into an analysis of crossing locations, as described below. It is also important to note that AVC data are not useful for identifying crossing zones. The primary source of these data is usually State patrol accident reports, which often estimate collision location to the nearest milepost, and rarely more precisely than the nearest tenth of a mile. Therefore, AVC data provide adequate precision to identify conflict zones, which are generally over 2km in length, but not for crossing zones, which are generally 30-600m in length.

## Conclusions and Recommendations

Some of the negative impacts of highways on wildlife can be eliminated if animals can safely and easily cross the highway. Because both landscape structure and features of the highway itself influence where animals naturally come to the roadside, a strategy that considers both types of features is needed to effectively identify crossing locations. The primary components of such a strategy are to:

- Use habitat suitability as the primary indicator of crossing activity.
- Consider how landscape structure interacts with habitat suitability to either increase or decrease the level of use an area of suitable habitat receives by a particular species.
- Consider how the design of the existing highway interacts with habitat suitability and landscape structure to influence crossing behavior.

- Synthesize this information by mapping the landscape and roadway features/conditions known to be associated with crossing or to be attractive/repellant to the species present. Use these maps to identify the most likely crossing locations.

In addition to identifying the most likely crossing zones, highway planners and designers should incorporate the following principles into their planning process to reduce highway wildlife conflicts:

- Evaluate each highway project individually. Not all crossing locations are associated with the same set of variables.
- Incorporate wildlife considerations into initial project planning and design to maximize cost and biological effectiveness,
- Because of local variation, employ professionals familiar with the landscapes and species of concern on the design team.
- Work with the entities that manage landscapes surrounding project areas to minimize animal crossing and/or maintain the landscape structure cues that bring animals to mitigated crossing locations.

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## References

Barnum, S. A, 2000. Summary of Animal/Vehicle Collisions From Glenwood Springs to the Morrison Exit. Unpublished CDOT Report.

Barnum, S. A., 2003. Characteristics of Wildlife Highway-Crossing Zones and Applying This Information to Reduce Wildlife/Highway Conflicts. Ph.D. Dissertation, Design and Planning, University of Colorado at Denver.

Carbaugh, B., Vaughan, J. P., Bellis, E. D., Graves, H. B., 1975. Distribution and activity of white-tailed deer along an interstate highway. *J. Wildl. Manage.*, 39, 570-581.

Carson, R. G., Kirkman, R., Neil. J., 2001. ODOT' salmon resource and sensitive area mapping project: a high-tech procedure for obtaining biological resource data for resource protection and regulatory compliance. *Proceedings of the International Conference on Ecology and Transportation.* Center for Transportation and the Environment, North Carolina State University.

Roof, J., Wooding. J., 1996. Evaluation of S.R. 46 wildlife crossing. Florida Cooperative Fish and Wildlife Research Unit, U.S. Biological Service Technical Report no. 54. 36 pp.

# STRATEGIES FOR RESTORING ECOLOGICAL CONNECTIVITY AND ESTABLISHING WILDLIFE PASSAGE FOR THE UPGRADE OF ROUTE 78 IN SWANTON, VERMONT: AN OVERVIEW

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**Abstract:** Vermont Route 78 travels through one of the largest and most significant wetland complexes in the State of Vermont. This fact is exemplified by the presence of the Missisquoi National Wildlife Refuge and the Carmens Marsh State Wildlife Management Area as the primary landowners of this large wetland system. This mosaic of wetlands offers outstanding wildlife habitat for a myriad of resident and migratory species ranging from waterfowl (e.g., black ducks, wood ducks, goldeneyes) and wading birds (e.g., great blue herons, American bitterns, Virginia rail – the state's largest colony of nesting great blue herons occurs in this wetland system), to rare, threatened and endangered species, such as the black tern and spiny softshell turtle. Although black bear and moose are not the common species in this part of the state, vehicle collisions with those species have occurred in the project area. Each year, many white-tailed deer are killed by vehicle collisions in one area of this roadway alone. Numerous other species of mammals, birds, reptiles and amphibians are killed by traffic in this area each year.

Route 78 is a relatively narrow, winding road with an increasing volume of traffic, most notably commercial truck traffic coming from and going to Canada. Public safety concerns regarding the high traffic volume and poor road conditions have caused the Vermont Agency of Transportation to pursue upgrade of the road along the Missisquoi River and through the Mississquoi wetland system and Missisquoi National Wildlife Refuge. In order to address safety issues related to the road conditions and the wildlife habitat and associated environmental concerns, a collaborative process was developed to identify issues and solutions. The Vermont Department of Fish and Wildlife in coordination with the Missisquoi National Wildlife Refuge and the Vermont Agency of Transportation identified impacts to wetland habitat, effects of traffic on sensitive wetland-dependent wildlife, and the barrier effect of the existing road conditions as primary concerns related to this project. In order to address those concerns, we evaluated landscape and habitat conditions along the road project corridor, distribution of road-related wildlife mortality, animal movement information based on evidence of animal movements and activity in habitats near the road (e.g., tracks, observations of animals), and local knowledge of animal movements and animal vehicle collision areas from Missisquoi National Wildlife Refuge biologists and Vermont Department of Fish and Wildlife Game Wardens.

Landscape analysis of this segment of Route 78 indicates an isolated area of upland habitat surrounded by wetland habitat associated with an S-curve in the road known as Louis Landing. Road-related wildlife mortality information indicates a high proportion of animal-vehicle collisions along the S-curve by Louis Landing suggesting that the upland habitat is serving as a primary travel corridor for many species of wildlife. Species that cross, or are likely to cross, within the wetland/upland complex along Route 78, such as deer, moose, black bear, mink, otter, beaver, muskrat, raccoon, coyotes, red fox, gray fox, other small mammals, amphibians, reptiles, and some birds, would utilize a transition zone between wetland and upland habitat which is provided by this area. As mentioned earlier, this is the only area where black bear and moose have tried to cross Route 78. In Vermont, we have found black bears are selective in their preference for locations to cross roads. This is a primary location where birds are struck by vehicles, including hawks, owls, waterfowl and songbirds.

