Title

Wildlife crossings in North America: the state of the science and practice

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Wildlife Crossings in North America: The State of the Science and Practice

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Abstract: In this paper we present results from a telephone survey as part of a National Cooperative Highway Research Program (NCHRP) project, *Evaluation of the Use and Effectiveness of Wildlife Crossings* (NCHRP 25-27). Specifically, we present a summary of North American efforts to mitigate road effects for wildlife. We stress the need to provide multiple wildlife passages along transportation corridors to begin to accommodate the movement of the full complement of species in an area. We surveyed over 250 transportation professionals in the United States and Canada by telephone to learn more about efforts to make roads more permeable for wildlife. We asked questions about both the practice and science associated with road ecology. Participants employed by agencies, private organizations, and academic institutions answered questions concerning wildlife crossings, planning for wildlife and ecosystems, animal-vehicle collision information, and past, current, and future research activities related to roads and wildlife. As of September 2005, we found that there were at least 460 terrestrial and 300 aquatic crossings in North America. Trends in practice over time since wildlife passages began to be installed in the 1970s appear to show an increased number of target species in mitigation projects, increased numbers of endangered species used as target species for mitigation, increasing involvement of municipal and state agencies, an increase in the number of passages and accompanying structures constructed, and a continent-wide trend of neglect of maintenance of these passages. The trends in the science revealed a tendency for a broadening of the scope of research in terms of the number of species considered, an increase in the length of time monitoring projects were conducted, and an increase in the number of participants in scientific monitoring of mitigation projects and in general road ecology research. There are several projects in North America where multiple crossings have been or will be installed to accommodate a large suite of species and their movement needs. These include Alberta's Trans Canada Highway mitigation efforts, Montana's U.S. Highway 93 mitigation projects, Arizona's projects along U.S. 93 and on State Route 260, Florida's I-75 Alligator Alley project, and Vermont's future Route 78 and US 7-SR 9 projects. These projects may be models for how road construction activities can increase the permeability of the roaded landscape. We also present recommendations to assist in the research, design, placement, monitoring, and maintenance of crossings. We summarize the state of the practice and science of road ecology with respect to wildlife with suggestions to increase permeability of transportation corridors, and to increase communication and cooperation among those who would be involved in the mitigation of roads and other travel corridors.

Introduction

How well are we mitigating the negative effects of roads for wildlife? Progress in the science and practice of road ecology in the past decade has increased dramatically, yet a summary of what has been accomplished and how these efforts are helping to make the roaded landscape more permeable for wildlife is lacking. In this paper we summarize the overall efforts and trends to mitigate roads for wildlife in North America as learned from a continent-wide telephone survey. We also suggest future needs in the practice and science of mitigating roads for wildlife.

Wildlife need to move across the landscape to meet their basic survival needs. Whether looking at phenomena such as long distance caribou migrations, butterfly movements, fish returning to inland waters to spawn, or frogs trying to find the nearest pond to lay eggs, there is a continuous theme of daily and seasonal movements throughout the entire life cycle of all faunal species. With our ever increasing "roading" of natural landscapes, barriers are created that tend to obstruct movements of both aquatic and terrestrial species. The inclusion of effective mitigation measures in our transportation programs and project plans, from the inception of long range plans, to the scheduled maintenance of roads and railways will help restore permeability to the roaded landscape and assist natural movement patterns. In North America, wildlife crossing passages have been installed along roads since 1950. Since that time they have been designed, built, monitored, and studied. While much has been learned, communication of results has been much less successful. One major theme in successful mitigation measures and in current scientific thinking of roads and wildlife is the need for restoring permeability. As biologists study movement needs of different species in a variety of ecosystems, it is increasingly evident that our efforts to help one or two focal species move under and over roads may not adequately compensate for the lack of permeability roads and railways cause for the entire complement of species in an area. Permeability is an essential concept to consider in efforts to accommodate wildlife in transportation corridors.

