Title

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Publication Date
2007-05-20

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Abstract: Roadways affect wildlife habitat disproportionate to the area of land they occupy while impacting wildlife directly through direct loss of habitat, road mortality and disruption of movement. Roadways indirectly impact wildlife by isolating populations and disrupting gene flow and metapopulation dynamics. A variety of strategies have been used with mixed success to mitigate the impacts of transportation systems on wildlife. Underpasses are commonly used to facilitate movement of wildlife across roadways in Europe, Australia, Canada and the U.S.

Through 2005, 460 terrestrial and 300 aquatic crossing structures have been identified throughout the United States but only a small portion of these crossings have monitoring incorporated into their project design. Most monitoring is limited to usage of the passage structures with little data collected on movement through the adjacent landscape. Monitoring of the passage structures helps determine wildlife use of the structures but is limited in the ability to determine landscape level impacts.

A variety of techniques are utilized in monitoring passageway effectiveness, primarily camera traps and track beds. Building on prior studies, the Bennington Bypass project takes a broad, multi – taxa approach to monitoring crossing structures on a newly constructed highway in southern Vermont. We are utilizing a variety of techniques to assess movements of an array of species at the passage structure and in the surrounding landscape.

Techniques utilized in our study include: small mammal trapping, track beds/plates, remote camera sensing, snowtracking, road kill surveys, roadside track beds, amphibian recording devices, snake pit tagging and observational studies. We are also using this broad approach to monitoring as an opportunity to test and refine many of the techniques used in the study. By monitoring a wide variety of animal movements rather than focusing exclusively on wildlife use of the passages, we expect to more accurately assess the effectiveness of the mitigation structures. We anticipate that the results from this work will assist in developing monitoring protocols for future studies in Vermont and throughout the United States.

Introduction

As long linear features on the landscape, roads and highways (roadways) impact wildlife and wildlife habitats over areas that are disproportionate to the land they occupy. Roadways affect wildlife through direct loss and fragmentation of habitats, as a source of additive mortality for wildlife and by disrupting animal movements. Through isolation of wildlife populations, roadways can also disrupt gene flow and metapopulation dynamics (Andrews, 1990; Bennett, 1991; De Santo and Smith, 1993; Jackson, 1999; Trombulak and Frissell, 2000).

Road kill is the leading direct human cause of vertebrate mortality; approximately one million vertebrates are killed daily on roads in the United States (Forman and Alexander 1998). In addition to direct mortality of wildlife, road kill is also a significant human safety issue. Wildlife/vehicle collisions can result in large amounts of vehicular damage leading to potential injury or fatalities.

A variety of strategies have been used with mixed success to mitigate the impacts of transportation systems on wildlife (Jackson and Griffin, 1998; Jackson, 1999). Underpasses are commonly used to facilitate movement of wildlife across roadways in Europe, Australia, Canada and the U.S. However, the effectiveness of these underpasses to facilitate wildlife movement depends on a number of variables, including: size, proximity to natural wildlife corridors, noise levels, substrate, vegetative cover, moisture, temperature, light, and human disturbance. For example, cover can play a key role in passageway effectiveness for small mammals. The installation of gutters in culverts significantly increased small mammal movement (Foresman 2001). Similarly, van der Linden (1987) reported that stump rows facilitated small mammal movements through underpasses. Different species have different requirements. Thus if passage systems are designed for use by a singles species they may act as barriers for other species with different requirements.

A 2005 review found 460 terrestrial crossing structures in the United States (Cramer and Bissonette 2005). Only a limited number of these structures have been monitored for effectiveness. Those that have been monitored generally focus on whether animals are using the structures. They employ methods like tracking beds, cameras and counters. These methods provide little information on those species or individuals that fail to use a structure.

A sampling of 21 studies reveals that on average 4 species are monitored per study, with larger carnivores (e.g. - bear, bobcat, coyote) and ungulates the taxa groups most frequently targeted. Some studies focus on a single species (Kaye et al. 2005, Gordon and Anderson 2003) but most studies record general use of the structures.

Radio-tracking, mark-recapture trapping and tracking studies are more useful for determining the extent roadways inhibit wildlife movements and the degree to which passage structures mitigate these effects. Thus, to fully assess the effectiveness of wildlife passageways, a combination of monitoring techniques are needed to evaluate structure use and the extent to which transportation systems affect animal movements at the landscape scale (Jackson, 1999).

To evaluate the effectiveness of wildlife passage structures it is important to have an idea of how much wildlife passage is enough to determine that a particular project is a success. Wildlife use of passage structures has to be assessed relative to some baseline level of passage determined either by 1) data on pre-construction wildlife movements in the area or b) an evaluation of the extent to which the highway (including passage structures) inhibits wildlife movement through the area. Thus, unless good pre-construction data on wildlife movement are available, post-construction monitoring strategies need to evaluation passage use as well as other wildlife movements that indicate the degree to which wildlife are failing to use the passage structures.

Wildlife crossings have evolved considerably since the first documented structure was completed in Florida in 1950. Florida continues to be a leader in the area of highway mitigations along with other states such as Arizona, Montana and Vermont. Through cooperative efforts of the Agency of Transportation and Department of Fish and Wildlife, Vermont has constructed nine crossings along with the scheduling of a half dozen more over the next 5 years (Cramer and Bissonette 2005). A focal project for the state of Vermont is the Bennington Bypass which has incorporated three wildlife crossing structures into its construction.

