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research report

An Evaluation
of the U.S. Highway 17 Underpass
in Chesapeake, Virginia, as a Wildlife Crossing

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16. Abstract:

In November 2005, the Virginia Department of Transportation (VDOT) realigned and widened more than 10 miles of U.S. Highway 17 in Chesapeake, Virginia, to accommodate the growing volume of traffic and increase safety. Through extensive coordination with regulatory and resource agencies, measures were designed to minimize impacts to the area's natural resources and the neighboring Great Dismal Swamp National Wildlife Refuge (GDSNWR). The primary mitigation included the construction of two parallel bridges, 984 ft long and approximately 8 ft high, that span a wetland within an important riparian corridor along the Paleo-Northwest River. Two berms were constructed on the wetland beneath the bridges to serve as dry areas for wildlife crossings, and nearly 2 miles of 10-ft-high fencing extends from the underpass to help guide wildlife toward the underpass and prevent them from entering the roadway.

A 29-month camera monitoring study was conducted to determine whether the structure facilitated wildlife passage. Cameras documented 550 crossings by at least 12 species. Thirteen black bear crossings occurred during the second year following underpass construction, evidence of the structure's ability to provide safe passage for bears traveling to and from the GDSNWR. Results suggest that the underpass connected important wildlife habitat. In addition, as deer represented 30% of the crossings, the underpass also reduced the risk of deer-vehicle collisions, which is a significant issue for Virginia.

The information gained from this project can assist with decisions regarding future investments in similar environmental mitigation projects. It is reasonable to argue that the value of such measures increases over time in terms of ecological significance (i.e., facilitating wildlife movement and conserving important habitat); benefits to drivers from a reduction in the risk of animal-vehicle collisions; and cost savings to VDOT in carcass removal and disposal expenses.

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FINAL REPORT

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ABSTRACT

In November 2005, the Virginia Department of Transportation (VDOT) realigned and widened more than 10 miles of U.S. Highway 17 in Chesapeake, Virginia, to accommodate the growing volume of traffic and increase safety. Through extensive coordination with regulatory and resource agencies, measures were designed to minimize impacts to the area's natural resources and the neighboring Great Dismal Swamp National Wildlife Refuge (GDSNWR). The primary mitigation included the construction of two parallel bridges, 984 ft long and approximately 8 ft high, that span a wetland within an important riparian corridor along the Paleo-Northwest River. Two berms were constructed on the wetland beneath the bridges to serve as dry areas for wildlife crossings, and nearly 2 miles of 10-ft-high fencing extends from the underpass to help guide wildlife toward the underpass and prevent them from entering the roadway.

A 29-month camera monitoring study was conducted to determine whether the structure facilitated wildlife passage. Cameras documented 550 crossings by at least 12 species. Thirteen black bear crossings occurred during the second year following underpass construction, evidence of the structure's ability to provide safe passage for bears traveling to and from the GDSNWR. Results suggest that the underpass connected important wildlife habitat. In addition, as deer represented 30% of the crossings, the underpass also reduced the risk of deer-vehicle collisions, which is a significant issue for Virginia.

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INTRODUCTION
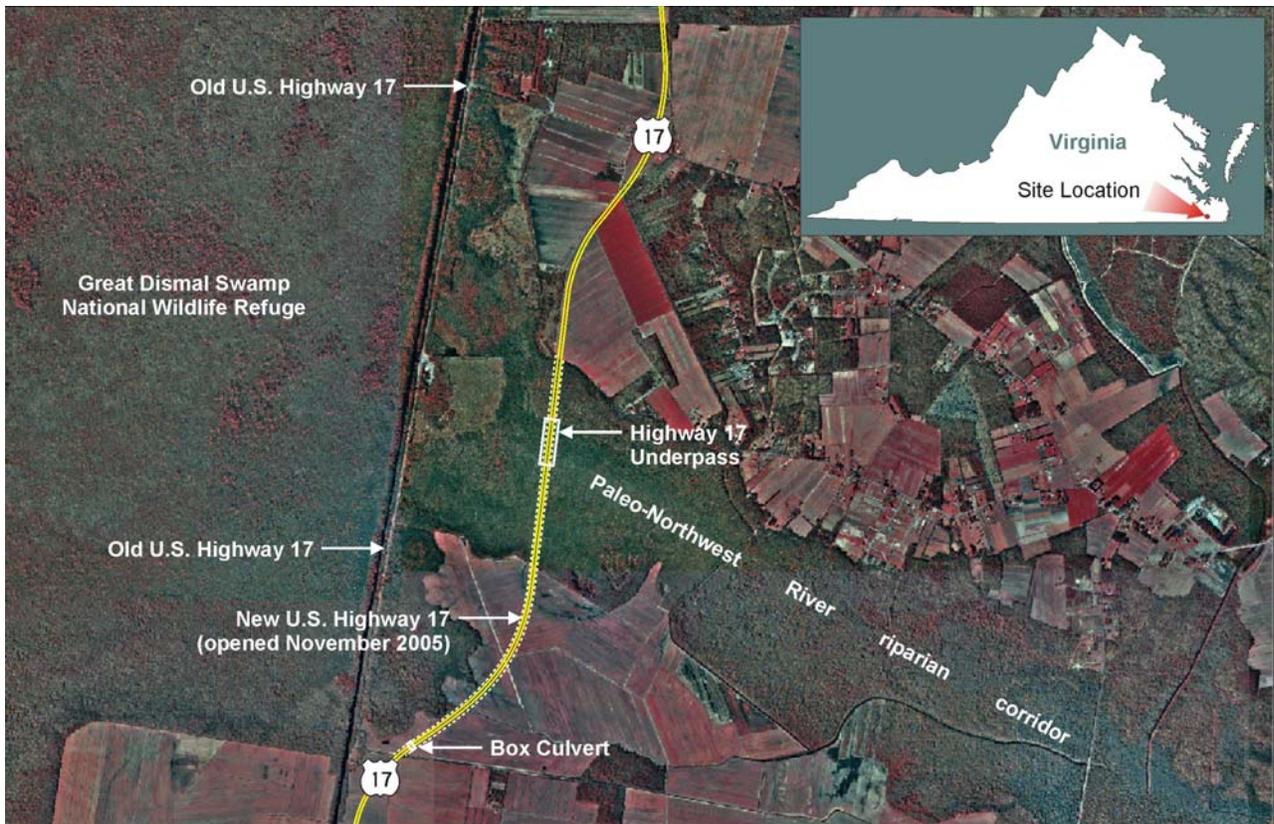
Background of the U.S. Highway 17 Underpass