Permeability

There is general consensus that ecosystems and landscapes must be connected and permeable to support sustainable wildlife populations. The terms "connectivity" and "permeability" often are interchanged, but we argue that it is important to distinguish their meanings. Connectivity most often is used from an anthropogenic viewpoint. For example, when one looks at a map and sees a wildlife passage across that landscape, in the most fundamental sense of the word, the landscape is "connected." Of course, with more passages, the number of connections grows, but is the landscape permeable to species? The term "permeability" is perhaps best defined from an animal perspective and has to do with the allometric positioning of crossing structures based on species movement neighborhoods (Addicott et al. 1987). A "neighborhood" is an area that an animal uses to fulfill its daily needs. Some species migrate and may have a summer "neighborhood" as well as a winter "neighborhood." On a given landscape, a mouse does not use or move across that landscape in the same way as does a moose. The same landscape is viewed in very different ways by each species. The movement neighborhood of any species is defined by its size and vagility. When we define permeability in the context of a species' movement potential, i.e., by allometric scaling, we then have a way of restoring permeability across the landscape. By this definition, a permeable landscape allows free daily movement of a species across its home range (Bissonette, in prep). A permeable roaded landscape is one where the type and placement of wildlife crossings is such that it allows free movement for the complement of species in any given area. If only one crossing was installed over an area, it is likely that only a few species and perhaps only some individuals of a particular local population would be close enough to use the crossing. Connectivity would be maintained to some degree, but the overall permeability of the landscape for all wildlife species and all individuals would be low. Progress towards permeability begins when several different types of mitigation measures, e.g., different types and sizes of crossings, are placed close enough together throughout the course of the transportation corridor so that most species and individuals of populations adjacent to the road are able to use these crossings. A sufficient number of crossings would allow almost free daily movement so that members of most species would be able to find and use crossings within their home ranges. By facilitating daily movement, at least some measure of permeability is achieved. True permeability may not be achievable in practice on the roaded landscape; however, to the extent that barriers can be made less impermeable, then the benefits can be measured in sustainable and less isolated populations.

NCHRP 25-27

Permeability is an important goal of intelligent mitigation and road ecology research. This paper presents the results of a telephone survey that is part of a larger National Cooperative Highway Research Program (NCHRP) project, a three-year research effort titled, "Evaluation of the use and effectiveness of wildlife crossings" (also known as NCHRP 25-27). The objectives of NCHRP 25-27 are to convey the conceptual basis as well as practical management options for the placement of wildlife crossings to transportation professionals, biologists, and others concerned with wildlife and roads. The goal of this research project is to develop effective management guidelines in the form of a decision tool that will lead to effective *landscape connectivity* and the restoration of ecosystem integrity – while at the same time providing recommendations for efficient and effective transportation infrastructure in a cost-effective economic manner.

As part of the project, our research team is conducting several efforts that will assist in the design of the decision tool including: (1) a national telephone survey of state departments of transportation (DOTs) and provincial ministries of transportation (MoTs) to learn about how they mitigate roads for wildlife, (2) the compilation of 27 North American priorities for road ecology science and practice in dealing with roads and wildlife, (3) safety modeling to predict the common factors in animal-vehicle collisions across the continent, (4) the evaluation of past wildlife crossings in their success in reducing animal-vehicle collisions, (5) modeling of how the accuracy of the collection of animal-vehicle collision and animal carcass data influences the results of analyses, (6) evaluation of the indirect effects of roads through small mammal research along highways, and (7) development of allometric scaling equations using species home range and dispersal distance data to help determine the placement and spacing of wildlife crossings. The focus of this paper is to summarize the results of the telephone survey of United States DOTs and Canadian MoTs.