Study Area

The Bennington Bypass (Hwy. 279) is a 7km long highway connecting NY Rte. 7 in Hoosick Falls, NY to VT Rte. 7 in Bennington, VT. It is a two lane highway with several three lane areas designed as passing zones. Highway 279 is the first part of a three phase highway project which will circumvent downtown Bennington. This western phase of the highway opened in October 2004 and includes three wildlife passage structures, including two extended bridges and a large culvert.

Both bridges were constructed as overpasses over two streams, East Airport Brook (EAB) and West Airport Brook (WAB). The two streams are separated by .9km and both occur in the eastern half of the 7km long bypass. They both flow south to north into the Walloomsac River. East Airport Brook is a 2m-wide intermittent stream, whereas the similar-sized West Airport Brook is perennial. The brooks within both passageways run off center, closer to the western edges of the openings.

The extended bridge over the EAB is 43.3m long, 8m wide and 18m above the terrain directly below it. The bridge over WAB is 56.55m long, 8m wide and 12.17m above the terrain directly below it. The length and height of the bridge creates a relatively large passageway underneath the highway. The drainage culvert (passageway) is located approximately 200m west of West Airport Brook. The 1.65m wide, 124m long culvert connects two retention ponds located to either side of the highway.

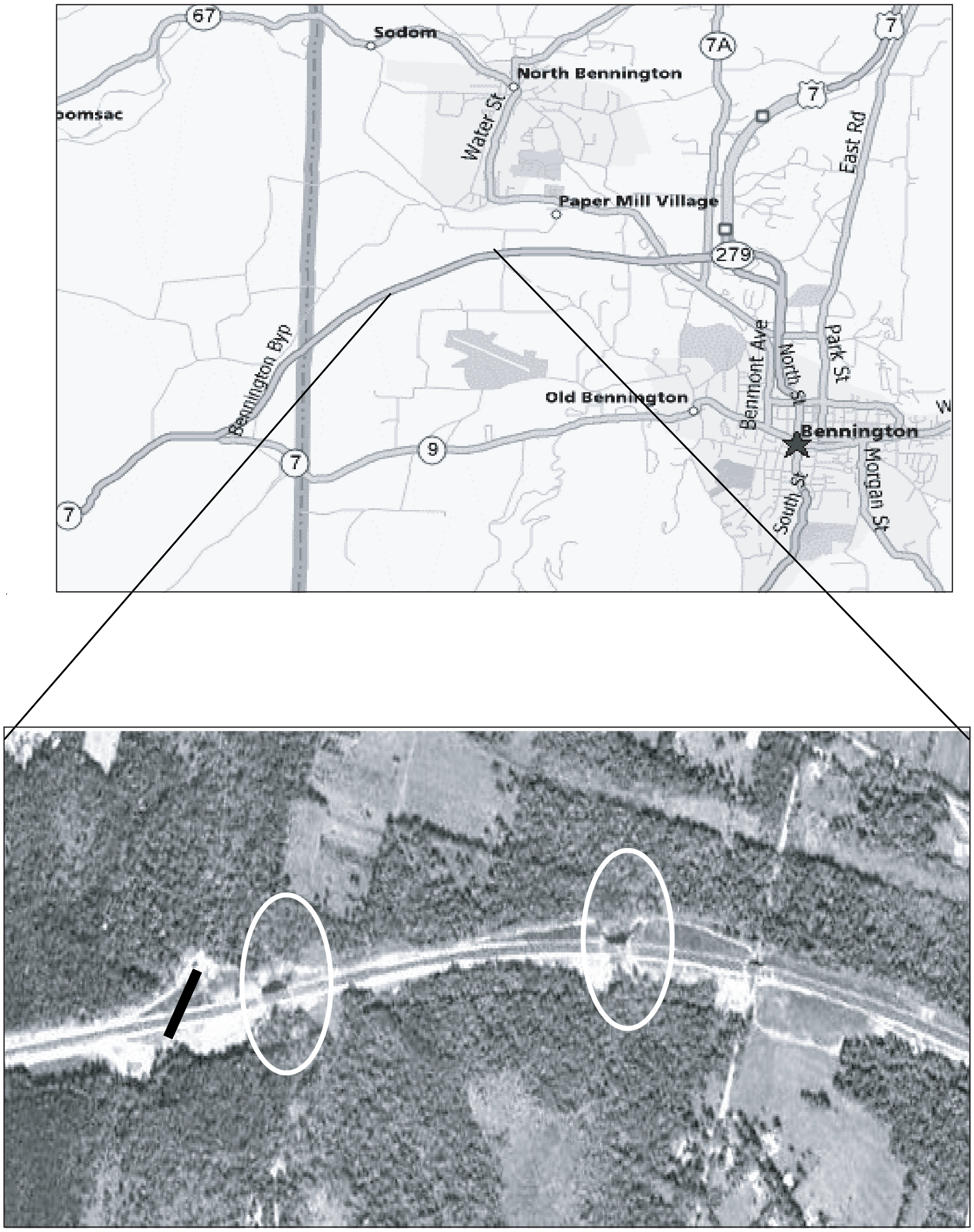

Figure 1. Location of 7 km long Highway 279 and primary study area with locations of passage structures (white circles) and drainage culvert (black line to west of structures). Passage structures are .9 km apart.

The vegetative community adjacent to the bypass is a Northern hardwoods broad leaf complex dominated by American Beech (*Fagus grandfolia*), Maple (*Acer* spp.) and Eastern hemlock (*Tsuga canadensis*). Much of the under story is dominated by Canada honeysuckle (*Lonicera Canadensis*). A 15m right of way, buffering the road from the forest, occurs along both sides of the roadway.

