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EVALUATION OF A WILDLIFE UNDERPASS
ON VERMONT STATE HIGHWAY 289 IN ESSEX, VERMONT

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Abstract: State Highway 289 (a.k.a. circumferential highway) in Essex, Vermont, was constructed in 1993 as a means of shifting growing traffic volumes in the area around Burlington, Vermont, to reduce traffic congestion in some areas. This highway bisects streams, wetlands, upland and deer winter habitats important for the survival of area wildlife such as white-tailed deer, beaver, mink and otter. A divided concrete underpass was installed under the highway to accommodate an existing stream channel on one side and wildlife passage on the other. The underpass was located along the stream to connect wetland habitat that exists both up and down stream from the structure thereby facilitating the movement of wildlife and related ecological processes across the road. This project evaluates the use of this structure by wildlife. We used trailmaster infra-red monitoring and photography equipment and track beds to document the use of the underpass by wildlife. This technology allowed us to determine what species were using the underpass, the time of year they used the structure, the time of day, the direction of movement, and how frequently the structure was used. Based on the results of this project, it appears that the diversity of wildlife using this structure is limited, but raccoons and mink use the underpass frequently. Further, underpass design, substrate, vegetation near entrances, and other parameters may be limiting the ability of wildlife to use the structure for moving across the roadway.

Description of Underpass and Affected Landscape

The underpass structure is composed of a large concrete box culvert that is split in the middle by a large concrete support. The dimensions are as follows: Length 97.54 m (320 feet); Width 3.05m (10 feet); Height 3.96m (13 feet). A stream flows through the northern tunnel and the southern tunnel serves to facilitate animal passage along the riparian zone. During periods of high water flow (e.g., spring runoff), both tunnels pass water. However, the bottom substrate in the wildlife tunnel slopes along its profile and has never been observed to be covered by water even during periods of high flow. The substrate of both tunnels is composed of large, course rock with mud and sand in the interstices. This substrate seems to provide good movement cover for small mammals, but likely restricts the movements of larger mammals such as white-tailed deer.

Fig. 1. The underpass as viewed looking downstream along Alder Brook.

The road is raised above the stream, associated riparian zone and bottom of the underpass by approximately 10.7m (35 feet). The top of the underpass is approximately 6.1m (20 feet) from the edge of the road. Vegetation around the tunnel entrances consists of tall grasses which are a result of road bank stabilization plantings. Approximately 30 feet from the tunnel openings vegetation changes to grasses, shrubs, sedges, and hardwood and softwood trees. (Include map of area showing wetlands, dwa, stream, development, etc.). Woven wire fence (4 feet high) runs along the lower grade of the road embankments and extends above the underpass entrance. The fence is disrupted in several locations near the underpass by fallen trees. The fence presents no substantial barrier for most wildlife in the area since deer are able to jump over the 4-foot-high fence, and other animals can crawl under or through the 6 inch wire mesh.

Figure 2 shows wetland and deer winter habitats in relation to the underpass. Much of the surrounding landscape has been converted into large scale residential subdivisions and commercial strip development. However, as illustrated in figure 2, there are large habitat patches that are connected by the underpass. This area has grown rapidly within the past decade. During 1997, traffic volumes for this road were estimated to be 4,200 vehicles per day.

Fig. 2. Landscape of the underpass and surrounding areas.

Methods

We monitored wildlife use of the underpass during the 6-month period June, 2000 through November, 2000 (the period July 6 through September 17 was not sampled). Wildlife use of the underpass was monitored and recorded using Trailmaster 550 passive infrared monitors, Trailmaster TM35-1 35mm cameras, and track plots. Infrared monitors were used to collect number of crossing events, time of crossing events, date of events, and direction of movement. Direction of movement was determined by using multiple infrared monitors at both ends of the underpass and evaluating the time between recorded events for both monitors. The cameras were used to record the species of animal using the underpass. However, after 6 weeks of recording data in the field, one of the cameras was stolen. We decided to remove the remaining camera and identify species using the underpass by observing animal tracks in a series of 4 plots established along the underpass. One track plot was located within the first 25 feet of the underpass opening on either end, another plot was established in the center of the underpass to confirm complete crossing events, and a fourth plot was located at the north end of the adjoining tunnel for stream passage. This fourth track plot was used to determine whether animals were using that tunnel, but we did not install infra-red monitors and cameras due to the consistently high water in that tunnel and apparent lack of use by animals. Track plots consisted of 3 foot by 3 foot zones of mud, sand, and “black magic” marble dust to collect animal track prints in a systematic fashion. Researchers visited the study site once each week during the study period. The period of July 6 through September 17 was not sampled. This lapse in sampling occurred as a result of the camera theft which caused us to remove all equipment for a period of time to avoid further loss of equipment and data.