On November 7, 2005, the Virginia Department of Transportation (VDOT) opened a newly constructed section of U.S. Highway 17 in the City of Chesapeake, Virginia, just east of The Great Dismal Swamp National Wildlife Refuge (GDSNWR). From the intersection of Highway 104 to the North Carolina state line, this 11.6-mi segment was widened from two lanes to four to increase safety and accommodate the increased traffic volume. Through the public involvement process and extensive coordination with federal resource and regulatory agencies, a road alignment was chosen to minimize environmental impacts. More than 10 mi of the new highway segment was relocated approximately 1,000 yd east of the original location to limit disturbance to the GDSNWR and the surrounding forests and wetlands (Figure 1).

The GDSNWR is a 111,000-acre refuge that is home to a variety of wildlife. It includes one of the largest black bear (*Ursus americanus*) populations on the U.S. east coast and harbors 40 other species of mammals, 59 species of reptiles and amphibians, and more than 200 species of birds, many of which are uncommon or rare throughout Virginia. Highway 17 crosses the paleo-drainage of the Northwest River, which consists of a riparian corridor that extends southeast from the GDSNWR (Figure 1). This riparian corridor contains wetland habitat (a swamp and saturated wetlands) that holds significant value in terms of its hydrologic functions and its plant and wildlife populations. Clairain and Latorre (2001) provided a detailed description of this wetland area. The riparian corridor is one of the last remaining corridors connecting the refuge to other patches of black bear habitat along the U.S. east coast (Wills, 2008). Although rarely documented in police records, animal-vehicle collisions were frequent along the original U.S. Highway 17 and included multiple bear deaths in the last several years before its closing (Wills, 2008).

Throughout the planning and design of Highway 17, VDOT coordinated with the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, and technical experts in the region to design measures to minimize impacts to the area's natural resources. Specifically, measures

Figure 1. Map Illustrating the Location and Surroundings of the U.S. Highway 17 Underpass. The underpass is along the realigned section of U.S. Highway 17 in Chesapeake, Virginia. The *dashed lines* represent the 1.9 mi of fencing. The location of an enlarged box culvert is also depicted.

was the construction of two parallel bridges, 984 ft long, 81 ft across, and approximately 8 ft high (from ground level to the bottom of the bridge deck), that span a saturated wetland within the riparian corridor (Figure 2). In the remainder of the report, size dimensions refer to dimensions from an animal's perspective; the Highway 17 Bridge is described as having a width of 984 ft, a length of 81 ft, and a clearance or height of 8 ft.

The bridges, which cost $4.2 million of the $42 million total project cost, consist of two northbound lanes and two southbound lanes separated by an open median. To prevent wildlife from entering the roadway and to help guide them beneath the bridges, VDOT constructed 1.9 mi of 10-ft-high fencing on both sides of the roadway, topped with three barbed wire strands, which extend across the riparian corridor along the bridge (Figure 1). Nearly 1.5 mi of this fencing extends south of the bridge. To encourage wildlife passage further beneath the bridges (hereinafter referred to as the "underpass"), earthen berms were constructed on the wetland beneath the far ends of the bridges to provide areas of dry crossing for wildlife, particularly for black bears that travel to and from the GDSNWR. These berms consist of slightly elevated areas of dirt and mulch, each approximately 25 ft wide. Vegetation was also planted up to the underpass entrances to encourage wildlife use.