Additionally, we identified several other important wildlife linkage areas that traverse Route 78 as well as an important amphibian breeding area that requires large migrations of frogs to cross the road each year during spring spawning season.

Based on this evaluation, we developed a "Route 78 Permeability Plan for Fish, Wildlife, and Ecosystem Functions." The purpose of this plan is to identify the most significant wildlife habitat linkage areas along the road project corridor and identify measures for resolving road-related conflicts with those areas. The plan proposes the following measures for restoring and mitigating wildlife movement and ecological functions within the Missisquoi wetland system:

> A. Construction of a 500-foot-long span bridge in an area identified as Louis Landing. This is the primary linkage area. The dimensions of the underpass have been designed to accommodate spanning the entire linkage area to accommodate the needs of a variety of taxa and species. We believe that this strategy will reduce the risk that the structure would fail to serve the needs and interests of some of the species and/or taxanomic groups that require unrestricted movement in this wetland system.
>
> B. Shifting of the existing road at least 100 feet away from the edge of the Missisquoi River and restore that area to functional riparian habitat.

C. Construction of at least 4 amphibian passage structures along a segment of the corridor to reduce amphibian road mortality and restore amphibian access to spawning habitat.

D. Construction of at least 3 large box culverts in the Carmens' Marsh area of the road corridor to restore hydrology in that part of the wetland system and allow for wetland dependent furbearers (muskrat, beaver, otter) to move within that wetland system.

E. Conserve through application of a conservation easement lands on the south side of Carmens Marsh to restore wetlands affected by the disruption in hydrology due to the road, and improve wildlife habitat condition and connectivity in that area.

Agreements related to this project will ensure that future research will be funded to explore the efficacy of this strategy and learn more regarding the effects of highways through biologically rich wetland systems. This project serves as an outstanding example of how collaborative efforts between natural resource and transportation agencies can achieve public safety, transportation, wildlife, and habitat interests in a meaningful and expeditious manner. This paper will explain further the process used to evaluate linkage area conditions, wildlife movement, and development of restoration and mitigation measures.

## Introduction

Vermont Route 78 travels through one of the largest and most significant wetland complexes in the State of Vermont. This fact is exemplified by the presence of the Missisquoi National Wildlife Refuge and the Carmens Marsh State Wildlife Management Area as the primary landowners of this large wetland system. This mosaic of wetlands offers outstanding wildlife habitat for a myriad of resident and migratory species ranging from waterfowl (e.g., black ducks, wood ducks, goldeneyes) and wading birds (e.g., great blue herons, American bitterns, Virginia rail – the state's largest colony of nesting great blue herons occurs in this wetland system), to rare, threatened and endangered species such as the black tern and spiny softshell turtle. Although black bear and moose are not common species in this part of the state, vehicle collisions with those species have occurred in the project area. Each year, many white-tailed deer are killed by vehicle collisions in one area of this roadway alone. Numerous other species of mammals, birds, reptiles and amphibians are killed by traffic in this area each year. In addition, the potential displacement effect of traffic on sensitive wetland-dependant wildlife may be significant (Jackson 2000).

The Missisquoi River is one of several major river systems that flow through Vermont into Lake Champlain. The Missisquoi River creates the lakeshore wetland system comprising thousands of acres. This is the second largest wetland system in the State of Vermont and possibly the most biologically diverse. Vermont Route 78 parallels approximately three miles of this river without any buffer. The lack of separation between the road and river precludes movement along the river by wildlife, creates water quality problems, and presents a serious public safety hazard.

Route 78 is a narrow, rural arterial state highway with an increasing volume of traffic, most notably commercial truck traffic coming from and going to Canada. In 1996, Route 78 was designated a national highway. Public safety concerns regarding the high traffic volume and poor road conditions have caused the Vermont Agency of Transportation to pursue upgrade of the road along the Missisquoi River and through the Mississquoi wetland system and Missisquoi National Wildlife Refuge. In order to address safety issues related to the road conditions and wildlife habitat and associated environmental concerns, a collaborative process was developed to identify issues and solutions. The Vermont Department of Fish and Wildlife in coordination with the Missisquoi National Wildlife Refuge, the Vermont Agency of Transportation and other government organizations (e.g., EPA, ACOE) identified impacts to wetland habitat, effects of traffic on sensitive wetland dependent wildlife, and the barrier effect of the existing road conditions as primary concerns related to this project. In order to address those concerns, we evaluated landscape and habitat conditions along the road project corridor, distribution of road-related wildlife mortality, animal movement information based on evidence of animal presence and activity in habitats near the road (e.g., tracks, observations of animals), and local knowledge of animal movements and areas where there has been a high frequency of animal/vehicle collisions from Missisquoi National Wildlife Refuge biologists and Vermont Department of Fish and Wildlife Game Wardens (Trombulak and Frissell 2000; Wagner et. al. 1998).

## Permeability Design for Route 78

### Assessment Process

The assessment of wildlife movement and linkage habitat associated with the Route 78 project area consisted of: (1) wildlife species inventories; (2) significant habitat inventories; (3) landscape and vegetative cover data; (4) evidence of animal movement along Route 78 (track data); and (5) road mortality data for wildlife. Aerial and ortho photography was used to identify habitat features within the road corridor (Fahrig and Merriam 1985; Singleton et. al. 2001). Areas reviewed for evidence of wildlife movement were within 300 feet on either side of the road edge. Due to the fact that much of the project area is in public ownership for conservation purposes by the U.S. Fish and Wildlife Service and the Vermont Department of Fish and Wildlife a great deal of institutional knowledge was available to identify important wildlife species, habitats, and road crossing locations without extensive field inventory work (Clevenger et. al. 2002).