Objectives

Continuous, long term monitoring of wildlife crossing structures are key components to assessing the true conservation value of mitigation passages for wildlife (Clevenger and Waltho 2003). Due to budgetary and logistical constraints, long term monitoring of passage structures is often implausible. Clevenger and Waltho (2003) evaluated 18 studies over the past 30 years, and revealed that the average monitoring period for those studies was 17.3 months. With a limited temporal scope to evaluate effectiveness, we felt it important to design a study that took a broad, multi-taxa approach to monitoring.

The objectives of the Bennington Bypass project are:

1. Evaluate the effectiveness of wildlife passageways for mitigating the impacts of the Bennington Bypass on wildlife
2. Test and refine monitoring techniques for evaluating wildlife use/avoidance of passageway structures.
3. Develop monitoring protocols for assessing the impacts of roads on wildlife for integration into future highway projects in Vermont and throughout the United States.

This study is monitoring the effectiveness of these passageways and comparing rates of wildlife movement across the highway in mitigated and unmitigated sections. We are also evaluating various techniques for monitoring wildlife use that may be used in future highway projects such as the proposed Route 78 project in northern Vermont. This project is part of a cooperative, phased research program by Vermont's Agencies of Transportation and Natural Resources (Department of Fish and Wildlife) to evaluate and mitigate the impacts of roads on wildlife.

Conceptual Model

A variety of techniques have been utilized in assessing wildlife passageway effectiveness. A sampling of passageway studies revealed that the most prevalent techniques used are remote camera sensing and track beds (Gordon and Anderson 2003, Servheen et al. 2003, Reed et al. 1982, Brudin 2003, Veenbas and Brandjes 1999, Foresman 2003, Krawcheck et al. 2005, Mata et al. 2005, Land and Lotz 1996, Yanes et al 1995, Mansergh and Scotts 1989, Clevenger and Waltho 2005 and Norman et al. 1998). In many studies cameras are used in conjunction with track beds to verify crossing occurrences. These techniques primarily provide information on the wildlife use of the structures. The most comprehensive study discovered in our sampling was a project in Victoria, Australia by Abson and Lawrence (2003), which incorporated 14 techniques to evaluate passage use by mammals, reptiles, amphibians and birds.

This project seeks to incorporate a multi-taxa approach by also monitoring impacts on taxa including carnivores, mesopredators, small mammals and amphibians. In order to illustrate the potential movements of animals relative to a highway and crossing structure, we developed a conceptual model (fig. 2) with accompanying techniques matrix (table 1) that may be helpful in deciding appropriate methods for monitoring those movements.

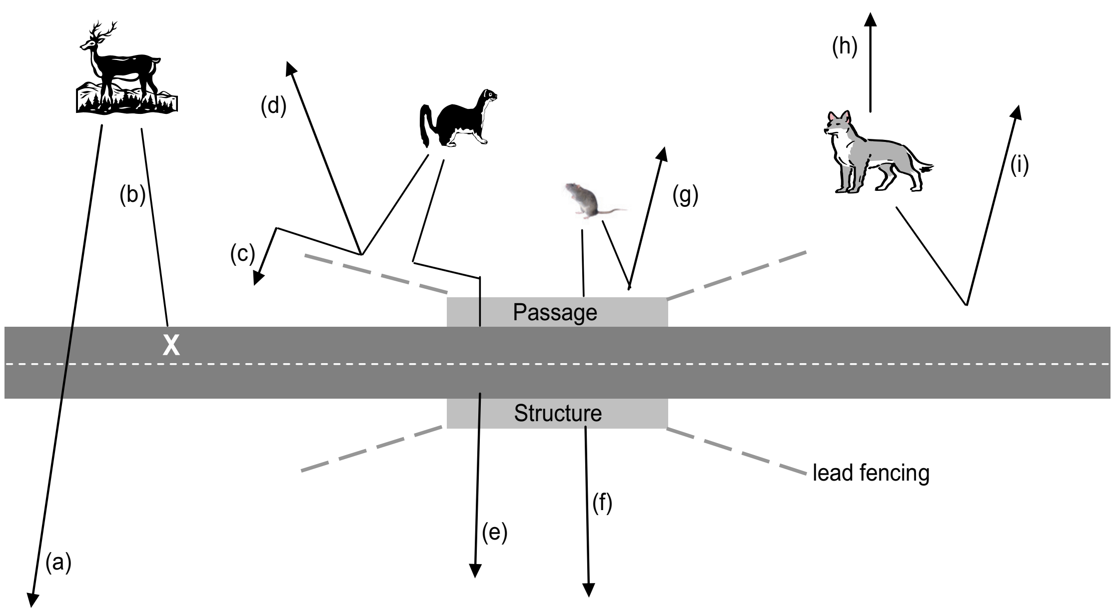

Figure 2. Potential wildlife movement relative to roadway and passage structure. (a) move successfully across the roadway, (b) vehicle collision, (c) approach lead fencing, moving away from passageway around lead fencing, (d) approach lead fencing and move away from roadway, (e) approach lead fencing and move successfully through passageway, (f) move through passageway unabated, (g) approach and avoid passageway (h) avoid roadway and (i) approach and avoid roadway.

Table 1: Techniques matrix – monitoring technique and movement monitored (see figure 2)

Method	Taxa group	Movement monitored
Small mammal mark/recapture	Small mammals	a, e, f
Snowtracking	Medium and large mammals	a, b, c, d, e, f, g, i
Track beds/plates	All	e, f
Remote cameras	Medium & large mammals	a, c, e, f
Roadside track beds	Medium & large mammals	a, b, i
Road kill surveys	All	b
Amphibian recording devices	Frogs and toads	n/a

Study Design

Understanding movement patterns relative to the roadway and passage structures are important elements in gaining a better understanding of effectiveness of mitigation strategies. By incorporating a variety of monitoring techniques the ability to evaluate effectiveness may be improved. The Bennington Bypass study incorporated an array of monitoring techniques in an attempt to understand movement patterns listed in figure 2. In some cases a single technique is used while in other cases a combination of techniques is used to quantify a single movement pattern. We here summarize the key findings for each technique.