Infra-red monitors were secured to metal fence posts along the inside edge of the underpass. Monitors were placed 10 to 15 feet inside each entrance to the underpass. Associated 35mm cameras were placed an additional 5 feet into the tunnel entrance adjacent to the monitors. Cameras were secured to metal fence posts as well. Cameras were aimed towards the tunnel entrances in order to take advantage of any limited ambient light, and further, to avoid easy visibility by humans, in hopes of avoiding theft and vandalism.

Data was analyzed using Microsoft Excel. Descriptive statistics were performed on the information collected to develop a general understanding of wildlife use of the underpass. These data are presented below.

Results

Infra-red monitors recorded 190 events of both confirmed and unconfirmed animal use of the underpass during 96 days of sampling from June 6, 2000, through November 21, 2000. Again, no data was collected during the period July 6 through September 17, 2000, which explains the lack of data for the month of August in figure 4. Photos from 35mm cameras that were triggered by the infra-red monitors, and track plots were used to identify species of animals using the underpass. While 7 species of wildlife were identified as using the areas around the north and south entrances to the underpass, only 4 species were confirmed to have used the underpass for moving under State Highway 289. These species include raccoon, mink, weasel, and skunk, in order of frequency of occurrence. Figure 3 illustrates the use of the underpass by these species. The number of species utilizing the underpass is low, but not necessarily surprising due to the dimensions, substrate and other factors related to the suitability of the underpass for animal use. Tracks of white-tailed deer, great blue heron, and mouse species were observed at both tunnel entrances, but were not confirmed as ever entering or utilizing the underpass.

Tree swallows used the tunnel for nesting purposes, building a nest at the north end of the tunnel (approximately 20 feet into the tunnel entrance) in the spring of 2000 and a nest at the south end of the tunnel in the spring of 1999. However, the presence of this species and its use of the structure was not considered as part of this evaluation because it had nothing to do with the purpose of the tunnel to facilitate wildlife movement across the road. In addition, aquatic invertebrates and fish were not sampled as part of this evaluation due to the purpose of the project, purpose of the underpass, and limitations of the sampling design. Fish and aquatic invertebrates (e.g., crayfish) were observed within the stream channels in the tunnel entrances. Crayfish may serve as an attractive food resource for species such as raccoon and mink which were found to use the underpass.

Figure 4 illustrates the level of underpass use by wildlife over the evaluation period. The level of use increased during the months of September, October, and November, as compared to the spring and summer months. Though we are not certain as to why this distribution of use occurred, it may be due to temporal behavior on the part of some or all of those species using the underpass such as the seasonal dispersal of young into new home range habitat, searching for mates for reproductive purposes, or access to important fall food resources.

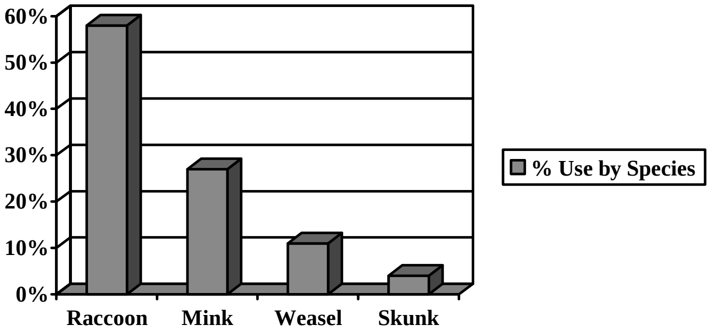

Fig. 3. Percent use of the underpass by wildlife species from June 2000 through November, 2000.

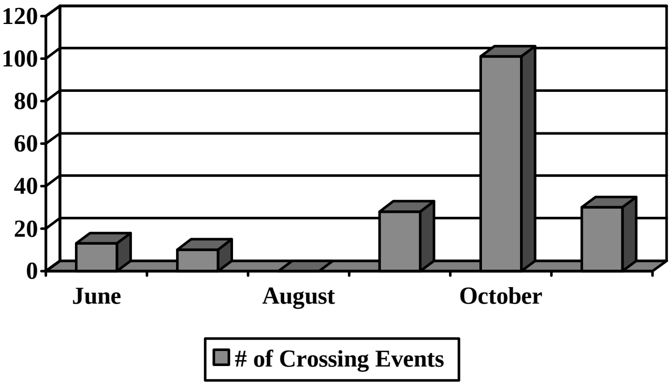

Fig. 4. Number of crossing events by wildlife from June 2000 through November 2000.