Road-related wildlife mortality was evaluated in a systematic fashion for 1.5 years by refuge biologists, Vermont Department of Fish and Wildlife biologists and game wardens. Standard information was recorded opportunistically while conducting regular field responsibilities, including the location of the road mortality, species, date, time of day. The process was designed to be simple in order to maximize the likelihood of receiving data from volunteer field staff.

A general landscape analysis of the area around the Route 78 corridor illustrates a long linear component of mature flood plain and upland forest within a large deep rush marsh. This area represents the only segment of Route 78 where forest habitat abuts both sides of the road. It also represents the only area of forested habitat within the western segment of the wetland system. This is a critical component to accommodating the movement of most mammals in a large wetland system (Clevenger and Waltho 2000; Hammond 2002).

Animals known to cross Route 78 in this area include: white-tailed deer, moose, black bear, American beaver, mink, muskrat, otter, numerous species of small mammals, snapping turtles, numerous amphibian species, a variety of waterfowl species, wading birds, song birds, owls, raccoons, skunk (this list does not necessarily represent all species that utilize this area for crossing Route 78).

During 2001, we confirmed concentrated use of this habitat zone on both sides of Route 78 by deer. Based on the landscape analysis of the habitat and land conditions as well as limited road mortality data and the history of professional knowledge by wildlife experts familiar with this area, many taxonomic groups and species of wildlife appear to be using this area to move across Route 78 to access habitats to the north and south. As an example, deer migrate from the habitat to the north of Route 78 to winter habitat on the south side of the road during early winter periods. We measured the area along the existing alignment of Route 78 that demonstrated the greatest concentration of animal activity as well as the best habitat conditions of transitional upland and wetland. This area measured 500 feet along the road.

## Results and Discussion

### Overall Fish and Wildlife Permeability Plan

Based on the results of the linkage area and wildlife movement assessment, a road permeability plan for restoring connectivity for fish, wildlife and related ecosystem functions was developed for the project area. This plan consists of five primary elements that are discussed below including: (1) construct a wildlife underpass that is 500-feet-long and spans a significant area of linkage habitat; (2) shift a 1.5-mile segment of the road away from the Missisquoi River and establish riparian habitat in the former road location; (3) install tunnels that will allow amphibians to access important reproduction habitat; (4) install multiple, large box culverts in strategic locations throughout the marsh habitat; and (5) conserve an important area of wetland habitat near the road that will be connected to other conserved habitat by large box culverts.

An additional wildlife component to this project that is not directly discussed in this paper involves the geometric design of the road to avoid critical nesting habitat for the state threatened black tern. The black tern is extremely rare in Vermont and northern New England. Its population in Vermont has declined drastically in recent years for causes that are not certain. At this time, the only remaining nesting population of black terns in Vermont is adjacent to the project site. Therefore, in accordance with Vermont's Threatened and Endangered Species Law, the participants in this collaborative process have gone to great lengths to ensure that this critical nesting habitat is properly protected.

### Wildlife Underpass

A 500-foot-long span bridge has been designed for the area identified in figure 1 (the primary linkage habitat for wildlife movement in the project area) in order to restore ecological connectivity within the Missisquoi delta wetland complex, to provide wildlife passage in an area identified as an important wildlife movement corridor, and to improve public safety by reducing the risk of vehicle collisions with wildlife.

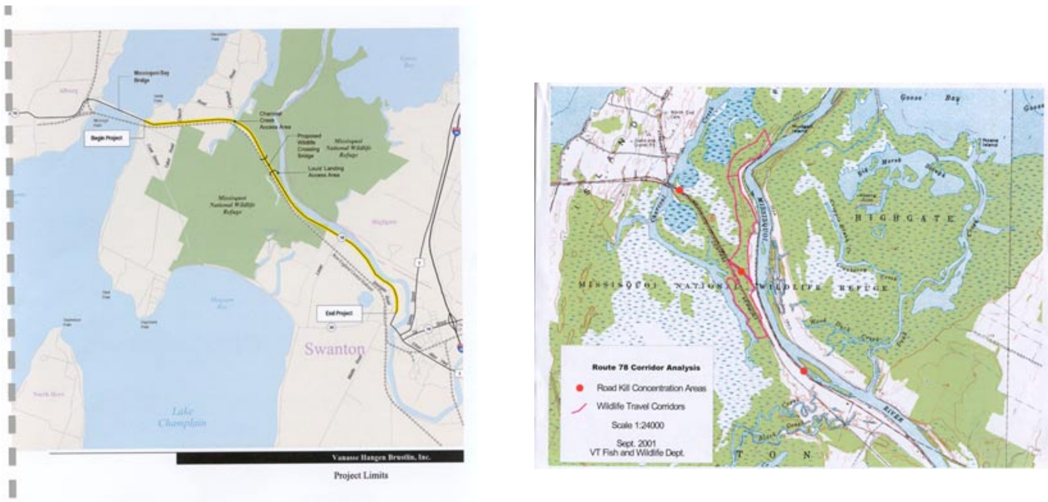


Fig. 1. Maps of the project area identifying the linkage habitat, road mortality hot spots, and location of the wildlife underpass.

Based on an assessment of the linkage area, and given the unique and significant environmental contributions to the state associated with the MNWR and the wetland system, a decision was made to span the entire width of the linkage area. This design is intended to avoid the risk that the structure will not serve the passage needs of the myriad fish and wildlife species that require mobility within this system of habitats (Ruediger 2001). The design of the structure represents an attempt to address the affects of a major state highway on an overall ecosystem rather than a single species of wildlife. A secondary benefit of spanning the entire area of linkage habitat is that it avoids additional wetland impacts and, therefore, reduces the need for off-site wetland compensation. Finally, raising the road over the linkage habitat allows the extreme curvature in the roadway to be reduced, thereby adding an additional level of safety to the traveling public.

