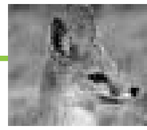

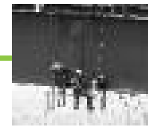

Transportation Ecology and Wildlife Passages

The State of the Practice and Science of Making Roads Better for Wildlife

PATRICIA C. CRAMER AND JOHN A. BISSONETTE

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Transportation ecology is a newly developed science that focuses on the interactions of organisms and the environment with transportation infrastructures and vehicles (*1*). A major goal is to understand the effects of roads on wildlife populations and the effectiveness of measures to assist wildlife over and under roads—to prevent collisions with vehicles and to help wildlife move across the natural landscape.

The practices and science to accommodate wildlife along transportation corridors aim to maintain safety and ecological integrity. In the past, transportation systems often were built with little regard for the need of wildlife to move. As wildlife–vehicle collisions with large animals, such as deer and moose, became more of a problem, the safety issues of wildlife on the road began to be addressed, mainly by fencing roads and installing wildlife crossings.

As the ecological effects of roads on wildlife and fish populations and on ecological processes such as water movement were identified, additional mitigation measures were developed to help wildlife, fish,

Photo: Patricia Cramer

A wildlife overpass allows these does to cross I-15 (not visible) in Southern Utah.

Photo: Patricia Cramer

Deer graze near a roadway in Utah. The practices and science to accommodate wildlife along transportation corridors aim to maintain safety and ecological integrity.

and water move under and over roadways. With improved understanding of these effects—and of the cost and efforts to mitigate these effects—planning for ecological systems and their inhabitants is becoming part of long-range planning for transportation, to avoid, minimize, and reduce the costs instead of waiting until later on in the project stage.

Most states have begun accommodating wildlife and fish along transportation corridors, with hundreds of terrestrial crossings and thousands of aquatic crossings. The ecological and safety reasons are clear, and trends are emerging in the mitigation of the effects of roads on wildlife across North America.

Safety Concerns

Safety is the most important wildlife-related concern for transportation agencies, but more than ever before, transportation planning and projects are taking into account the ecological effects of roads and vehicles on multiple species. More than 1.5 million wildlife–vehicle collisions occur annually in the United States (2).

Many of these collisions cause human deaths. In 2008, the Highway Loss Data Institute reported that

Photo: Patricia Cramer

Wildlife crossing over roads can pose danger to animals and motorists. In 2008, the Highway Loss Data Institute reported that the number of fatalities from wildlife–vehicle collisions has more than doubled in the past 15 years.

the number of fatalities from wildlife–vehicle collisions has more than doubled in the past 15 years, with 223 people killed in 2007. In addition to human deaths and injuries, other costs are associated with these accidents. In a study of deer–vehicle collision costs in Utah from 1996 to 2001, Kassar found that the average cost for vehicle damage, lost lives, deer lost values, and human injury from a single accident was $3,470 (*3*). This conservative estimate would place wildlife–vehicle collision costs nationwide at more than $5.2 billion annually. Others estimate the cost as closer to $8.3 billion (*4*).

These averages also can be used to evaluate the cost-effectiveness of mitigation measures. For example, a wildlife crossing that costs $1 million would pay for itself over the service life of the structure if it prevented 180 to 288 collisions with wildlife—depending on the cost estimates used.

Transportation ecologists are only beginning to understand the many costs of vehicle collisions and road effects on populations of animals and ecosystems. According to averages calculated in one study, 1 million vertebrates are killed each day on U.S. roads (*5*).

Preserving Populations

Many ecologists are concerned about animal populations and their ability to exist in the presence of roads. If a population cannot sustain its numbers because of high rates of road-related mortalities or because of impediments to movement, the species may face local extinction.

An example is the Florida panther, a highly endangered species. In 2007, at least 15 panthers were killed on Florida roads. The population of 80 to 100 animals cannot compensate for this road mortality.

Gibbs and Steen found a higher percentage of male to female turtles in wetlands near roads than in wetlands at a distance from roads, because of the mortality associated with the females moving across or near roads to nest upland (*6*). Another study discovered signs of genetic isolation among bighorn sheep populations in southeastern California mountain ranges that were bisected by Interstate highways (*7*).

Data-based research results such as these offer insights into how roads and traffic affect wildlife and can assist in developing mitigation measures for roads and ways to avoid building new roads in ecologically sensitive areas. Efforts to mitigate and avoid have grown exponentially in the past four decades (*8*) as transportation agencies have become more concerned about wildlife and about potential methods for mitigation.