In addition to the bridge, VDOT provided an enlarged double box culvert 1.8 mi south of the underpass and within the 1.9-mi span of the 10-ft-high fencing (Figure 1). Though primarily designed to facilitate drainage, the culvert was enlarged potentially to function as a wildlife

2

Figure 2. U.S. Highway 17 Underpass. The underpass is 984 ft wide (from the animal's perspective) and spans 4 lanes and an open median. The photograph illustrates one of the dry areas (berms) that was constructed at each end of the underpass, intended for use by wildlife.

crossing. The culvert openings are 10 ft by 6 ft, and the structure extends 197 ft in length. To avoid detracting from the costs available for the large underpass, additional measures were not undertaken to encourage wildlife use of the culvert. For instance, the culvert was constructed without raising the elevation of the road and thus remains partially filled with water throughout the year. The primary focus of this monitoring study was, therefore, on the underpass.

As part of the U.S. Highway 17 project mitigation, VDOT donated 758 acres of existing wetlands to the Virginia Department of Game and Inland Fisheries as wetland preservation. VDOT also purchased approximately 16 acres of mineral soil wetlands and created about 9.6 acres of forested, organic soil wetlands within the project corridor. For these efforts, the U.S. Highway 17 widening project was designated as a 2004 Exemplary Ecosystem Initiative by the Federal Highway Administration (FHWA) for protecting wildlife and preserving the ecosystem along the GDSNWR. This designation is given to transportation projects that develop innovative and forward-thinking ways to enhance and preserve ecosystems.
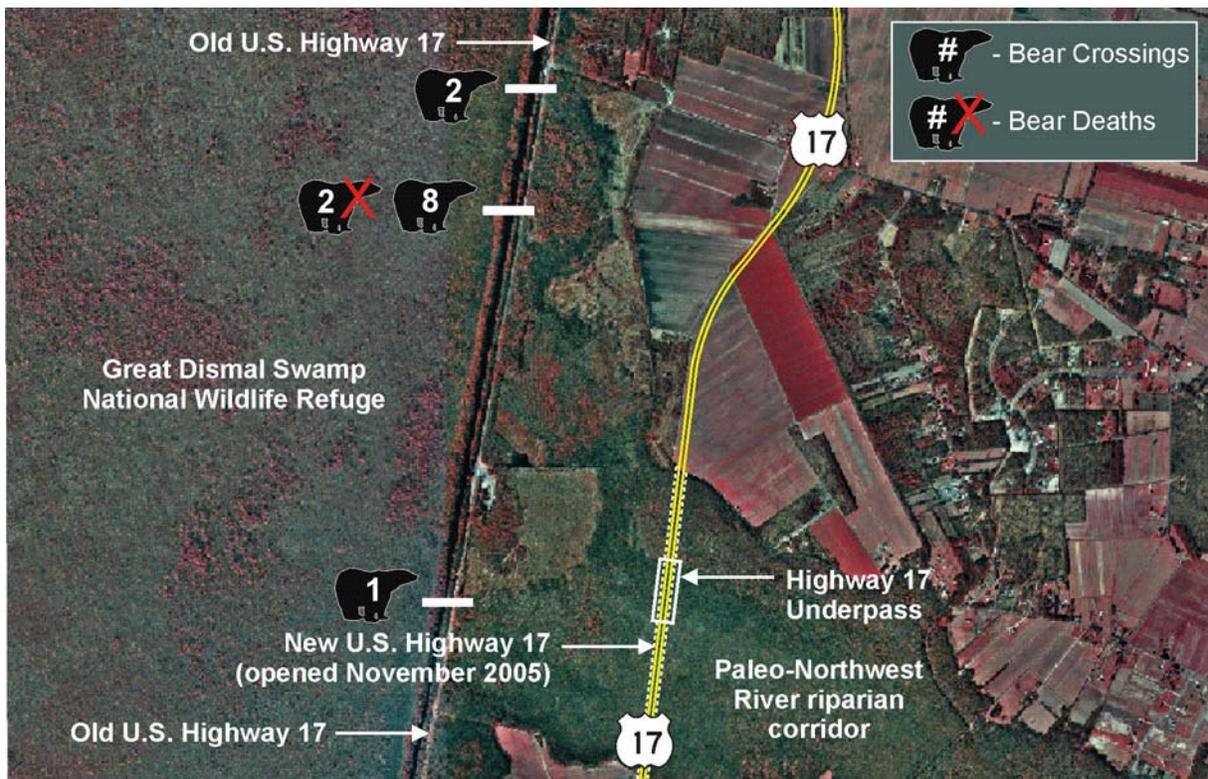
Regional Black Bear Monitoring Studies

Black Bear Research at the GDSNWR

Researchers from Virginia Polytechnic Institute & State University (VPI) have conducted studies on movement patterns and population genetics of black bears in the GDSNWR and along the neighboring U.S. Highway 17 (Tredick, 2005; Wills, 2008). From August 2001 through May 2002 (3 years prior to the opening of the underpass), a "hair snare" study was conducted along a 1.4-mi section of the original U.S. Highway 17 to determine patterns of bear travel relative to the locations of the proposed U.S. Highway 17 underpass (Wills, 2008). A single strand of barbed

wire was placed along the western edge of the original U.S. Highway 17, spanning the section proposed for the underpass. The wire was placed 50 cm above ground level to capture hair samples from bears crossing this section of highway. Twenty-three bear hair samples were collected during the 9-month sampling period along this short road section. All crossings occurred from March through May and in August. Of the six individuals that could be genetically identified from the samples, the majority of their crossings occurred within the same 260-ft road section on the northern edge of the Paleo-Northwest River corridor (Figure 3). This was approximately 1 mile north of the location of the proposed underpass. Based on the limited hair snare data collected on this project, Wills (2008) concluded that the then-proposed (now existing) underpass appears to be in the general area frequently used by black bears to cross the highway.