Methods

The telephone survey

A telephone survey was administered to agency personnel and others in all 50 United States, and most Canadian Provinces. The survey consisted of 25 questions centered on three areas of interest: (1) wildlife-road mitigation measure, (2) animal-vehicle collision data, (3) and transportation planning. Interviewees in the U. S. were selected from contact information on individual state project entries on the Federal Highway Administration's "Keep It Simple" website, and through consultation with Federal Highway Administration (FHWA) representatives. Primary as well as secondary and tertiary contacts were made. Canadian respondents were selected through personal contacts of NCHRP 25-27 team members. Once introduced to the survey, the contact was given the opportunity to refer the survey or specific questions to someone more knowledgeable within the agency. A minimum of two people were interviewed within every state to represent both the state DOT and the state (or Federal) wildlife agency. Interviewees not only provided answers to the survey questions, but were also asked to provide reports, articles, and photos of their mitigation measures, and DOT-sponsored research projects that focused on how wildlife move with respect to roads. The survey was conducted from July 2004 through September 2005.

Wildlife passage definition

An important component of this research was in the definition of a crossing passage. For this survey a crossing passage was defined as a new or retrofit passage over or below a roadway that was designed specifically, or in part, to assist in wildlife movement. Culverts and bridges already in place when fencing was installed to lead animals to these pre-existing structures were *not* included unless they had been altered with such methods as weirs for fish passage, shelves for terrestrial wildlife, rip-rap removed for wildlife movement, or other such similar actions. In many cases we had to make an informed decision on inclusion of the passage.

Results

Survey participants

As of 16 September 2005, 255 people had participated in this survey. The number of participants varied from one to 32 per state or province (figure 1 illustrates interviewees within the U.S.). In some states and provinces, it quickly became evident that information was not centrally available within the state DOT or provincial MoT, and biologists/planners within each district or region were called for their knowledge of crossings in their regions. Respondents included engineers, planners, and biologists/ecologists. The different expertise of the respondents provided a broad range of information not available from any single person. Respondents included representatives from every state DOT, some Canadian MoTs, most state wildlife agencies, the Federal Highway Administration, the U.S. Fish and Wildlife Service, the U.S. Forest Service, the National Park Service, university professors and research personnel, several non-profit natural resource-based organizations, and consulting companies.

Practice - historic crossings

The first documented wildlife crossing in North America can be traced to Florida outside the Ocala National Forest. A pair of box culverts was installed for black bears at the request of a private landowner in 1950 (Evink 1996). This initial action was the beginning of Florida's leadership in wildlife crossings in North America which continues today. The next documented round of wildlife crossings began in 1970, with the second and third crossings installed in Colorado and New York, both for deer. The first overpass in North America was built for deer and elk in 1980 over I-15 near the town of Beaver in southwestern Utah.

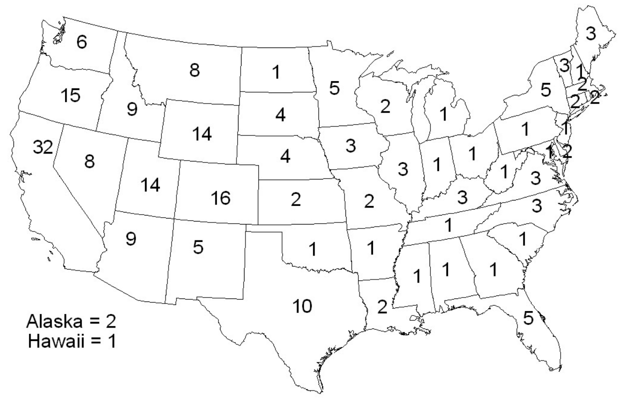

Figure 1. Number of survey participants per state, as of August 2005. (Canada not included)

Total crossings

The total number of wildlife crossings in North America can only be estimated: the number depends, among other things, not only on how they are defined, but also on who is asked, and if terrestrial and aquatic crossings are considered separately or together. From our data, we estimate that there are a minimum of 460 wildlife crossings in North America for terrestrial species, and 307 for aquatic species. Crossings are classified by type. In the United States there are at least 253 larger crossings at least two meters high that allow larger animals (e.g., deer, moose, elk, bear) to cross, 149 smaller crossings for other terrestrial wildlife, and more than 307 aquatic crossings for riparian-based species, such as fish. Although our data for Canada are still incomplete, there are a minimum of 56 terrestrial crossings that we have yet to classify. Results as of August 2005 can be seen in figure 2.