Initiatives and Approaches

As concerns rise for all species affected by roads, initiatives and legislative actions are directing transportation agencies to consider during the planning processes the needs that terrestrial and aquatic species have for ecological connectivity. For example, under Washington State law, culverts that block the passage of salmon must be identified and replaced, whether as part of a transportation project or as a stand-alone project. A 2007 Washington State Department of Transportation (DOT) Executive Order directs regional and statewide long-range transportation plans to identify potentially affected fish and wildlife habitats as early as possible during planning and to seek opportunities to restore habitat connectivity already damaged by transportation corridors.

The Vermont Agency of Transportation and the Vermont Fish and Wildlife Agency have signed a memorandum of agreement to work together to improve the accommodation of wildlife and aquatic organism movement around and through transportation systems and to minimize habitat fragmen-

Photo: Florida DOT

This Florida panther, a highly endangered species, uses a wildlife crossing near Big Cypress, Florida.

tation caused by transportation infrastructure.

In 2008, the Western Governors' Association (WGA), representing 19 states, adopted the Wildlife Corridors Initiative. The WGA Transportation Working Group developed policy recommendations for the initiative that would prioritize the preservation of wildlife corridors and crucial habitat in transportation planning, design, and construction.

At the national level, Section 6001 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005) instructs transportation agencies in long-range transportation planning development to consult with state, tribal, and local agencies responsible for land use management, natural resources, environmental protection, and conservation. The agencies must compare the transportation plans with the other groups' plans or maps, to evaluate potential impacts. The long-range

Best Practices for Reducing Wildlife–Vehicle Collisions

PATRICK T. MCGOWEN AND MARCEL P. HUIJSER

Approximately 300,000 collisions between cars and large animals—mostly deer—are reported each year on U.S. highways, and the number is increasing by about 6,700 per year. Insurance industry data and carcass tallies, however, indicate that the actual number of wildlife–vehicle collisions (WVCs) with large animals is 1 to 2 million per year. These collisions cost society $8 billion annually.

The U.S. Congress directed the Secretary of Transportation to conduct a national study of WVCs, detailing the causes, impacts, and potential solutions. The report to Congress was submitted in November 2007, and the Federal Highway Administration is to publish the report. FHWA recently released a manual with technical guidance on measures that are considered best practices.

PHOTOS: U.S. FISH AND WILDLIFE SERVICE

*Several species threatened and endangered by road traffic (*left to right*): Bighorn sheep, San Joaquin kit fox, American crocodile, bog turtle, and Hawaiian goose.*

WVC Characteristics and Threats

Compared with other crash types, collisions with wildlife

- Occur most often on two-lane, low-volume roadways;
- Are more likely to be on straight, dry roads;
- Happen more frequently in areas with large wildlife populations;
- Cause less severe crashes—except when the collisions involve either moose or motorcycles;
- Occur where roadways cross drainages;
- Are mostly single-vehicle crashes;
- Occur more often during early morning and evening hours;
- Occur more frequently during the fall and spring months; and
- Show less of a peak for younger and older drivers.

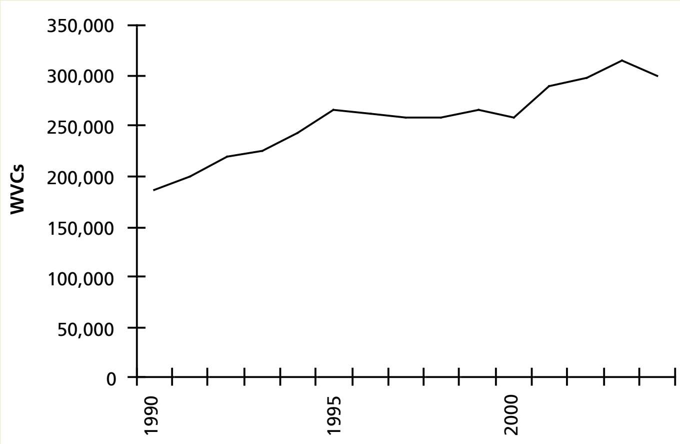

***FIGURE 1** Number of wildlife–vehicle collisions (WVCs), 1990–2004.*

Road mortality is a substantial concern in the conservation of some species. The report identifies 21 threatened and endangered species for which road mortality is among the major threats to survival in the United States:

- *Mammals:* Lower Keys marsh rabbit, Key deer, bighorn sheep (peninsular California), San Joaquin kit fox, Canada lynx, ocelot, Florida panther, red wolf.
- *Reptiles:* American crocodile, desert tortoise, gopher tortoise, Alabama red-bellied turtle, bog turtle, copperbelly water snake, eastern indigo snake.
- *Amphibians:* California tiger salamander, flatwoods salamander, Houston toad.
- *Birds:* Audubon's crested caracara, Hawaiian goose, Florida scrub jay.