An investigation of bear-vehicle collisions near the GDSNWR indicated that four or five documented deaths occur on the periphery of the refuge each year, although the actual number may be higher given the low reporting rate of animal-vehicle collisions in the area (Wills, 2008). In 2004 alone, four black bear deaths were reported on the original U.S. Highway 17. Bear-vehicle collision data verified Wills' (2008) findings that the corridor within which the underpass is situated is frequently traveled by black bears moving to and from the GDSNWR. On the original U.S. Highway 17, three bear-vehicle collisions occurred in a 2-year period from 2000

Figure 3. Locations of 11 Black Bear Crossings Prior to Construction of Underpass. The crossing by six individuals that could be genetically identified across the old U.S. Highway 17 is shown as determined by a 2001-2002 hair snare study prior to construction of the new section of U.S. Highway 17 and the underpass. Two bear deaths from vehicle collisions at an area of high crossings were also documented during this period.

through 2002, and one bear skeleton was found from an earlier collision. Two of these bear deaths occurred in an area where the hair snare study indicated heavy crossings, approximately 1 mi north of the underpass (Wills, 2008; Figure 3).

Another VPI study entailed an investigation of the population abundance and genetic structure of black bears at the GDSNWR and two other national wildlife refuges in eastern North Carolina (Tredick, 2005). Black bear density at the GDSNWR, estimated using DNA hair samples, ranged from 0.56 to 0.63 bear/km^2. Genetic variability of 40 sampled bears at the GDSNWR was high, suggesting that gene flow across the landscape is adequate to prevent differentiation of this population from populations further south. However, genetic statistics of bears at the GDSNWR compared to bears further south suggested that the bear population at the GDSNWR is isolated to some degree, potentially because of geography (i.e., the Albemarle Sound) and encroaching urban development (i.e., the towns of Suffolk and Chesapeake) (Tredick, 2005).

Effectiveness of Underpasses

Adequate gene flow is essential for the long-term viability of wildlife populations and can be facilitated by the maintenance of natural corridors between populations (Forman et al., 2003). Wildlife underpasses and overpasses across roadways, if designed and located properly, can be highly effective measures for providing safe movement along natural corridors (Clevenger and Waltho, 2000; Forman et al., 2003; Hedlund, 2003; Knapp et al., 2004). In the absence of means to cross roadways safely, road mortality has significantly affected black bear populations in the southern Appalachians (Brandenburg, 1996). As roads are upgraded to accommodate greater traffic volumes, the rate of successful black bear crossings decreases significantly and black bears become reluctant to cross roads (Brody and Pelton, 1989; Virginia Department of Game and Inland Fisheries, 2002). This avoidance of roads can isolate wildlife populations and ultimately reduce biodiversity and genetic variability (Forman et al., 2003).

Given the partial isolation of the black bear population in the GDSNWR, it is especially useful to understand whether an underpass can facilitate safe movement to and from the refuge along an existing habitat corridor. Specifically, an unimpeded passage for wildlife across the new widened U.S. Highway 17 may prevent further isolation of the local bear population from more southern populations. In addition, if an underpass can accommodate large species such as black bear, it is likely to be used by a variety of other mammals, including those that pose larger threats to driver safety (i.e., white-tailed deer) when crossing a road (Forman et al., 2003).

Although research on variables that increase the effectiveness of underpasses is increasing in the United States, relatively few of these studies have determined the structural attributes that facilitate use by black bears in the eastern United States. Monitoring studies in Madison County, North Carolina, found that two 8 ft by 8 ft box culverts, approximately 150 ft long and bordered by 4.5-ft-high fencing on either side, have been unsuccessful in facilitating black bear passage beneath I-26 (A. Burroughs, personal communication). Similarly, black bears approached, but did not enter, a 10 ft by 12 ft by 189 ft box culvert in Albemarle County, Virginia (Donaldson, 2005). Larger underpasses with higher fencing have been more effective at facilitating black bear passage. Researchers who monitored wildlife use of bridges and culverts

in Florida determined that the most effective underpass dimensions for black bears would be a minimum width of 9 ft and a minimum height of 11.5 ft (Smith, 2003). In Washington County, North Carolina, three wildlife underpasses were constructed in 2005 beneath a new section of I-64. Bridges had 8 to 10 ft clearances and 95 to 154 ft widths, with 0.5 mi of 10-ft chain link fence extending from each end. One year of monitoring documented 17 black bear crossings and more than 3,000 deer crossings through the three underpasses (McCollister and Van Manen, 2008).