Small Mammal Movements

Small mammals play pivotal roles in ecosystem processes as prey for reptilian, avian and mammalian predators and as consumers of invertebrates and plants (including seeds and fruits). Small mammals disperse many plant species and consume some invertebrates that have potential to alter ecosystems (Carey and Johnson 1995). Roads inhibit the movement of small mammals (Oxley et al. 1974), which may lead to local extinctions, social disturbance and morphological divergence (Dickman and Doncaster 1987). We are using a mark/recapture study to assess the degree to which movements are affected by the roadway and enhanced by the passageways.

Sampling Procedures. We captured small mammals and ear-tagged them to assess movement patterns in areas adjacent to the roadway and passageway structures. We placed Sherman live traps (n = 276) at 25m intervals along eight 500m long transects spaced 50m apart, starting 50m from the roadway (fig. 1). In front of the two passageways (~35m), we spaced traps 10m apart to better detect small mammal movements associated with the passageways.

Traps are baited with peanut butter and placed at habitat features (i.e. logs, trees, burrows) within 1m of each trapping point in the late afternoon. Once trapping begins, each trap is checked daily (mornings). Captured animals are identified, weighed, sexed and aged. Animals are marked with metal ear tags, and released where captured. We considered the area along the transects, 125m to either side of the center of each passageway as the treatment areas, the area most likely affected by the passageway structures. We considered the 250m portion of the transects located on the western edge of the survey area as the control areas, least affected by the passageways.

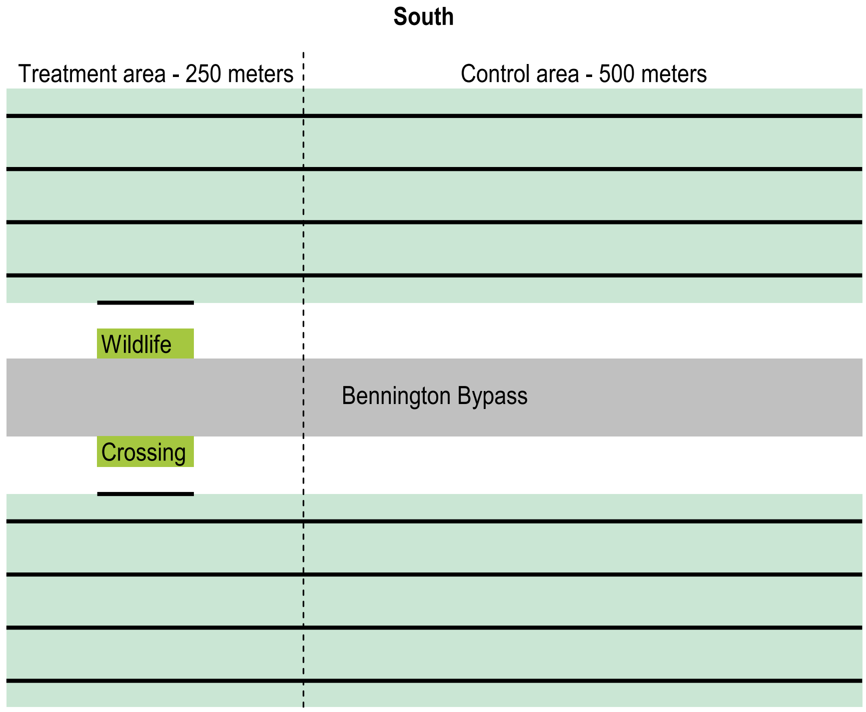

Figure 3. Small mammal trapping grid. 1) Large shaded area depicts forest, 2) black lines = transects. Traps are spaced 25m apart except in along short transects at forest edge aligned with passageways where they are spaced 10m apart.

High disturbance rates from squirrels and raccoons in year 1 required us to change trapping protocol from 5 night sessions conducted once a month to 2 night sessions conducted weekly. This shorter, but more frequent method of trapping allowed for more flexibility around rainy weather and also decreased disturbance rates. We achieved our objective of obtaining an 80% recapture rate by the end of the field season.

Key Finding

- More frequent, shorter duration trapping periods appear to be an efficient method in areas of frequent precipitation or high disturbance

Analysis. Using the recapture data, we calculated the distances between recapture locations to determine travel distance probabilities. These probabilities will be used to determine if small mammals are crossing the passageways in similar proportions to their average movements in the natural habitat. Preliminary analysis suggests that the passageways appear to be mitigating the effects of the highway

Future modification. In order to determine whether additional cover will increase passage usage, we plan on building a wall of tree-stumps as suggested by van der Linden (1994).

Monitoring of Mitigation Structures

Monitoring animal movement within the passageways is important in determining whether the structures are functional. We are using track beds/plates and remote cameras to obtain information for large and medium sized mammals including: deer, moose, bear, bobcat, fox, coyote, otter, raccoon, opossum, skunk, long tailed weasels, ermine, fisher, woodchuck and mink. Both passageways and one large culvert passage structure are being monitored.

1. Track beds

Sampling procedures. Track beds are located in the middle of the underpasses and track plates at both ends of the culvert. Various track bed methods were experimented with during the first year of our study. Two methods utilizing play sand were utilized: 1) sand laid atop tarp material 1m wide along the entire width of the passageways and 2) sand laid directly on top of existing substrate. Our pilot study revealed that the optimal method was to lay the sand on bare ground after grass, rocks and roots have been removed.