In addition to the structure itself, the former roadbed will be reclaimed to functional wetland habitat similar in character to the surrounding forested swamp. Habitat will also be established within the wildlife passage structure by planting appropriate vegetation and incorporating course woody debris, large rocks/boulders, and other organic material that will provide cover for migrating animals.

While fencing may be necessary to direct animals, particularly large mammals such as deer, to the passage structure, the natural funneling affect of the habitat lends itself to focusing animal movements in the area of the proposed bridge. Future monitoring and evaluation of this area may examine the efficacy of the passage structure both with and without fencing. The type and length of fencing necessary to ensure the proper function of this structure for wildlife is not yet determined. It is possible that given the significant funneling effect that this habitat has on animal movement, fencing requirements may be limited.

In order to ensure that this and other elements of the Route 78 fish and wildlife permeability plan function properly it is necessary to create openings in the adjacent railroad bed that parallels the road to the south. The railroad serves as a parallel barrier along Route 78; however, the train traffic in this area is infrequent (1 train trip per day). While it is likely that many large- and medium-sized mammals successfully negotiate this barrier due to infrequent train traffic, it is necessary to perforate that barrier for other small wildlife as well as to allow fish free movement within the wetland system during periods of high water, typically during the spawning season for many resident species (e.g., northern pike). Additionally, the wildlife underpass may increase the volume and frequency of wildlife movement in the area, thus requiring a greater level of permeability for both barriers in order to maximize the benefit of the substantial investment in the bridge. No openings are required in the railroad bed along the Missisquoi River segment of the project since two bridge openings already exist in that area.

**Restoration of Riparian Habitat and Associated Wildlife Mobility Along the Missisquoi River**

Roughly 1.5 miles of the Route 78 upgrade runs directly along the Missisquoi River. In this area, the road will be removed from its current location and shifted approximately 100 feet to the west of the river, thus affording the opportunity to restore valuable riparian habitat. Over time, and following appropriate riparian vegetation restoration, this area should serve myriad important ecological, recreational, educational, and public safety functions including: (1) reduction in driving hazards; (2) wildlife movement along that portion of the Missisquoi

River; (3) nesting habitat for songbirds; (4) habitat for reptiles and amphibians; (5) angler access; (6) nature hikes and bird watching; and (7) improved water quality.

**Movement for Amphibians to Access Important Reproduction Habitat**

The wet meadow and shrub wetland habitat to the west of Route 78 serves important breeding functions for many species of amphibians. In order to accommodate and improve access to and from this important spawning habitat, amphibian tunnels will be installed along this segment of roadway (Carr and Fahrig 2000; Jackson 1997). Since the habitat on both sides of the road is relatively homogenous, four amphibian tunnels will be placed equidistant throughout the segment of road identified in figure 2. The intent is to establish a high frequency of passage structures in concert with concrete barrier to direct amphibian movement, such that there is a probability of frogs and other amphibians, reptiles and small mammals finding a tunnel and attempting to cross.

Figure 2. Area of amphibian spawning habitat and Route 78 adjacent to Missisquoi River.

In order to ensure that the tunnels function properly, permanent fencing will be required to direct amphibians to tunnel openings (Jackson 1997). Permanent fencing in the form of metal or concrete barriers will be necessary since less permanent fencing will require a great deal of annual maintenance. Additional research is necessary to determine the length of fencing necessary to capture and direct most migrating amphibians. If culverts are also used to drain water along this segment of roadway, future monitoring could be used to evaluate the disparity of use by amphibians between the amphibian tunnels (open grate, trapezoidal cast concrete) and conventional culverts (round metal corrugated pipe). Given the cost of the amphibian tunnels and their open grate component, maintenance will likely be required to ensure proper long-term functioning.

**Other Crossing Structures and Habitat Acquisition**

Wetland habitats on both the north and south sides of Route 78 at Carmen's Marsh include outstanding examples of deep rush marsh, forested swamp, and wet meadow habitat. These habitats serve outstanding functions for spawning fish (e.g., northern pike), migratory waterfowl and wading birds, breeding and feeding habitat for reptiles and amphibians, among many other important functions. This is an area where, during spring migration, it is not uncommon to see hundreds of ducks resting and feeding, including many species which are not otherwise seen in Vermont.

Currently, only two small (approximately 18-inch diameter) culverts exist in this area and do not function properly. In order to accommodate and improve wildlife movement within this outstanding wetland system along Route 78, three large (minimum 4-feet wide) concrete box culverts will be installed (Clevenger and Waltho 1999). Figure 3 identifies the segment of road planned for perforation. Unless future observations provide cause for adjusting this strategy, one culvert will be placed in the middle of the area; one will be placed near the western edge and one near the eastern edge. The height of the box culverts should be designed such that there is open air space during periods of high water (e.g., spring flooding). In order to improve the efficacy of fish and wildlife use of these passages, it will be useful to establish shrub vegetation around the openings of the culverts. This will provide valuable cover for traveling animals.

Fig. 3. Aerial view of the segment planned for installation of box culverts and land conservation. The yellow points indicate the proposed locations for box culvert placement.

In order to ensure that these improvements for animal and fish passage are maximized, it is necessary to conserve an area of forested swamp and wet meadow habitat on the south side of Route 78. A conservation easement or fee acquisition of this habitat is a requirement of the permeability plan and settlement agreement.

Parallel crossing structures in the railroad bed will be necessary at Carmen's Marsh in order to ensure animal and fish passage through the box culverts. It is not certain whether a corresponding structure in the railroad bed will be necessary for each roadway box culvert of whether something less than that will suffice. This will be determined collaboratively between Vermont Agency of Transportation, Vermont Agency of Natural Resources, and other interested government agencies, as well as the railway company. Vegetation will be incorporated into the design of openings along the railroad bed, similar to that proposed for the roadway openings.