Trends in practice

In this study of North American wildlife crossings, a number of trends have become apparent. These trends are based on the information from crossings first established in the 1970s and 1980s throughout North America. These trends include an increase in the number of target species in mitigation projects, increases in the number of endangered species as target species for mitigation, increased involvement of municipal and state agencies, an increase in placement of accompanying structures, and a continent-wide trend of neglect of scheduled maintenance of these structures.

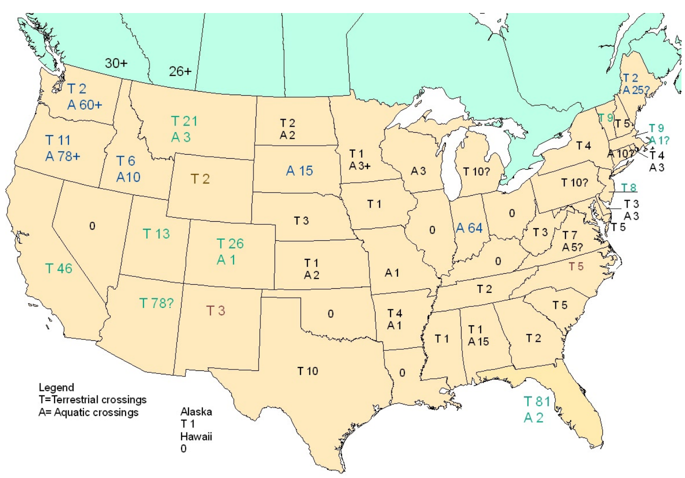

Figure 2. Number of wildlife crossings in each state and province of North America, as of August 2005. Some crossing have not been fully verified and located, and hence some states' numbers are followed by a question mark pending final verification.

Multiple crossings – achieving permeability
There are several projects in North America where a series of crossings has been or will be installed to accommodate a suite of species and their movement needs. A sample of these projects includes the Trans Canada Highway in Banff National Park, Alberta, with 24 crossings in place and eight more planned. These crossings include overpasses, underpasses, and culverts for species ranging from small mammals to grizzly bear and elk (Clevenger and Waltho 2000, Clevenger et al. 2003). In Montana, Highway 93 has 22 crossings of different sizes south of Missoula, and over 50 additional crossings planned from Sula at the Idaho border north to Polson at the south end of Flathead Lake in northern Montana. These crossings are typically intended for multiple species. Several have already been monitored, and they appear to be working for the intended species (Foresman 2001). In Arizona, Highway 93 has four crossings for species ranging from desert tortoises to bighorn sheep, and possibly as many as 50 more planned in the coming 10 years. In Florida the first series of crossings were built in 1992 along Florida's Alligator Alley for the Florida panther and accompanying wildlife species (Florida black bear, bobcat, deer, alligators, wading birds, fox, raccoon, opossum, fish, and others). Thirty eight crossings, from large underpasses to culverts were established over 64 kilometers (Foster and Humphrey 1995), apparently allowing for a higher degree of permeability than has been verified for most established crossings. Vermont has several simultaneous projects under construction across the state that may assist in creating better permeability in the roaded landscape. These include the Route 78 project near the Missisquoi National Wildlife Refuge, the Bennington Bypass on US 7, and work on State Highway 9.