Research can expand the knowledge of what types of mitigation efforts are successful in facilitating wildlife passage, particularly for eastern black bears. Long-term monitoring studies of underpass use are especially important, as wildlife passage has been found to increase as animals learn a structure's location and become accustomed to it over time (Land and Lotz, 1996; Walker and Baber, 2003).

PURPOSE AND SCOPE

The purpose of this study was to evaluate the effectiveness of the U.S. Highway 17 underpass as a wildlife crossing. The objectives of the study were to determine (1) whether the underpass facilitated wildlife passage, and (2) whether the frequency of wildlife crossings increased over successive years.

The scope of the study was limited to a camera monitoring study over a 29-month period beginning in November 2005.

METHODOLOGY

Three tasks were carried out to achieve the study objectives:

1. A literature review was conducted to identify studies that documented successful underpass features for wildlife crossings.

2. Cameras were placed at both ends of the U.S. Highway 17 underpass, and wildlife activity related to the underpass was monitored.

3. The resulting data were analyzed to determine the following:

   - the success of the underpass in facilitating wildlife passage, particularly black bears

   - the months and seasons in which passage was most frequent

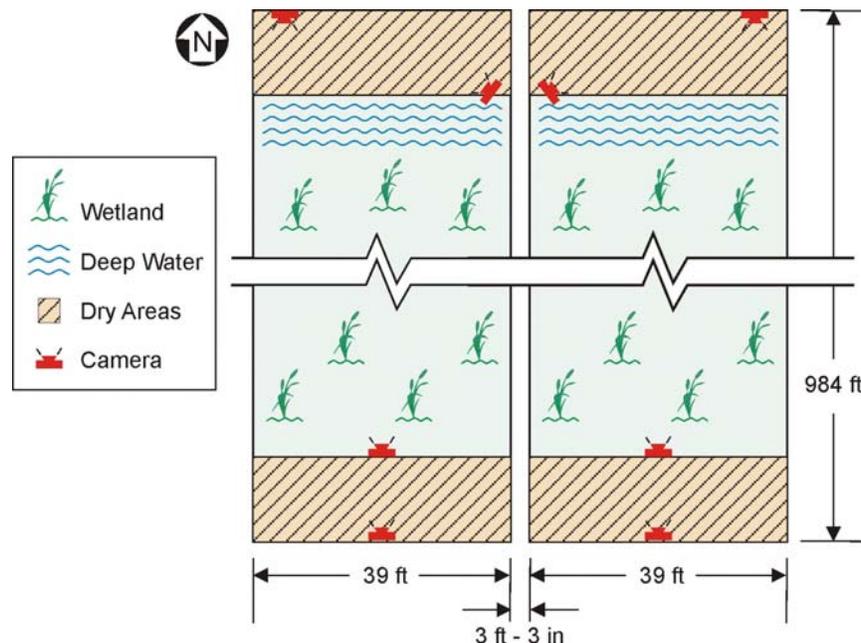   - the increase (if any) in species' use over time.

Literature Review

A literature review was conducted to gather information on the attributes of underpasses that facilitated wildlife passage. The review focused on camera monitoring studies, particularly those that documented the use of crossings by black bears in the eastern United States. Multiple online databases were searched, including TRISWorld, WorldCat, and Transport.

Camera Placement and Wildlife Monitoring

Eight Game-Vu digital trail cameras (Nature Vision, Inc.) were used to monitor the underpass. These remote cameras photograph images based on infrared heat and motion sensors and use undetectable infrared illumination at night rather than a flash. Cameras were installed November 8, 2005. Every 3 to 5 weeks, the photographs taken by the cameras were downloaded onto a laptop computer. Cameras recorded data for 27 months over a 29-month period. Data were not recorded in February and March because of a battery failure in the cameras.

Cameras were positioned on stakes on the dry areas at both ends of the underpass (Figure 4). Camera range extended up to 15 ft in the daytime and was slightly smaller night. Cameras were therefore able to capture a large portion of the width of the southern dry area and the full width of the northern dry area. Cameras captured only a small portion (approximately 4%) of the wetland interior of the underpass. For the first 4 months of monitoring, four cameras were faced toward each of the two dry areas and four were faced toward the wetland interior. Two of the cameras on the north side of the underpass were initially facing the areas of deeper water. Because no activity was documented on these cameras, they were repositioned to provide

Figure 4. Positioning of Eight Cameras Beneath the U.S. Highway 17 Bridge. The dry areas (berms) constructed for wildlife passage are each approximately 25 ft wide. Illustration not to scale.

complete coverage of the dry area on the north side of the underpass. The positions of the two cameras facing the water on the south side of the underpass were not changed so that the more shallow areas of water would continue to be monitored.

For 3 months (November 2006 to February 2007), cameras monitored the 10 ft by 6 ft double box culvert that conveyed a continual stream of water throughout the year. When no activity was documented during this period, cameras were removed from these locations.