## Future Research and Monitoring

Given the unique nature of this project and considerable opportunities for learning the extent to which the road conditions and associated traffic are influencing wildlife movement, behavior, survival and mortality, research will examine the upgraded conditions. In particular, research efforts will focus on the efficacy of the overall permeability plan to understand the extent to which it has affected ecological connectivity, wildlife movement, mortality, and possibly population isolation. The University of Vermont or other appropriate academic institution will be employed to conduct this research in a rigorous fashion. The structures themselves will be monitored for no less than two years following construction to understand their functions and values for wildlife movement. This is another provision of the permeability and road upgrade plan. The collaborative process provided the opportunity to identify this as an important need for the success of the project and to secure a guarantee for research funding in the associated agreement.

## Conclusions and Recommendations

The habitat conditions and environmental circumstances associated with the Route 78 upgrade project are unique in several respects that influence conclusions. The fact that much of the project area is owned and controlled by the United States Fish and Wildlife Service as a National Wildlife Refuge had a significant influence on the outcome of this project design and permeability plan. Several conclusions arise from this preliminary phase of the project.

a. The primary area of wildlife movement across Route 78 is discrete and easily identified. Rather than studying the precise location of wildlife movement within this linkage habitat, and given the objective to restore ecological connectivity for the entire wetland system, a decision was made to raise the road above the entire area of linkage habitat. This was possible due to the dimensions of the linkage habitat. The area itself is rather narrow and made it possible to consider this option. This strategy reduced the time necessary to reach a conclusion on the design of the project by reducing the time necessary to identify the location of a more narrow crossing structure. To the extent similar linkage habitat conditions are found elsewhere, this may be an advisable approach.

b. Given the diverse system of habitats and the broad array of fish and wildlife species that required consideration for passage in this area, it was necessary to apply multiple strategies for establishing effective connectivity throughout the project area. This seems to be an important point in that many road permeability strategies focus on single species or single taxonomic groups. Taking an ecosystems approach towards road permeability may prove effective for this set of circumstances.

c. As part of the collaborative process that was used to address these and other project-related issues, a settlement agreement was established to memorialize the myriad mitigation and enhancement measures. The settlement agreement and associated permeability plan for the project includes a provision to fund research to understand the efficacy and affects of the permeability measures and future road conditions on wildlife and ecosystem functions. This is a critical component to any mitigation or enhancement plan since projects like this can yield a wealth of useful information and scientific knowledge to better understand what works for wildlife movement and what does not.

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## References

Carr, L.W. and L. Fahrig. 2000. Effect of road traffic on two amphibian species of differing vagility. Cons. Biol. 15(4):1071-1078.

Clevenger, A.P. and N. Waltho. 1999. Dry drainage culvert use and design considerations for small- and medium-sized mammal movement across a major transportation corridor. Pp. 263-277 In G.L. Evink, P. Garrett, and D. Zeigler (eds.) Proceedings of the Third International Conference on Wildlife Ecology and Transportation. FL-ER-73-99. Florida Department of Transportation, Tallahassee, Florida.

Clevenger, A.P. and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Cons. Biol. 14(1):47-56.

Clevenger, A.P., J. Wierzchowski, B. Chruszcz, K. Gunson. 2000. GIS-generated, expert-based models for identifying wildlife habitat linkages and planning mitigation passages. *Cons. Biol.* 16(2):503-514.

Fahrig. L and G. Merriam. 1985. Habitat patch connectivity and population survival. *Ecology* 66(6):1762-1768.

Hammond, F. 2002. The effects of resort and residential development on Black bears in Vermont. Stratton Mountain Black Bear Study. Final Report. Vermont Agency of Natural Resources, Department of Fish and Wildlife.

Jackson, S.D. and C.R. Griffin. 2000. A strategy for mitigating highway impacts on wildlife. Pp. 143-159. In Messmer, T.A. and B. West (eds.) Wildlife and Highways: Seeking Solutions to an Ecological and Socio-economic Dilemma. The Wildlife Society.

Jackson, S.D. 2000. Overview of transportation impacts on wildlife movement and populations. Pp. 7-20. In Messmer, T.A. and B. West (eds.) *Wildlife and Highways: Seeking Solutions to an Ecological and Socio-economic Dilemma.* The Wildlife Society.

Jackson, S.D., 1996. Underpass systems for amphibians. In G.L. Evink, P. Garrett, D. Zeigler and J. Berry (eds.) *Trends in Addressing Transportation Related Wildlife Mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar.* Florida Department of Transportation, FL-ER-58-96. Tallahassee, Florida.

Ruediger, B. 2001. High, wide and handsome: Designing more effective wildlife and fish crossing structures for roads and highways. A Time for Action. *International Conference on Ecology and Transportation. 2001 Proceedings.* Pp.509-516.

Singleton, P.H., W. Gaines, and J.F. Lehmkuhl. 2001. Using weighted distance and least-cost corridor analysis to evaluate regional-scale large carnivore habitat connectivity in Washington. A Time for Action. International Conference on Ecology and Transportation. *2001 Proceedings.* Pp. 583-594.

Trombulak, S.C. and C.A. Frissell. 2000. Review of Ecological effects of roads on terrestrial and aquatic communities. *Cons. Biol.* 14(1):18-30.

Wagner, P., M. Carey, and J. Lehmkuhl. 1998. Assessing habitat connectivity through transportation corridors on a broad scale: an interagency approach. Pp. 66-67 In G.L. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.) *Proceedings of the International Conference on Wildlife Ecology and Transportation.* FL-ER-69-98. Florida Department of Transportation, Tallahassee, Florida.