Trends in science
This survey and our concurrent literature search revealed hundreds of relevant papers and reports related to wildlife crossings and roads. The most obvious scientific trends show a tendency for a broadening of the scope of research in the number of species considered, increases in the length of time for monitoring specific crossings, and increased numbers of partners in research projects. Monitoring of wildlife passages began in 1970 with the second underpass for wildlife in North America. This underpass was placed in the Vail Pass area along I-70 in Colorado and was monitored for mule deer use for four years with the most updated electronic technology of the time which included a video surveillance system (Reed et al. 1975). This level of monitoring was rare for passages placed during the following 20 years. Monitoring of passages has steadily increased during the past decade, and has significantly increased for the pre-construction phase of placing mitigation measures. Over the past decade there has been an ever increasing number of studies that considered multiple species near roads, thus broadening the knowledge base as well as mitigation efforts. Research projects today tend to monitor species' use of passages for greater lengths of time than studies conducted during the 1980s and 1990s, with an increase in the length of effort to several years post-construction. Finally, the scientific community is partnering with more entities than in past decades, broadening research to include connectivity analyses conducted by the consensus of natural resource professionals, and inclusion of other professionals in the design and placement of crossings. The increasing sophistication of technologies, such as geographic information systems (GIS), infra-red video cameras, and Global Positioning System (GPS) collars have greatly facilitated all aspects of scientific research of wildlife in relation to roads.

Discussion

Science – general recommendations for crossings
As part of research for the NCHRP 25-27 project, we have begun examining the general recommendations for installing wildlife crossings. Here we list the consistent trends that appear in the literature, conference presentations, and in our telephone interviews. This is what appears to be the consensus about what we know about the science of crossings:

- Bigger is better.
- Cover is important at the ends of passages and for some species inside the passage.
- Ungulates and carnivores appear to prefer different types of passages, for example, ungulates may prefer overpasses while certain carnivores prefer underpasses (see Clevenger's work in Banff).
- Natural light in the middle of tunnels or under-road passages (e.g., as might be provided under a divided lane highway where light is allowed into the underpass in the median) may be helpful for most prey species. Whether carnivores prefer light is unknown.
- Reduction of noise is helpful.
- In general, reduced human use, especially at night, is thought to facilitate passage.
- Pathways or shelves for wildlife to pass through underpasses or culverts with water appear to work for animals as large as deer and moose and for smaller animals, e.g., mice and voles.
- Considerations concerning special conditions for the target species or suites of species are necessary, for example:
    - Deer and perhaps other ungulates require a larger openness ratio than other mammals.
    - Some deer in urban-suburban situations will use pre-existing structures that are far smaller than what their counterparts in more natural landscape will use, for example, a culvert less than 2 meters high or with a 90-degree angle, suggesting that some behavioral plasticity exists in deer response.
    - Amphibians need tunnels that are wet and cool.

- Small mammals need cover in the form of logs, rocks, and bushes.
- Pronghorn need open, natural conditions as much as possible.
- Fish passage through perched culverts decreases significantly in relation to culvert height. Juvenile fish especially need culverts that rise no higher than two body lengths above natural water levels and they prefer low natural volume flows (1cfs) (May these proceedings).
- Fish can more readily cross culvert bottoms that mimic natural stream bottoms better than concrete or corrugated steel.
- Fish weirs may be necessary to accomplish low flow rate in existing culverts.

- When exclusion fencing is used, it is essential to include accompanying mitigation, such as jump outs (escape ramps), because large animals often access fenced right of ways.
- Ensure conservation protection for lands and waterways on both sides of the passages.
- Allow for a straight line of site through a passage for animals.
- Involve local biologists in all phases of project.
- Use adaptive management to monitor and improve future designs and maintenance based on monitoring results.
- In order to help restore permeability, provide several different types of crossings, or crossings adapted for suites of species. For example, provide cover, wildlife shelves or paths, small tubes, a culvert within a culvert, and similar modifications.
- Passages and accompanying mitigation elements, e.g., passage floors and holes in fencing need to be continually maintained and repaired in order to help insure their continued use.
- Monitor passage use for at least 3 years after construction: it may take wildlife 2 years or more to adapt, especially if they use the area only for seasonal migration.