Data Analysis

Every 3 to 5 weeks, photographs from each camera were downloaded onto a laptop computer. From each photograph, the species, date, and time were documented into a spreadsheet to determine monthly crossing frequencies for each species. As discussed previously, on some occasions, the battery power of a camera became depleted prior to replacement. To account for monthly differences in camera operative days, monthly crossing indices were calculated by adjusting the number of species' crossings per month by the number of operative days in the month. This crossing index (CI), was calculated by the formula

$$CI = SC \,(TM/OD)$$

where

SC = number of a particular species' crossings in one month, as captured by cameras
TM = total number of days in the month
OD = number of days cameras were operative in the month.

Cameras did not photograph species that were too small to be captured by camera sensors, such as reptiles, amphibians, and small mammals. It is also important to note that a small number of camera observations may not have been true "crossings," as the animal may have been exploring or foraging in the underpass rather than using it as a means for travel across the roadway. This is pertinent to most bird species photographed by the cameras as well as the squirrel (given its small home range). Other species captured by any one of the cameras were presumed to be using the underpass as a means of crossing. In some cases it was difficult to determine whether an animal photographed by one camera was the same animal photographed by another camera. This was especially true when a photograph of an animal from one camera was closely followed by a photograph of an animal from the neighboring camera. To avoid double-counting of an individual crossing event, photographs of indistinguishable individuals taken by neighboring cameras within 2 min of each other were considered to constitute a single crossing event.

For species with a monthly CI of 10 or more, linear regression was used to determine whether the species CI increased over time. A one-way analysis of variance (ANOVA) was used to determine whether there were seasonal or monthly differences in species CIs.

In order to evaluate the success of the underpass in terms of bear passage, it was necessary to specify the criteria for success. Given the partial isolation of the bear population at

the GDSNWR as a result of both geography and urban development, the subsistence of this population relies on the ability to maintain genetic interchange with populations further south (Tredick, 2005). To determine whether this was occurring as a result of underpass use, genetic sampling of individuals using the underpass would be required. The scope of this study, however, lent itself only to the determination of whether the underpass maintained habitat connectivity for bears on either side of U.S. Highway 17. To achieve a goal of habitat connectivity, cameras would need to document use of the underpass by black bears.

RESULTS AND DISCUSSION

Camera Monitoring

A total of 550 crossings were documented over the 29-month monitoring period. This number may be conservative, given the large expanse of wetland and small portion of the southern dry area that could not be captured by the camera range. At least 12 species were photographed in the underpass, some of which are shown in Figure 5.
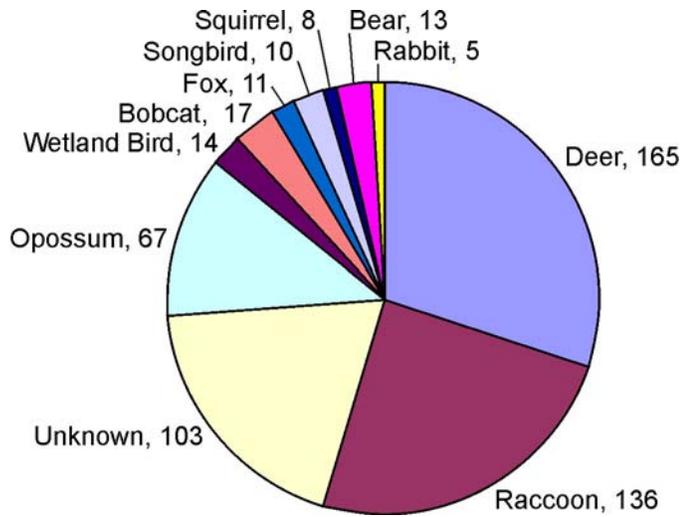
Thirteen black bear crossings were documented, all during the second year following underpass construction. Deer used the underpass the most (representing 30% of all crossings), followed by raccoons (Figure 6). A large portion of the photographs was categorized as "unknown"; the images in these photographs were recognized as wildlife but the species could not be identified (see example in Figure 5G). The great blue heron, great egret, and Canada goose were grouped into a "wetland birds" category; of this grouping, great blue herons were documented the most (8 times), followed by great egrets (5 times) and the Canada goose (1 time). The fox was also grouped into a larger category because it could not always be identified with regard to the species level (i.e., red or gray).