A second group of methods utilizing marble dust was also utilized. Marble dust is a fine powder that allows for the finest resolution of footprints. Three marble dust methods were experimented with: 1) sift the marble dust onto tarp material, 2) sift the dust onto natural substrate and 3) sift the dust onto 4' X 4' squares of plywood. We concluded overall that the optimal method was the sifting of the dust onto plywood. The hard foundation allowed for more reliable tracks, required less dust and issues of vegetation growth and uneven surface were alleviated.

We monitor the track beds at least three times a week to document those species using the passageways. We record species (or at a minimum, family), direction of travel, time and weather variables. The beds are reset as necessary. These data will be collected for all three years of the study because some species may not immediately habituate to mitigation structures (Clevenger and Waltho 2000).

Key finding.

- Marble dust placed atop plywood serves as the preferred tracking substrate for our study but issues of color contrast may need to be addressed.

2. Track plates

Sampling procedures. We utilize sooted track plates to monitor the culvert passageway. The track plates consist of 3' X 3' sheets of metal, sooted with an acetylene torch. A strip of contact paper is placed in the middle of the metal sheets in order to record the soot laden footprints of animals walking over the plate. One plate is placed on each end of the culvert in order to verify crossings. The plates are checked 2-3 times a week and species, date and direction are recorded.

Key findings.

- Sooted track plates provide higher resolution of animal tracks than any of our track bed methods but are difficult to implement on larger scales, such as spanning our 43 or 56 meter passageways.
- Structures that may seem unsuitable for wildlife movement (such as long, narrow culverts with no natural substrate) serve as passage for animals that may be reluctant to use larger structures.

3. Remote cameras

Sampling procedures. A single 35mm camera is rotated bi-weekly among the four sections (streams bisect both passageways) of track bed that are present under the two passageways. Data from this camera is used to confirm track bed data and record animal movements not captured by the track beds. Digital cameras are placed along the streams to monitor those areas not suitable for track bed construction. All cameras are checked weekly.

Key findings.

- Cameras are important for validating track bed data and monitoring areas unsuitable for track beds.
- Digital cameras (set for 10 – 15 picture sequencing) are excellent tools for recording animal behavior relative to passage structures. They may serve as a low cost alternative to video cameras.
- The pairing of cameras on opposite sides of a roadway may provide data on wildlife that cross over the roadway rather than through the passages.

Analysis. Information gathered from track beds/plates and remote cameras are used to provide an index of passage use by taxa group. Weekly and monthly rates of passageway use are calculated for track beds. In addition, information from this portion of the study will be compared to that from snow tracking to identify potential seasonal differences.

Snow Tracking

Snow-tracking during winter provides the opportunity to 1) evaluate animal movements relative to the roadway and passageways, and 2) document the presence of animals in the study area not detected by track beds/plates. Data from track beds/plates and remote cameras during 2005 documented the occurrence of woodchucks, raccoons, white tailed deer, mink and muskrat within the passageways. However, species such as bobcat, coyote fisher, otter, porcupine and beaver were not detected, yet occur in the area. The snow-tracking provides us the opportunity to assess the movements of these animals relative to the roadway and passageways.

Sampling procedures. The grid design for snowtracking consists of four transects parallel to the highway, extending 500m to the east of the East Airport Brook passageway and 500m to the west of West Airport Brook passageway (Fig 2). Two transects occur on each side of the highway with one along the highway edge and the other 100m in the forest. Additionally, six transects extend perpendicular to the roadway on each side. Four of these perpendicular transects on each side extend 100m out from the edges of the passage structures and two occur on either end of the tracking grid connecting the two long transects parallel to the roadway. The parallel transects along the highway edge are designed to identify movements in relation to the roadway and crossing points. The transects that occur in the forest allow us to monitor movements not directly associated with the passageways or roadway. The perpendicular transects provide us information about the behavior of animals as they approach the passageways and the associated lead fencing. During each snow-tracking day we also check the passageways for movement through the structures.

Snowtracking sessions occur 48 hours after snowfalls of ½" or more. We use Palm Pilots with cybertracker software integrated with GPS to record species, track and gait measurements, gait pattern, direction of movement, markings (e.g. – scat, scent marking), highway location crossings, weather, days since last snowfall, snow depth, date and time. The order of transect coverage is reversed on subsequent tracking sessions.

During the 2005/06 and 2006/07 snow-tracking seasons, we frequently were not able to walk the entire grid in a single day. When this occurred, we initiated tracking the following day from the last point covered the previous day, weather permitting.

When we encounter deer tracks that have crossed the roadway we trace their movements from forest edge to forest edge. For carnivores crossing the road we backtrack and foretrack for distances up to 200m from the highway. Snow plowing typically disturbs the snow pack ~5 meters to either side of the highway, thus areas just beyond the "snowplow zone" are checked carefully to capture tracks that are heading towards the highway. Efforts are made to match up tracks on the opposite side of the roadway for potential road crossings. When matched tracks are not found, the tracks are marked and classified as a likely crossing but not used in the data analysis. In addition, if we encounter deer or carnivore tracks that approach the highway but do not cross, we record these tracks to and from the forest edge. These data are important for understanding possible barrier effects of the highway.

We also backtrack and foretrack carnivores that cross the 100m forest transect, as far as clear tracks will allow. This information will be used to identify potential wildlife corridors and to identify areas adjacent to the roadway that may serve as significant habitat in winter. These data can also be used to determine if behaviors of animals change as they approach the roadway and passageways by comparing movements away from and near the roadway. Individual animal movements are also monitored along the perpendicular transects that extend directly out from the passageways and within the passageways.