Projects to watch

While every state and province in North America may be at a different stage in creating more permeable roads for wildlife, a few existing projects and programs might serve as examples of what can be done to mitigate roads for wildlife. The route that will perhaps be the most mitigated in the United States is U.S. 93, which extends from just northwest of Phoenix, Arizona, through Nevada, into Idaho, and through Montana and into Alberta. This road already has a minimum of four crossings for desert tortoises and ungulates in Arizona, and several crossings for fish and small mammals and 20 large mammal crossings in Montana. This highway will have an estimated 40 additional crossings in Montana, including one overpass, and dozens of crossings in Arizona, for a total of over 125 crossing across its stretch. Perhaps the best known of mitigation measures are those in Banff National Park on the Trans Canada Highway, with two overpasses and 22 underpasses over 45 kilometers, and 8 more planned along the next stage of construction (McGuire these proceedings). An example of a well designed mitigation and research project is the widening and mitigating of State Road 260 in Payson Arizona on the Tonto National Forest. This project was designed, constructed and monitoring in joint collaboration with the Arizona DOT, Arizona Game and Fish, the U.S. Forest Service, and several other collaborators. Seventeen bridges and culverts have been placed along the highway so that elk, mule deer, and other wildlife can cross safely underneath. The biologists working on the project have monitored wildlife use of these passages through the use of GPS collars, video surveillance systems, and road associated mortality data (Dodd and Gagnon these proceedings). Colorado's Mountain Corridor project for I-70 through the Rocky Mountains (Kintsch, these proceedings) with a possible overpass, and Washington's I-90 Snoqualmie Pass project (Wagner these proceedings) will use as many as a dozen new crossings per project. In the east, there are at least nine crossings constructed or under construction in Vermont and at least a half dozen more scheduled for the next five years, many of which will provide opportunities for many species. Florida continues to construct crossings, with 30 more planned for the next 10 years, including an overpass near Orlando.

Summary

Wildlife crossings and road ecology have evolved dramatically in the 55 years since the first crossings were installed in Florida. Wildlife and roads will continue to be an issue for the scientific and transportation communities as well as the general public. In fact, a recent survey of over 1,000 registered voters in the United States found that 89 percent of those surveyed felt that roads and highways were a threat to wildlife (Weigel 2005). The viability and sustainability of wildlife populations will be enhanced by the development of knowledge necessary for installing mitigation measures that create more permeable landscapes, thus allowing free movement by species. To achieve the goal of greater landscape permeability, it will take dedicated work to help insure that consideration of wildlife passages is included early in long-term highway planning, at the project level and in scheduled maintenance operations, as well as support for research that assesses whether passages are meeting stated goals and objectives. Successful mitigation will require effective communication between all stakeholders, including planners, engineers, and administrators. It is important to learn from our successes and failures and build on the current level of awareness among the profession and the public to create a continent-wide system of passages. It is a vision that will take time and needs our collective efforts.

Biographical Sketches: Patricia Cramer (Patty) is currently research associate for the NCHRP project "Evaluation of the Use and Effectiveness of Wildlife Crossings," with the USGS Utah Cooperative Unit at Utah State University. Her bachelor's, master's, and Ph.D. (University of Florida) degrees are all in wildlife conservation. Her work in road ecology includes time as a consultant for Western Transportation Institute at Montana State University, and as a member of the Paynes Prairie Wildlife Coalition which was instrumental in placing a herpetile wall and four additional ecopassages for wildlife in Paynes Prairie State Preserve along a state highway in Florida. She has also served as a visiting assistant professor at Montana State University and the University of Florida. Her research interests center on wildlife connectivity in the landscape with special emphasis on wide ranging carnivores.

John Bissonette is leader of the USGS Utah Cooperative Fish and Wildlife Research Unit and professor, Department of Forestry, Range and Wildlife Resources, in the College of Natural Resources at Utah State University. His degrees were received from University of Vermont (B.A.), Yale University (M.F.S), and the University of Michigan (Ph.D.). His research interests include landscape ecology, wildlife management, and road ecology. He spent 5 months in Germany in 2002 at the Technic University of Munich as a Senior Fulbright Scholar, and four months as a visiting professor at the Albert-LudwigsUniversitaet Freiburg in fall 2005. He was co-author of *Road Ecology: Science and Solutions*. When not working he rides his horse in the mountains of Utah and his Harley on the backroads of the West.

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