Except for black bears, passage frequency for any species did not significantly increase or decrease over the monitoring period; the same was true of the total crossing frequency (representing all species' crossings). There were no significant seasonal or monthly differences in any species' crossings throughout the monitoring period (Figure 7). This may be attributed to the fact that the monitoring period included only two to three seasons. Additional years of monitoring may be required to determine whether species' use increases over time and whether seasonal or monthly patterns exist in crossing frequencies.
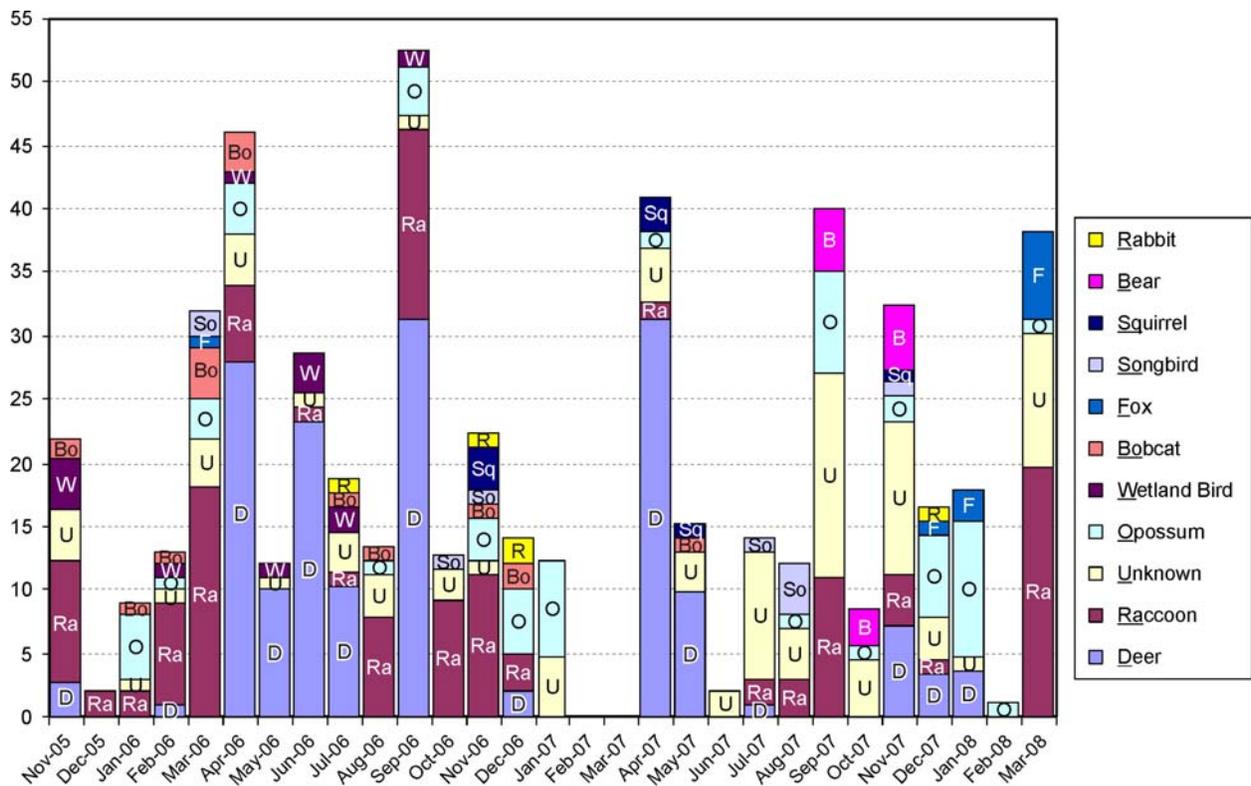
Underpass use was heavier in the dry areas of the underpass than in the wet areas that were within camera range. Wetland birds were the only species documented by cameras facing the wetland interior of the bridge. Only 2 wetland birds were documented by these cameras versus the 12 wetland birds documented by cameras facing the dry area. Because camera ranges could capture only a small extent (approximately 4%) of the wetland area, however, it is possible that these species used the underpass more than the data indicated.

Figure 5. Photographs Captured by Remote Cameras in the U.S. Highway 17 Underpass. A, great blue heron; B, black bear; C, bobcat; D, white-tail deer; E, raccoon; F, fox; G, example of an "unknown" species.

Figure 6. Number of Wildlife Documented Using the U.S. Highway 17 Underpass From November 2005 Through March 2008

Figure 7. Monthly Passage Frequency for the U.S. Highway 17 Underpass From November 2005 Through March 2008.   Data were not recorded from February through March 2007.

11

Black Bears

Following underpass and fence construction, no bear-vehicle collisions were known to have occurred within the extent of the 1.9 mi of fencing along the underpass (A. Deem, personal communication). However, in the fall of 2007, the researchers found a black bear on the roadside that had presumably been struck by a vehicle approximately 1 to 2 mi north of the underpass, beyond the span of the 10-ft-high fencing. This is an area of 4-ft-high fencing, which can easily be crossed by large species such as bear and deer.

Based on camera data, black bears were not documented using the underpass during the first year following its construction. This was not unexpected, given the findings of a previous study that suggested that an established bear trail extended up to and across the original U.S. Highway 17, approximately 1 mi north of the underpass (Wills, 2008). As mentioned previously, 13 bear crossings were documented through the underpass during the second year following its construction. If a similar crossing frequency continues in subsequent years, particularly by males during breeding season, it may be sufficient to satisfy the dispersal and reproductive needs that will help prevent isolation from populations further south. Definitive determination of the population benefits from the use of the underpass, however, would require knowledge of not only the number of individuals using the underpass but also their sex and genetic relationships (Clevenger and Sawaya, 2010).

These findings suggest that the underpass is successful thus far at facilitating the safe passage of black bears and thereby maintaining habitat connectivity across U.S. Highway 17. The results are consistent with the findings of other studies that animals can learn and adjust their movements once they discover the location of a non-threatening underpass (Forman et al., 2003; Gagnon et al., 2010).