# VERMONT AGENCY OF TRANSPORTATION WILDLIFE CROSSING TEAM; BUILDING AN INTER-AGENCY PLANNING TOOL TO ADDRESS ECOLOGICAL CONNECTIVITY IN VERMONT

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**Abstract:** Wildlife movement and related road crossing strategies are becoming an increasingly important factor in the development of transportation projects in Vermont – whether these projects involve reconstruction on existing alignment or new construction. The Vermont Agency of Transportation (VTrans) and the Vermont Department of Fish and Wildlife (VDFW) have identified wildlife movement and habitat connectivity as important factors to consider in the transportation project development process from three perspectives: human safety, environmental stewardship, and fiscal responsibility. Moreover, we have begun to construct wildlife crossing structures, in collaboration with VDFW, in some recent transportation projects. Unfortunately, there is a lack of wildlife road crossing data to support the inclusion, location, design, and construction of these crossings in many parts of the state. Currently, much of the information that is used in the design and location of wildlife crossing structures is from an existing database of road crossing and road mortality information for white-tailed deer, moose and black bear that is maintained by the VDFW. To assist in making, and implementing, these sometimes very expensive project decisions, VTrans desires to have a resource review team to gather wildlife movement, habitat and road mortality data relevant to specific projects.

VTrans, in collaboration with VDFW, Keeping Track, Inc., and Jim Andrews of Middlebury College, has developed an inter-agency Wildlife Crossing Team. The primary objective of this initiative is to develop a data gathering protocol to assess habitat fragmented or otherwise affected by Vermont roads, and to train a group of VTrans staff to utilize that protocol as a project planning tool. The goal of this effort is to gather sufficient data regarding wildlife movement and habitat conditions, in the early stages of the transportation project development process, to make substantive recommendations, in conjunction with VDFW, to project managers and designers so that wildlife movement and ecological connectivity can be considered in the design and construction of appropriate VTrans projects. Through this process wildlife movement and habitat connectivity can become an integral part of the environmental review process at VTrans – similar to how historic, archaeological, and other natural resources are considered. It is hoped that this effort will take wildlife movement and habitat connectivity beyond an issue of compliance and become a more standard consideration for transportation projects in Vermont where appropriate. This paper will discuss the development of this inter-agency wildlife crossing team.

## Introduction

Local Vermont wisdom tells us to look for the skid marks on the pavement to identify where the moose are crossing the roads. To some extent this methodology may actually have some merit; nevertheless, VTrans wanted to develop a more scientific and systematic approach to locating wildlife crossings. To that end, VTrans, in collaboration with the VDFW, the nationally-recognized Keeping Track Inc., and Middlebury College research herpetologist Jim Andrews has developed an inter-agency Wildlife Crossing Team. Importantly, the VDFW has collected road crossing and mortality data for white-tailed deer, moose and black bear for nearly 20 years. This information, though insufficient in and of itself, will be used to help direct the efforts of this initiative.

### VTrans' Approach

VTrans recognizes habitat connectivity as an important consideration in the development of transportation infrastructure. To date, VTrans has demonstrated this effort in a number of ways. VTrans Director of Program Development, David J. Scott, P. E., has been an active participant in Federal Highway Administration's (FHWA) explorations into the issues of ecological connectivity. He participated in the 2001 FHWA European Scan Tour, the Western Institute wildlife crossing Workshop in Banff in 2002, as well as the ongoing FHWA effort to develop a best practices manual for transportation agencies. As a primary decision maker within VTrans, Director Scott has identified habitat connectivity as an important agenda item for our agency, from a safety as well as stewardship perspective. Ultimately, efforts to consider wildlife crossings and habitat connectivity within the context of VTrans projects and programs is in keeping with our Agency's mission statement as it directs us "to maintain a transportation system that allows for the safe movement of people and goods in a cost-effective, environmentally sensitive and timely manner." The development of this Wildlife Crossing Team is occurring in an institutional climate that supports innovative initiatives and projects, some of which are described below.

Specifically, VTrans and VDFW have undertaken a number of efforts to reconnect, and/or enhance some areas of habitat affected by roads in Vermont. In 1993, as part of the construction of Vermont State Highway 289, also known as the Chittenden County Circumferential Highway, a divided concrete underpass was installed under the roadway to accommodate stream passage on one side and wildlife movement on the other. For a number of reasons, outlined in Wildlife Biologist John Austin's 2001 ICOET paper and presentation, this structure is, at best, a very limited success (Austin and Garland 2001). In addition to design and substrate concerns, the location of this structure is not ideal. Suburban sprawl development has encroached around the habitat that this structure was designed to connect. The placement of this structure was one of the motivating factors in developing the Wildlife Crossing Team. In the future, early evaluation of a potential location for a wildlife crossing structure should identify potential problems such as those at the VT 298 location. Additionally, this type of evaluation can be considered within the context of other potential locations so that wildlife road crossing sites can be prioritized.

In 2003 during the construction of the Vermont State Highway 279, also known as the Bennington Bypass, two bridges were extended well beyond the banks of the watercourses that they span in order to accommodate the movement of wildlife. Other wildlife crossing structures are planned for future segments of the Bennington Bypass. These wildlife corridors were identified by the VDFW who worked cooperatively with VTrans roadway designers and engineers to develop the final bridge designs.

VTrans has committed in concept, after much negotiation and collaboration with the VDFW and other State and Federal regulatory agencies, to the implementation of a permeability plan for the reconstruction of Vermont Route 78 in northwestern Vermont. This road bisects the Missisquoi National Wildlife Refuge. The permeability plan includes a 500-foot bridge that will allow for the movement of wildlife and restore ecological connectivity in an area identified as a significant and unique wildlife linkage area. Road alignment will be shifted away from the Missisquoi River in order to re-establish riparian habitat. Multiple large box culverts will allow for the passage of wetland-dependant furbearers, waterfowl, fish species and other aquatic organisms through deep rush marsh habitat. Finally, new openings in an adjacent railroad bed will be constructed to perforate that parallel wildlife barrier.