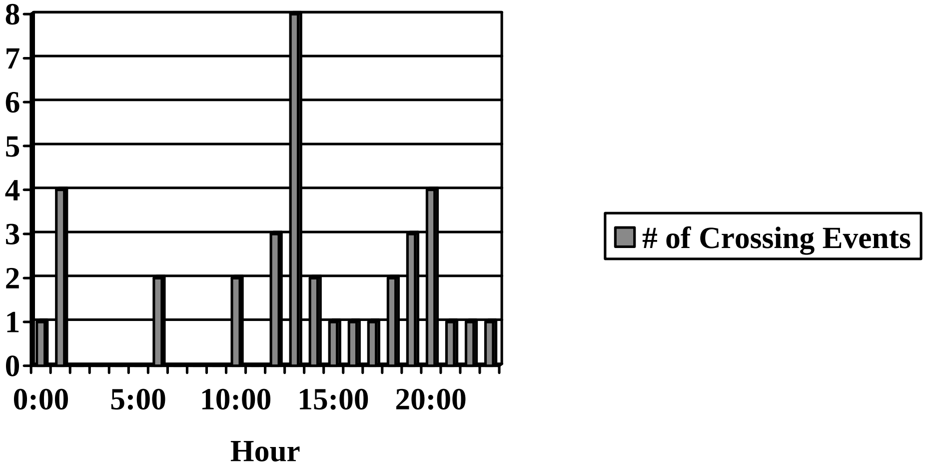

Fig. 5. Number of wildlife crossing events as a function of time of day.

As figure 5 indicates, animal use of the underpass may be a function of time of day. Based on our information, the majority of animal use of the underpass occurs during late evening and early morning hours. Therefore, most animal use of the underpass is nocturnal. Surprisingly, however, animal use of the tunnel appeared high during mid-day hours as well (e.g., 13:00). This may be a function of food availability in the stream, thermal refuge during periods of high air temperatures (air temperatures in the tunnel seemed low compared to ambient temperatures), or other factors.

Discussion

Roads, transportation infrastructure and related development can impact wildlife by destroying and fragmenting habitat, increasing mortality, displacing or disturbing animals from otherwise suitable habitat, and affecting the ability of animals to move within their environment (Jackson, 2000). In addition, vehicle collisions with animals, particularly large animals such as white-tailed deer and moose, present a significant public health and safety risk.

Structures designed to facilitate movement of wildlife under or over roads and highways have been successfully employed in many areas around the United States and in other countries (Jackson). In Vermont, however, the use of underpasses and overpasses to mitigate transportation impacts to wildlife has been limited. Route 289, the subject of this evaluation, represents the first instance in Vermont where an underpass structure was employed to mitigate the effects of road development on wildlife movement. Results from this evaluation indicate that relatively few species of wildlife use the crossing structure. We believe this is due to deficiencies in the design of the underpass and other associated social and environmental variables that are discussed below.

Use of the Underpass by Wildlife

Raccoon, mink, weasel, and skunk were the only species of wildlife confirmed to use the underpass to cross Route 289. Evidence of other species observed as being present in or near the underpass entrances includes great blue heron, white-tailed deer, and peromyscus spp. The objective of the underpass was to allow for a wide diversity of wildlife to cross Route 289 and thereby maintain the riparian link between wetland and upland habitats located up and downstream from the structure. In particular, it was hoped that the underpass would accommodate the movements of wetland dependant wildlife such as beaver, otter and mink. Since Route 289 bisects important deer winter habitat, it may have been possible to accommodate the movement of deer through the structure. Based on our findings, it appears that the underpass has only limited effectiveness at accommodating its intended ecological functions. This evaluation did not consider the possible or potential use of the underpass by reptiles or amphibians. Our techniques were not designed to observe evidence of use by these taxa. While it may be possible that the underpass is used by some turtles, salamanders, frogs or toads, we did not observe any anecdotal evidence of this during our field investigations.

Based on our findings, it appears the species using the underpass may be exhibiting temporal behavior in their use of the structure. Results show an increase in the use of the underpass during September, October, and November. While we are not certain as to why this distribution of use occurred, it may be due to temporal behavior on the part of some or all of those species using the underpass such as the seasonal dispersal of young into new home range habitat, searching for mates for reproductive purposes, or access to important fall food resources. Without additional information related to population dynamics of those species observed to have used the underpass, or specific habitat distribution data for the area, it is not possible to answer this question.