Comparison of Study Findings with Underpass Monitoring Studies in the Literature

The results from this study indicate that the U.S. Highway 17 underpass facilitates passage for black bears and numerous other species traveling along or inhabiting the Paleo-Northwest River riparian corridor. Although the scope of the study did not lend itself to definitive determination of the factors that encourage use by wildlife, there are important features of the underpass that likely play a role. For example, the findings from this study are consistent with those of other underpass monitoring studies that found that large and open underpasses are successful at facilitating passage for black bears and other large mammals in the eastern United States (M. F. McCallister and F. T. Van Manen, unpublished data; Smith, 2003). The extensive 984 ft width of the underpass (which was determined by the need to span the wetland) is more than sufficient to provide for large mammal passage. However, in the design of an underpass for such species, the openness of the structure is critical to its success. Openness is largely a measure of ambient light in the passage; the larger the factor, the less of a narrow "tunnel" appearance of the structure (Reed et al., 1975). A previous study of a 10 ft by 12 ft box culvert (with a dark tunnel appearance) in Virginia found that deer commonly hesitated before crossing through the culvert and bears would approach the culvert and remain for several minutes without entering the culvert (Donaldson, 2005). At the U.S. Highway 17 underpass, however, deer and

bears did not hesitate and were not deterred by the smaller (8 ft) height of the much wider (and thus more open) structure.

In this study, the placement of the underpass between two high-quality habitats (a riparian corridor and a wildlife refuge), as well the plantings of herbaceous vegetation at the underpass entrances, may also have been important factors encouraging its use by wildlife (Smith, 2003).   The nearly 2 mi of fencing along U.S. Highway 17 (on either side of the underpass) is also an important element of this mitigation. As deer represented 30% of the crossings in this study, the fencing may play a critical role in minimizing deer-vehicle collisions along this section of roadway. A recent study in Arizona found that elk-vehicle collisions were reduced by 97% following the erection of 2.5 mi of fencing and wildlife underpasses along State Route 260 (Gagnon et al., 2010).

CONCLUSIONS

- *Results from the camera monitoring study of the U.S. Highway 17 underpass suggest that the underpass facilitates passage for numerous wildlife species.* A total of 550 crossings were documented over the 29-month monitoring period by at least 12 species. White-tailed deer represented 30% of all crossings.

- *The underpass is successful thus far at facilitating the safe passage of black bears, and the results suggest that bears may adjust their movements once they discover the location of a non-threatening underpass.* Cameras documented 13 bear crossings during the second year following underpass construction; if a similar crossing frequency continues in subsequent years, the underpass will continue to serve as a means for maintaining habitat connectivity for bears along the Paleo-Northwest riparian corridor.

- *The data did not support a conclusion that wildlife passage frequency increased over the course of the monitoring period; further, the data did not show evidence of seasonal or monthly trends.* Additional years of monitoring may be required to determine whether species' use increases over time and whether seasonal or monthly patterns exist in crossing frequencies.

- *Wildlife did not use the enlarged double box culvert during 3 months of camera monitoring.* This was not unexpected given the permanently flooded condition of the culvert.

RECOMMENDATIONS

1. *VDOT district environmental managers and construction engineers should continue efforts to coordinate with researchers and regulatory and resource agencies to implement mitigation that provides unimpeded movement for wildlife through important habitat corridors.* A map of statewide habitat corridors is planned for use by VDOT staff in new project planning (Donaldson, 2007).

2. *VDOT district environmental managers should contact the Virginia Transportation Research Council (VTRC) if additional studies on the placement, design, or effectiveness of new or existing wildlife underpass structures are desired. Minimal effort and expense would be required to conduct the monitoring given the existing monitoring equipment and resources available to VTRC.*

COSTS AND BENEFITS ASSESSMENT

The 11.6-mi newly constructed section of U.S. Highway 17 cost approximately $42 million. The bridge included along this highway cost $4.2 million, representing 10% of the project budget. Approximately $40,000 of the bridge cost was for additional fill used for berm construction to provide areas of dry crossing for wildlife.

As mentioned previously, the U.S. Highway 17 widening project was designated a 2004 Exemplary Ecosystem Initiative by the FHWA for protecting wildlife and preserving the ecosystem along the GDSNWR. This award identified the U.S. Highway 17 project above other projects as one that

- helps sustain or restore natural systems and their functions and values
- uses partnering and collaborative approaches to advance common goals
- uses the best available science in ecosystem and habitat conservation
- provides clear examples of innovative environmental solutions by transportation agencies and achieves high standards in the environmental process
- achieves high-quality results
- is recognized by environmental interests as being particularly valuable or noteworthy (FHWA, 2008).

Although it is difficult to monetize the benefits provided specifically by the underpass, the FHWA award firmly establishes that there are significant publicly recognized benefits from the application of this mitigation. These include facilitation of wildlife movement along an important habitat corridor (thereby decreasing the isolation and possible extinction of local species' populations) and a reduction in animal-vehicle collisions (resulting in improved driver safety, property damage savings, and a reduction in mobility/operations and carcass disposal costs to VDOT).

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