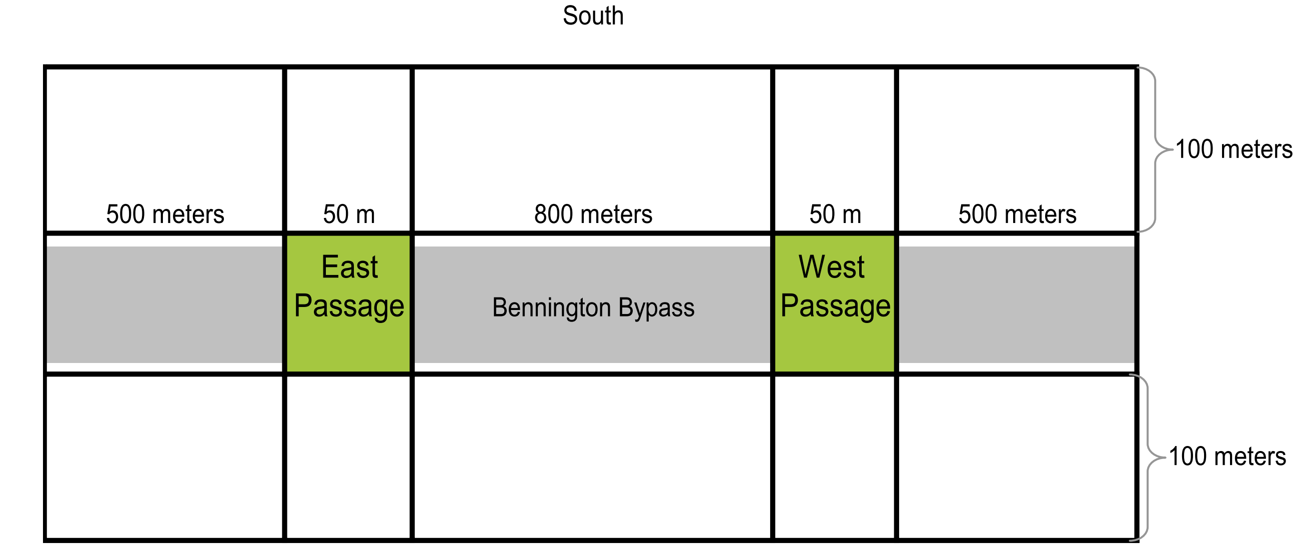

Figure 4. Snowtracking grid. Black lines represent transects.

Key findings.

- From monitoring perspective, snowtracking is the most comprehensive method of detecting animal movements. Unfortunately it is viable only during a limited portion of the year and in latitudes that provide snow cover.
- It can serve as a low cost alternative to radio telemetry
- It is an excellent method to assess non-passage movement of animals
- Information derived from snowtracking may assist in determining placement of other monitoring techniques such as cameras and roadside track beds that can monitor movements not associated with passageways in seasons other than winter.

Preliminary Results. Snow-tracking data provide us information on animal movements relative to the roadway and nearest passageways. Our 2005/06 and 2006/07 data suggests there are two primary highway crossing areas for bobcat and coyote apart from the passageways. Further, we documented that roadway crossings were more frequent than crossings through the passageways. This portion of the study can also provide a baseline that can be used to evaluate changes in movement behavior over time. The preliminary data suggests that fencing plays a key role in mitigation. Animals cross the highway in the highest numbers away from the 8-foot lead fencing, where the 4-foot right of way fencing serves as the only barrier preventing access to the highway. We have documentation that this fencing is easily jumped over or dug under by wildlife.

Road Kill Surveys

Wildlife passageways can potentially reduce vehicle/wildlife collisions by minimizing road crossings, thereby also reducing animal mortality. In our study, the control portion of the highway is a 1.1 km section of the highway located on the far western end of the 7km long Bennington Bypass, away from the passage structures. The treatment section of the highway is a 1.1 km section of highway that encompasses both passage structures. The null hypothesis for this segment of the study is that road kill rates will not vary between the control and treatment areas. If the passageways are effective, road kill rates should be higher in areas farther from the passageways.

Sampling procedures. The entire 7km of the bypass is being surveyed for road kills. Surveys are conducted 3 times a week (M, W and F). Driving at 15 mph, each side of the road is monitored and species or group (i.e. – small mammal), direction traveling, and location to the tenth of a mile (using odometer readings) are recorded for each road kill found. In addition, we use monthly traffic counts provided by VTrans to assess the impact of traffic volumes on rates of roadkill.

Key findings.

- In high traffic areas, the majority of roadkill is unidentifiable.
- Roadway features such as guardrails, right of way vegetative cover, slope of embankments and location of retention ponds may influence rates/species of roadkill

Analysis.

Two hypotheses will be tested during this portion of the study.

Hypothesis 1 – Road kill will be higher on the control (unmitigated) portion of the highway

Hypothesis 2 - Road kill will increase at distances further from the passage structures

Preliminary results. Data from the first two field seasons suggest there is no statistical difference in road kills, control vs. treatment and roadkill rates do not change at varying distances from the passage structures.

Roadside Track Beds

This monitoring technique has great potential. Unlike our snowtracking sessions, it is difficult in the warmer months to discern animals moving across the highway without the use of radio telemetry. We utilize pond fill as a tracking substrate. Pond fill is mud with a silt and clay component that allows it to hold up well in most weather conditions except torrential rain. Efforts will be made this upcoming field season to modify this technique and to make it a key monitoring method in our study.