VTrans has also undertaken other habitat stewardship initiatives that are much less expensive than those described above. For instance, in 2002 and 2003 the VTrans Environmental Section, in collaboration with VDFW, has been experimenting with recycling of construction silt fencing as a temporary barrier to keep amphibians off of an extremely busy section of roadway that bisects the Sandbar Wildlife Management Area at Lake Champlain in northwestern Vermont. This initiative has reduced amphibian road mortality by more than 60 percent in the fenced sections.

**Wildlife Crossing Team**

During 2002 and 2003, VTrans earmarked some of Vermont's Federal planning (STP) and research (SPR) funds from the FHWA for the development and training of an inter-agency Wildlife Crossing Team. The team comprising of planners, designers, engineers, biologists, and environmental specialists, has been trained to identify the presence of wildlife and habitat along roads in Vermont where roadway improvements are scheduled or new roadways are planned. The Wildlife Crossing Team consists of 15 VTrans employees from diverse sections of the Agency and a rotation of several VDFW biologists who act as technical advisors. All members of the team went through a specifically designed training program that consisted of 10 sessions (8 field and 2 classroom) over the course of eight months. The design and implementation of the training was a true collaboration that involved VDFW, Keeping Track, Inc., and Jim Andrews from Middlebury College. The field trainings exposed the team to a diversity of landscape and habitat conditions for many taxa and species of wildlife. It focused on habitat conditions associated with roads as well as those not directly associated with roads.

A primary objective of this effort is to address public safety concerns related to animal/vehicle collisions. Wildlife/vehicle collisions in Vermont are frequent in certain parts of the state, and are most noticeable for deer, bear and moose since these species tend to cause the greatest damage and threat to property and lives of the traveling public. According to VDFW, there have been over 64 moose killed on Vermont highways since January 1, 2003. This number may actually be 25 percent higher than what has already been reported because of recording and reporting delays. One of those collisions resulted in a human fatality. The annual number of collisions with white tailed-deer in Vermont is approximately 4,000.

In addition to safety, one of the motivating factors for the development of this team is environmental stewardship. According to the EPA, between 1982 and 1992 development in the State of Vermont consumed 6,500 acres each year of undeveloped land. That number was expected to increase at the time that information was reported. Vermont is experiencing significant development pressure, including sprawl development, at a rate of 2.5 times the rate of population growth. In addition, according to the Vermont Agency of Natural Resources, approximately 20 acres of wetlands are lost annually on top of a loss of at least 35 percent since European settlement. Other examples of the loss of significant wildlife habitat to development includes deer winter habitat, black bear feeding habitat, and the habitat for threatened and endangered species. Loss of important natural resources such as these is a concern for the long-term conservation of fish and wildlife in Vermont. Unrestricted loss of habitat and its attendant affects on the ability of some species of wildlife to survive affects the long-term viability of populations for some species that can result in extirpation or extinction.

Federal and State regulations and associated permits exist to insure that the impacts from transportation development do not unduly impact natural resources, among others. Compliance with permits is essential to achieve related conservation goals and public interests. However, compliance essentially means no net loss of resources, and in some instances that may be insufficient. Through this initiative the Wildlife Crossing Team is addressing ecological connectivity in situations where State or Federally listed threatened and endangered species and other regulated habitats are not involved, resulting in proactive conservation stewardship.

**Vermont Department of Fish and Wildlife**

The Vermont Department of Fish and Wildlife also holds the opinion and perspective that it is extremely important to address wildlife movement and ecological connectivity associated with transportation in Vermont. These issues have increasingly become an important component of VDFW's conservation responsibilities and efforts. Since 1990, VDFW has worked to incorporate wildlife movement considerations into Vermont transportation projects as evidenced by the circumferential highway underpass and research, the Bennington Bypass, and most recently the Vermont Route 78 project. Conservation planning at a variety of scales, including transportation planning, is becoming more crucial for state agencies to consider due to development pressures and their attendant effects on wildlife. As a result, the VDFW considers collaboration with VTrans as absolutely essential to properly address wildlife conservation and related public interests as well as public safety.

Similar to VTrans, VDFW has demonstrated a commitment to these issues as evidenced by their regular attendance and participation in many ICOET conferences. A VDFW wildlife biologist participated in the Western Institute Wildlife Crossing Workshop in Alberta, Canada in 2002. In addition, VDFW has offered a strong voice of support to Vermont's U.S. Senators for the reauthorization of the Federal Transportation Bill as it relates to wildlife conservation efforts in Vermont.

Wildlife biologists from VDFW collaborated in the development of this initiative and performed some of the training for the Wildlife Crossing Team. VDFW has served as a technical advisor in the development of this initiative and has performed much of the training in how to examine wildlife and habitat conditions in the context of roads in Vermont.

VDFW has worked to foster a strong collaborative relationship with VTrans through this effort and is an active part of the Wildlife Crossing Team. Data collected by the Wildlife Crossing Team will be reviewed and approved by experts from the VDFW. As such, the work will continue to be collaborative in nature, and have the scientific credibility of VDFW's review and approval. Representatives from VDFW serve as members of an inter-agency steering committee to direct this and other initiatives related to transportation and wildlife in Vermont.

**Keeping Track, Inc.**

VTrans established a contract with Keeping Track, Inc., a nationally recognized non-profit organization that trains groups in habitat monitoring and wildlife tracking. Keeping Track's monitoring and education programs focus on mammalian species in the following categories: area-sensitive carnivores, threatened and endangered carnivores, keystone species, and species with rapidly shifting populations. Their focus on these generally wide-ranging mammals provides a vital indicator of the ecological health of the landscape as a whole. In a series of meetings the Wildlife Crossing Team, working closely with Keeping Track staff, used the well-established Keeping Track data collection protocol to develop a transportation and wildlife data collection protocol that accounts for the unique environmental context of the state's transportation infrastructure.