Photo: Z. Funkhouser, Idaho Transportation Department

Culvert replacements are opportunities for transportation planners and wildlife ecologists to accommodate wildlife movement. Pictured (*left*) is an Idaho culvert before and (*right*) after rehabilitation.

Many more species are affected by other impacts of roadways, such as loss, reduction in habitat quality, or fragmentation of habitat.

Expert Panel Recommendations

To identify measures to reduce the numbers of animal–vehicle collisions, an expert panel was formed with representatives from resource agencies, state departments of transportation, nongovernment organizations, and universities from across the country. The panel received a draft of the report to Congress and categorized the effectiveness of more than 30 measures for reducing WVCs with large animals.

According to the panel, measures that should be implemented include the following:

- Wildlife fencing,
- Wildlife underpasses and overpasses with fencing, and
- Public information and education.

Although uncertain that public information would reduce crashes, the panel was convinced that public information and education were good practice.

Measures that should be researched further include the following:

- Reducing speed by traffic calming measures, reducing the posted speed limit, or reducing the design speed;
- Installing warning signs that are larger, nonstandard, seasonal, or triggered by animal detection;
- Developing in-vehicle devices to warn drivers about animals on the roadside;
- Improving visibility through lighting or by removing vegetation;
- Avoiding vegetation or deicing alternatives that may attract animals to the roadway;
- Reducing population size through culling or habitat alteration;
- Keeping animals off the roadway with boulder barriers, long tunnels and bridges, or overpasses and underpasses without fencing;
- Reducing traffic volume;
- Using crossing guards to stop traffic for wildlife;
- Installing wider, more reflective white stripes; and
- Expanding the median.

FIGURE 2 Total approach to reducing WVCs.

The panel recommended that the following measures should neither be implemented nor researched further:

- Warning the driver with standard wildlife warning signs or with reflective collars on wildlife;
- Warning animals or keeping them off the road with such devices as reflectors and mirrors, audio signals in the right-of-way, deer whistles on vehicles, scent repellents, hazing, intercept feeding, or deer flagging models;
- Attempting to reduce the wildlife population through relocation or antifertility treatments; and
- Scheduling seasonal road closures.

Mitigation only at known locations of frequent animal crossings may not reduce WVCs significantly—the approach must be comprehensive. Good data are needed to identify and prioritize the mitigation locations. The problem must be considered in the context of the landscape and with an understanding of the target species. Principles that minimize the potential for WVCs should be incorporated into alignment selection and road design. The measures that are implemented should be monitored, evaluated, and published.

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Photo: Patricia Cramer

A moose makes use of a wildlife crossing at US-89 in Utah. Several states and provinces have built multiple wildlife passages for a range of species.

plans must include a discussion of potential environmental mitigation activities with the greatest potential to restore and maintain environmental functions affected by the plan.

The federal natural resources agencies and the Federal Highway Administration have developed Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects, which helps agencies work together over the long term to protect natural resources, to mitigate harmful effects, and to ensure that mitigation agreements are kept.[1] The approach is evolving to assist in larger-scale spatial and temporal analyses of transportation effects on ecological communities and in actions that can minimize these effects.

[1] www.environment.fhwa.dot.gov/ecological/eco_index.asp.

Assessing Road Barriers to Aquatic Species

Lessons Learned in the Northwest

MATTHEW D. BLANK

Many of the estimated 1.4 million road–stream crossings throughout the United States use culverts for water to pass underneath the roadway. Culverts, however, can create barriers to the upstream movement of aquatic species and, in some cases, to the downstream movement. Many different methods are used to assess whether a culvert crossing is a barrier. Varieties of barriers include the following:

- A total barrier, which allows no movement;
- A partial barrier, which allows only some species or life stages within a species to move; and
- A temporal barrier, which allows movement at only some flow rates.

Different techniques can yield different assessments. One technique may identify a structure as passable, yet another may identify the same structure as a barrier. The goal is for a culvert to provide the free passage of all aquatic species in the stream for all flows.

Identifying Barriers

Total barriers are easy to identify. Culverts that have large drop-heights at the downstream outlet will limit severely—or prevent—the upstream movement of many fish species; at some height, all species will be blocked—including good leapers like trout and salmon. The U.S. Forest Service in Montana has established 6 feet as the leap height threshold for rainbow trout.