Results are not clear on the extent to which time of day affects animal use of the underpass. We expected to observe a greater frequency of use by wildlife during late evening, night time, and early morning hours which would suggest either nocturnal or crepuscular behavior. To some extent, the results suggest nocturnal behavior due to the frequency of underpass use between the hours of 18:00 and 2:00. Unfortunately, our lack of time of day data has effected our abilities to draw further conclusions on this element of wildlife use. Some data from the infra-red monitors was lost due to operator error. However, the infra-red technology did prove effective at understanding daily and seasonal patterns of use by wildlife. This equipment is highly sensitive and must be used with great care and a good understanding of how it works in order to avoid losing data.

Factors Affecting Wildlife Use of the Underpass

Underpass Location and Design

Although this evaluation was not designed to determine whether the current location of the underpass is appropriate, consideration of surrounding habitat conditions suggests the location of the structure is reasonable. In particular, it was located along the main course of Alder Brook rather than a smaller tributary to Alder Brook. Alder Brook connects a series of beaver influenced wetlands up and down stream from the underpass.

We believe, based on our observations of animal use of the underpass and underpass dimensions and associated light conditions, that the structure was not designed appropriately to accommodate the movement of many mammals that might otherwise have used a structure in this location. The underpass is too long, too narrow and subsequently has very poor light conditions. These features can preclude the use of an underpass by some wildlife such as deer. In addition, its location relative to the channel of Alder Brook may reduce its effectiveness for wildlife movement. The underpass frequently passes water that spills over from Alder Brook, effectively resulting in a second stream channel, rather than an effective riparian corridor for wildlife.

Reed et al. (1979) presented what he termed an openness equation for determining the suitability of an underpass for use by ungulates, and specifically mule deer. This equation has been applied in other circumstances to gauge the relative effectiveness of underpass structures for deer movement and other species. Underpass openness, largely as a measure of the degree of ambient light in the tunnel, appears to be a significant factor in determining whether some species of wildlife, particularly large mammal, will use it. This equation was used by the Department during the planning phase for the Bennington bypass project in Southern Vermont. The equation relies on the dimensions of an underpass to determine its relative openness, which affects the amount of light and possibly cover within the tunnel, and subsequently visibility by deer. The ratio of $\frac{\text{width x height}}{\text{length}}$ (in meters) must result in a figure greater than 0.6 to be effective for deer crossing.

In this case, the dimensions, as a function of this equation, result in an openness figure of 0.12. This figure is well below the proposed minimum openness factor for an underpass to be suitable for deer. This process equates height with width. There is information that suggests width may be a more important factor in determining if deer will use an underpass (Jackson,). This underpass is very long and relatively narrow with poor (very low) light conditions. In addition, the large, jagged rip rap substrate is unsuitable for deer movement. In fact, even if the openness factor were suitable for deer, the substrate in the underpass effectively precludes its use by deer. In order to facilitate deer movement through the tunnel, the existing substrate would need to be removed and replaced with material that created a more even micro topography within the tunnel. This could be accomplished in conjunction with the placement of other habitat such as logs, root wads, and large rocks to create cover for the movement of small and medium sized mammals such as mink, mice and voles. The length, width and lack of light in the tunnel may also restrict use by other wildlife such as beaver, coyote, and fox, among others.

Substrate

Substrate within the underpass is composed of large, course rip-rap material with sand and mud in the rock interstices. This substrate could provide good movement cover for small mammals such as mice and voles, however, no evidence of those species were observed within the underpass. In the alternative, this is very poor substrate for most other mammals. Large animals such as deer are precluded from using the underpass due to the nature of the substrate. Even some medium-sized mammals such as fox and coyote might avoid using the underpass due to the substrate.

Substrate is an environmental variable affecting wildlife use of the underpass that can be changed. A fine substrate of small rocks, stones and sand in conjunction with course woody material such as logs and stumps would allow for easier movement of some mammals. This could increase the diversity of species use of the underpass. Consideration should be given to improving the character of the substrate and interior cover habitat followed up with continued monitoring of animal use to evaluate the effect of substrate change on underpass efficacy.

Vegetation and Cover

Vegetation leading up to the entrances of underpass structures can be important in determining whether some species will use the structure. The suitability of vegetation as cover varies depending on the species of wildlife being accommodated. In this case, the underpass was installed to accommodate the movement of small, medium and large mammals. The vegetative cover near the underpass openings consists of grasses and some shrubs. It is relatively open, and the stream substrate (sand and gravel) seems to preclude the establishment of vegetation at the underpass openings. Vegetation of this character provides poor cover for medium and large mammal, and even some small mammals. For instance, it is possible that small mammals such as mice and voles are not willing to expose themselves to the risk of predation by entering the tunnel where there is no vegetation, or other form of cover. Vegetative cover leading to the underpass entrances is not suitable for wintering deer to access the structure. Planting softwood tree saplings around the tunnel entrances and connecting to the winter habitat would improve the ability of deer to access the tunnel, though existing substrate in the tunnel still precludes use by deer.