**Herpetological Concerns**

From the start, it was recognized that an important consideration for the Wildlife Crossing Team should be reptiles and amphibians. To that end, research herpetologist Jim Andrews was hired to assist in the development and training of the Wildlife Crossing Team. Reptiles and amphibians are important populations to consider for a number of reasons, seven of which follow. First, there is a very large and growing body of literature that documents the impacts of roads/traffic on herptile populations. Second, the limited range and multiple habitat requirements of herptiles make them particularly susceptible to habitat consumption, fragmentation, degradation, and direct mortality from vehicles. Third, annual movements to and from breeding, foraging, and over-wintering and denning areas, often require movements across roads. Fourth, local herptile population declines and extirpations as a result of drought, winterkill, other weather anomalies, disease, and anthropogenic disturbances require re-colonization movements which often times take the animals across roadways. Fifth, compared to many game and fur-bearing species, the small size of herptiles makes them difficult to see and avoid on the road surfaces. Four-toed salamanders, for example, are essentially invisible to motorists. Even larger reptiles such as ratsnakes and wood turtles are rarely seen and if seen, rarely avoided. Moreover, the relatively low speed of herptiles makes them particularly susceptible to road mortality. Sixth, the long lives and low productivity of many reptiles make them particularly sensitive to road mortality. And finally, road surfaces, because of their warmth, actually attract and hold some species, thus increasing the likelihood of mortality.

The data collection methodology imparted to the group by Jim Andrews included training in the techniques of night-time road searches (calling of frogs and crossing of amphibians) to be performed twice per month on a site, April through July, to determine significant use areas for all herps; and day-time road searches in September and October to determine snake crossing and basking areas. Mr. Andrews trained the group in identification techniques for herptiles and their egg masses as well as frog calls and choruses. Within selected project areas, efforts to increase permeability will be concentrated on road sections that have rare, threatened, or endangered species crossing; and sections of road where there are concentrations of more common species.

**Goals of Inter-Agency Wildlife Crossing Team**

One of the primary goals of this effort was to develop a data collection methodology that this team can implement on tranportation projects in Vermont. This initial goal was met. A data collection protocol was established, and a team was organized and trained. The team will collect long-term data on habitat and wildlife movement associated with transportation project areas throughout the state.

An interagency steering committee was established to oversee and administer this effort and related wildlife and transportation initiatives. This steering committee will select appropriate projects for the Wildlife Crossing Team to survey, review the team's data collection, make recommendations for treatments as a result of the data gathering, and integrate wildlife crossing, transportation, and ecological connectivity issues. This is a unique strategy for fostering a strong inter-agency relationship. It allows both parties to collaborate on important projects and make decisions with the benefit of multiple perspectives and expertise.

An additional goal that was realized during the development and training of the Wildlife Crossing Team was improved interagency coordination on transportation planning and environmental regulation as it relates to wildlife conservation through collaboration, education, and information. We have collectively accomplished this, and are continuing to move forward with other inter-related initiatives. Collectively, VTrans and VDFW have gained a greater sense of understanding and appreciation for the responsibilities of each respective organization, what each organization does and why they do it.

## Conclusions and Future

Ultimately, we accomplished what we set out to do. Collectively, we developed a new survey and data collection technique based, in part, on the Keeping Track model of habitat monitoring.

Since the conclusion of this training, the steering committee has deployed the group to survey several sites around Vermont. In particular, the group will investigate cattle crossings installed on Interstates 91 and 89 that are no longer being used for agricultural purposes. The question we intend to answer is whether wildlife use these passages. Information from this effort will be used to decide whether to investigate these structures further for their value in connecting habitat and reducing wildlife road mortality and vehicle collisions. Additionally, areas along the spine of the Green Mountains associated with major road barriers will be investigated to identify or confirm linkage areas for wildlife. These areas may be identified as priority candidates for wildlife crossing structure investments.

Another important and related initiative involves the development by VDFW of a statewide GIS database for wildlife road crossing, habitat and transportation planning. VTrans is funding a grant proposal by VDFW to complete the development of this statewide GIS database of wildlife habitat, road crossing, road mortality, and transportation information. This database will be utilized in conjunction with landscape data to perform a statewide linkage area analysis. Significant linkage areas associated with highways and town roads will be identified. Moreover, VTrans is currently proposing to utilize STP and SPR funding to develop a pilot project to investigate aquatic organism passage through State-maintained large culverts. As other states have done, VTrans and VDFW hope to become leaders in performing environmental and transportation planning in a way that is pragmatic, cooperative, and effective. VTrans and VDFW firmly believe, based on our recent collaborative efforts, that through cooperation, we stand to accomplish a great deal more for all the interests we are responsible for, i.e., Vermont's environment, wildlife safety, human safety, fiscally responsible infrastructure decisions. Ultimately, all of this work will allow VTrans and VDFW to make better and more informed decisions and investments in roadway permeability.

**Biographical Sketches**: Chris Slesar is an environmental specialist at the Vermont Agency of Transportation. He has an M.A. in Environmental Studies from Antioch University Seattle.

Jim Andrews is a research herpetologist at Middlebury College. He serves as chair of the Vermont Reptile and Amphibian Scientific Advisory Group, and is coordinator of the Vermont Reptile and Amphibian Atlas.

John Austin is a senior wildlife biologist with the Vermont Dept. of Fish and Wildlife. John is responsible for administering the department's Habitat Assessment Project, which deals with inter-agency coordination and impacts to wildlife and habitat from development.

Susan C. Morse has studied carnivores and their uses of habitat in the northern forest, southwest, and Rocky Mountains for more than 30 years. Her focus has been on wild felids and black bear. She founded Keeping Track, Inc., in 1994, and today serves as the organization's research and program director.