Sampling procedures. Two pairs of roadside track beds were constructed and monitored along the roadway to monitor highway crossings. The beds are 100’ long x 3’ wide and constructed using pond fill supplied by VTrans. We constructed these beds in areas where we had observed high use during the previous snowtracking season. Unfortunately, unusually high rainfall washed out the track beds within 7 days after installation. Thus, we only recorded four deer crossings during five days of monitoring. No other species were recorded on the track beds.

Key findings.

- In the absence of snowtracking or telemetry, roadside track beds may provide the most useful data on wildlife road crossings not associated with passage structures.
- Pond fill is an excellent tracking substrate but may require frequent repair during times of high precipitation

Calling Amphibian Monitoring

To better evaluate the potential changes in amphibian populations over time, we use automated acoustic recording devices (Frogloggers) to monitor the density of calling males at several sites. Following the procedures of Peterson and Dorcas (1994), frogloggers are set to record for 12 seconds every 10 min throughout the night during the breeding season (March-August). Microphones are suspended above breeding pools from a tree limb to minimize the relative contribution of any single individual to the chorus. This allows comparison of the intensity of calling effort across sites. Choruses are identified to species and chorus intensity is measured according to the following scale developed by Mohr and Dorcas. (1999): 1) one individual, 2) distinguishable individuals, and 3) many indistinguishable individuals. Chorus ratings are summed over species to provide a relative index of anuran density at each site (Mohr and Dorcas 1999). Overlapping sites (sites within range of more than one microphone) are excluded from this study to reduce the probability of detecting the same individuals more than once. Recording devices are checked weekly for maintenance purposes.

Sampling Procedures. Frogloggers are placed at the wetland located 200m southwest of the Airport Brook West passageway and at the southern retention pond, located 200m to the west of WAB. Additionally, we are monitoring two ponds along the proposed route of the northwest extension of the Bennington Bypass. These data will provide baseline data to potentially be used in any post construction studies for that section of the highway.

Key findings.

- Frogloggers are user friendly and hold up well in inclimate weather
- Background noise such as crickets and birds may require sophisticated equipment such as a sonogram for deciphering of amphibian calls

Observational Studies

We tested a method for determining whether animals display evidence of aversion or excessive wariness in the vicinity of the passage structures. In addition, we used direct observation in an attempt to detect animal movement through the passageways that was not captured by the track beds or cameras.

Sampling procedures. We used night vision goggles to observe animals in the passageways between 1830 hrs and 2230 hrs. An observation period consisted of a 2-3 hour period during which the observer recorded all animal movement and behavior in the passageway. Each passageway was observed 4 times between July 2 and July 29. Only one sighting (a family of raccoons) was recorded during the month of July.

Key finding.

- This method may be of limited value due to the number of hours required to obtain significant results.

Snake Distribution and Abundance

Two methods of monitoring snake movement were utilized during the first year of the study (2005). The goal of this portion of the project was to assess the impacts of the highway on snake movements. A mark/recapture method using pit tags was to be implemented.

Sampling procedures. The first method was the use of fence arrays with accompanying funnel traps and pitfall traps. We used 1 meter high drift fence to set up an "X" fence array. Each arm of the array was 5 meters long. Half meter long funnel traps were placed midway along each side of the 4 arms of the array. A second design incorporated the "X" design with a pitfall trap placed at the center of the "X". The pitfall trap was a sunken 5 gallon bucket. Funnel traps were aligned along each side each side of the 4 arms in this design also. In both designs the funnel traps and pitfall traps served as a passive technique for snake capture.

A second method was the use of cover boards. Cover boards serve as artificial sources of cover and warmth for snakes. We experimented with two types of cover boards. The first was the use of corrugated aluminum and the second was the use of tar roofing sheets, both cut into 1m x 1m squares. The cover boards were placed 10m apart along three 150m transects. The three transects were parallel with the highway, centered on the WAB passage structure. They were placed at three distances from the highway; 1) at the forest edge, 2) 20m from the forest edge and 3) 60m from the forest edge. Two fence arrays were constructed along each transect, one at 50meters and one at 100 meters.

Over a one month period, we only captured one snake using these methods. This portion of the study was discontinued after the first field season.

Key finding.

- Monitoring of snake movement may require extensive coverage, hence high labor/materials cost, which may be desirable only in a snake specific study.

Discussion

Most studies of the effectiveness of crossing structures have been narrowly focused on evaluating passage use. Yet without some clear sense of the mitigation objectives or clear criteria for success it is hard to imagine how these types of studies can determine whether or not a mitigation project can be considered effective. Data on the movement of individual animals through a passage structure is, at best, only an indirect measure of the success of a mitigation project.

For mitigation projects built for the primary purpose of preventing animal-vehicle collisions (for conservation or human safety) a more direct measure of success would be a reduction in the number of collisions or the risk of collisions. Where wildlife conservation is the primary concern long-term effects on wildlife populations are the only direct measure of success. Although desirable, it is not likely that long-term population monitoring will be regularly used to evaluate the effectiveness of wildlife mitigation measures. However, population modeling can help define the desired level of movement through the landscape needed to maintain populations over time. Combined with population modeling monitoring projects that evaluate the full range of wildlife movement can serve as a reasonable approach to evaluating mitigation success.

Developing Metrics and Establishing Criteria for Success

Using the conceptual model in Figure 2 we can create metrics for determining success based on project objectives. If the objective of a project is solely to prevent animal-vehicle collisions then the following metric would be appropriate.