Hydrology

The underpass was not raised above the streambed enough to avoid regular inundation by water from the stream channel. Regular water flows within the underpass may effect wildlife use and structure effectiveness. Although expensive, an expanded bridge that maintained existing riparian habitat along one or both sides of the stream channel would have been a more effective method of accommodating wildlife movement, habitat connectivity, and the flow of ecological processes within the affected area.

Landscape and Surrounding Development

Route 289 bisects deer winter habitat in the area of the underpass. The impacts to this significant habitat were not adequately considered during the planning process for this road. The fragmentation effect, and direct loss of significant habitat is severe in this case. The underpass is not located or designed to effectively account for the fragmentation of this habitat, or to allow wintering deer to access or use the structure.

Since the construction of Route 289, a great deal of residential and commercial development has occurred around the area (refer to figure 2). This development has resulted in direct loss and fragmentation of habitat, and essentially resulted in an isolated area of habitat with the road in the center. It is possible that some of the ecological processes that may have existed prior to Route 289 and subsequent development no longer exist. It is also possible that some of the species of wildlife that might have used the underpass, can no longer find suitable habitat due to expanded development. This is a critical component to any review of transportation projects, their effects on wildlife and determining appropriate means of mitigating impacts. It is necessary to consider the broad effects of new or improved roads such as subsequent development and increased traffic volume and speed on wildlife and ecosystems in order to develop an effective mitigation strategy. These circumstances strongly encourage the use of conservation easements or land acquisition as a means of avoiding habitat loss and fragmentation resulting from road development and potential subsequent residential and commercial development.

Fig. 6. Raccoon using the underpass structure during high water conditions as recorded by the remote monitoring and photography equipment.

Unfortunately, this evaluation did not consider the impact of Route 289 on wildlife in general, nor did it focus specifically on what species of wildlife do not use the underpass and for what reasons. Although, to some extent, we offer speculation on those wildlife species that we know use habitats within the general area of the road and possible reasons why they are not using the underpass. Evidence of white-tailed deer and great blue heron were observed at the entrances of the underpass. On other parts of Route 289, red fox and beaver were observed as roadkill. Another small stream runs through a 4-foot diameter culvert pipe under Route 289 approximately 0.25 miles south from the underpass. This stream flows from a beaver influenced wetland with current beaver activity. This is also an area that is used by wildlife for crossing Route 289. We do not know to what extent, if any, animals use the culvert pipe to move across the road, however, this has proven to be a primary location for vehicle collisions with small to medium sized mammals.

Conclusions

While this underpass structure serves some function for facilitating the movement of wildlife under Route 289, its value is limited by its design, substrate, surrounding vegetation, surrounding development, human activities (ATV use), and possibly location. Considering these issues, there may be some merit to: (1) changing the substrate within the underpass, (2) enhancing the vegetation around the underpass entrances, and (3) coordinating with local enforcement officials to more carefully monitor and control ATV use near the structure. These improvements may significantly enhance the use of the structure by wildlife, which would have the effect of maximizing the public investment in this transportation infrastructure. We recommend continuing this research following manipulation of the tunnel substrate to a less course material such as small stone with root wads or other appropriate cover. This would allow us to compare the use of the tunnel relative to the improvement of substrate.

In light of our current understanding of the affects of roads on wildlife and mitigation strategies, a short span bridge would have been a better investment in this area. A bridge would have maintained some of the existing riparian habitat conditions on either side of the stream as the primary passage routes for wildlife under Route 289. We strongly suspect that, all else being equal, this scenario would have allowed for the movement of many species of wildlife ranging from amphibians and mice, to coyotes and deer.

Perhaps the most important consideration for future projects that can be learned from this experience is to consider the overall landscape effects of transportation development, particularly as it relates to potential residential and commercial development subsequent to the new or improved road. In this case, consideration was not given to future growth and development of the area as a result, in part, of Route 289. This resulted in, essentially, stranded habitat surrounded by extensive commercial and residential development, and bisected by the road. The public’s interests in their natural resources, and investment in mitigation of road impacts would have been better served if these issues were considered, analyzed and planned for prior to road design and construction.

This evaluation serves as an example of the value of a collaborative relationship between Vermont’s Agency of Natural Resources, Department of Fish and Wildlife, and Vermont’s Agency of Transportation to learn from our past experiences and improve our abilities to address similar issues associated with future projects.

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