$\sum (a, b, c)$

In cases where the number of collisions that can be tolerated is low (moose, elk, Florida panthers) the criteria for success would be set at a very low number. In this case continued use of the roadway by wildlife (movement types a & c) or ongoing roadkill (b-type movement) would indicate that the mitigation has not been successful. Where the objective is to reduce but not necessarily eliminate roadkill (amphibians on a causeway through extensive areas of habitat) then the criteria for success would be set at a higher number.

Many mitigation projects have combined objectives of reducing animal-vehicle collisions and allowing some degree of movement through the area. If the conservation objective is to maintain population continuity or metapopulation dynamics then it may be acceptable to pass only a portion of population (some inhibitory effect would be acceptable). In this case a useful metric might be:

$$\frac{\sum (e,f)}{\sum (a,b,c)}$$

This metric places the number of successful movements through the structure in the context of the number of movements at risk for animal-vehicle collisions. The criteria for success would be set at a high number if the level of desired passage (as determined by population modeling) is high and the acceptable risk of collisions is low (ungulates, turtles). The criteria for success might be lower for species whose movement requirements (based on population modeling) are lower and/or the impact of roadkill is less severe.

Where the objective is to prevent roadkill and provide access to vital habitats for a population, then the metric should seek to evaluate the amount of successful passage in the context of road avoidance or unsuccessful passage (roadkill).

$$\frac{\sum (e,f)}{\sum (a\text{-}d,\ g\text{-}i)}$$

Other projects may be relatively unconcerned about roadkill (low traffic volume; strongly r-selected species) but seek to facilitate movement across a road or highway in cases where the road has a strong psychological inhibitory effect on passage (small mammals). If the objective is population continuity or metapopulation dynamics then the following metric might be appropriate.

$$\sum (a,e,f)$$

If the project objective is to provide access to vital habitat (mountain pygmy possums) then the following metric might be more appropriate.

$$\frac{\sum (a,\ e,f)}{\sum (b\text{-}d,\ g\text{-}i)}$$

Bennington Bypass Study

During the initial 2 years of this project, our varied techniques approach has provided us movement data on a wide variety of species. Table 2 outlines the various species detected by each of the techniques implemented.

Table 2: Species detected by various monitoring techniques

Method	Species detected
Small mammal mark/recapture	white footed mouse (*Peromyscus leucopus*), deer mouse (*Peromyscus maniculatus*), southern red-backed vole (*Clethrionomys gapperi*), meadow vole (*Microtus pennsylvanicus*), eastern chipmunk (*Tamias striatus*), northern short tailed shrew (*Blarina brevicauda*), meadow jumping mouse (*Zapus hudsonius*), red squirrel (*Tamiasciuris hudsonicus*)
Snowtracking	bobcat (*Lynx rufus*), coyote (*Canis latrans*), fisher (*Martes pennanti*), white tailed deer (O*docoileus virginianus*), gray fox (*Urocyon cinereoargenteus*), raccoon (Procyon lotor), long tailed weasel (*Mustela frenata*), mink (*Mustela vison*), river otter (*Lontra canadensis*)
Track beds	bobcat, coyote, fisher, white tailed deer, raccoon, mink, river otter, wild turkey (*Meleagris gallopavo*), virginia opossum (*Didelphis virginiana*), eastern chipmunk, ermine (*Mustela erminea*), woodchuck (*Marmota monax*), striped skunk (*Mephitis mephitis*), gray squirrel (*Sciurus carolinensis*), red squirrel, eastern cottontail (*Sylvilagus floridanus*), muskrat (*Ondatra zibethicus*), porcupine (*Erethizon dorsatum*), domestic cat (*Felis catus*)
Track plates	ermine, mink, raccoon, woodchuck
Remote cameras	white tailed deer, bobcat, coyote, fisher, woodchuck, opossum, striped skunk,
Roadside track beds	white tailed deer
Road kill surveys	all species
Amphibian recording devices	eastern american toad (*Bufo a. americanus*), northern spring peeper (*Pseudacris c. crucifer*), gray treefrog (*Hyla versicolor*), bullfrog (*Rana catesbeiana*), green frog (*Rana clamitans melanota*)
Observational study	raccoon
Snake distribution	common garter snake (*Thamnophis sirtalis*)

Data for each portion of the study is currently being analyzed but preliminary results reflect a wide array of responses to the passage structures and the highway. By collecting data on eight of nine movement patterns depicted in figure 2 our study should allow us to go beyond the simple consideration of passage use in evaluating success for this mitigation project.[1] Once data collection has been completed we intend to investigate the use of various metrics for evaluating mitigation success for the Bennington Bypass

[1]This study does not provide us the opportunity to collect data on animals totally avoiding the highway denoted by (h) in figure 2.

Conclusions

As the field of highway mitigation continues to evolve we feel this study may provide useful tools in designing monitoring protocols for future passage structures. Our broad approach to monitoring has allowed us to refine effective techniques or discontinue ineffective ones and to pass on "lessons learned" from our study. This broader, landscape level approach to monitoring may aid researchers in developing study designs and to more rigorously evaluate the effectiveness of highway mitigation structures.

Acknowledgements: The Vermont Agency of Transportation (VTrans) provides funding for this project along with cooperative efforts from Vermont Fish and Wildlife Department (VFW). Logistical support is provided by Jennifer Fitch and Chris Slesar of VTrans along with John Austin, Forrest Hammond and Doug Blodgett of VFW. Tom Maier of U.S. Forest Service provided valuable information for the small mammal portion of this study. Invaluable field assistance was provided by Alan Thompson, Lauren Gilpatrick and Noah Charney. This study would not have been possible without the permission of private landowners to access their land.

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