This culvert in western Montana serves as a leap barrier to resident fish species.

Another type of total barrier occurs in medium- to high-gradient streams. Without baffling systems or natural substrate bottoms, culverts at steep slopes will generate fast flows. The velocity of water can become too fast for aquatic species to swim or crawl against without exhaustion. In contrast, road crossings that mimic natural stream channel conditions or that have properly designed and constructed baffling systems to slow the water down and to provide resting areas are easy to identify as passable. Culverts between these extremes are difficult to assess.

A concrete box culvert in a medium- to high-gradient mountain stream. The culvert width is less than the width of the stream channel; therefore, during high flows, as shown in the photo, the constriction creates a velocity barrier to the upstream passage of most fish species. Because the water velocities also create scouring downstream, the culvert includes an outlet drop, which fish must negotiate in addition to the water velocities within the structure.

Contributing to the difficulty are the changing flow conditions in the stream and the crossing. An assessment at low-flow conditions may find the crossing passable; however, as the flow rate increases, the velocity of the water may reach a point at which it

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Multispecies Crossings

Wildlife crossings—which help wildlife move over and under roads—have been constructed in North America since 1973, when Colorado installed the first underpass for wildlife under Interstate 70 near Vail Pass. More than 700 terrestrial and thousands of aquatic passages accommodate wildlife in the United States and Canada (*9*).

A review of 26 studies examining the effectiveness of 76 crossings revealed that all of the crossings passed wildlife, and that 74 passed the target species (Cramer, unpublished data). Many crossings initially were built for a single target species, chiefly deer. In the 1980s, Florida DOT built 38 wildlife passages under Interstate 75 in Southern Florida, primarily for

PHOTO: K. MORGAN, ARIZONA GAME AND FISH

A bighorn sheep crosses US-93 in Arizona using an underpass.

limits or prevents passage. During high-water periods, excessive water depth, high velocities, moving bedload, and debris can create conditions that are unsafe for measurements and that prevent the use of many assessment techniques.

Regional Screening

One approach to performing quality assessments of a large number of culverts is to develop a regional screening tool. The tool would apply physical parameters such as culvert length, slope, and outlet drop height—combined with information about the locomotive abilities of the aquatic species within the stream—to separate the culverts into total barriers, passable barriers, and undetermined. Structures that cannot be assessed can be grouped by physical, geomorphic, hydrologic, and biological attributes.

More detailed assessments can be performed on a subset within each group, using a direct measure of passage. Passive integrated transponder—or PIT—tags placed inside representative individuals of the aquatic species of interest are effective as a direct measure of passage, even during high-water periods; detection antennae are installed on the upstream and downstream ends of the structure. The technique is time-consuming and labor- and equipment-intensive; nonetheless, natural movements can be monitored in relation to a range of flow conditions.

Results from the direct assessments can be used to determine or refine regional thresholds for structures within each group for various species and life stages. Passage can be inferred for structures that were not directly assessed. Thresholds that are defined and refined for a region should be published and pooled nationally.

Comprehensive and Practical

An assessment should consider all potential barriers—including irrigation diversions and dams—on a watershed scale. Entities beyond the transportation agencies should be involved, because the solutions to aquatic connectivity are the shared responsibility of all landowners, public and private. Restoring passage at a single crossing may expand the range of an already isolated population only marginally if other barriers remain upstream or downstream. Assessing a structure or all structures for all aquatic species that live within the watershed may not be practical; identifying a priority species may be necessary.

Direct Approach
Monitor movement directly with a field experiment that measures aquatic species movement and compares the movement timing to flow conditions in a structure.

- Tagging studies: mark-recapture, PIT tagging, or others (e.g., radio telemetry)
- Visual observations
- Video camera

Indirect Approach
Approximate movement potential using thresholds, hydraulic modeling, or comparisons between population characteristics measured upstream and downstream of a structure.

- Regional screen based on field and laboratory experiments that establish thresholds such as maximum outlet drop height, maximum culvert slope, or slope by length
- Hydraulic modeling synthesized with locomotive abilities of aquatic species
- Comparisons between upstream and downstream population characteristics
- Genetic differences

FIGURE 1 Direct and indirect approaches to assessments of culverts.

After assessments are complete, and the decision is made to replace or retrofit a structure, design can begin. Many state departments of transportation, such as Maine and Washington, as well as the Federal Highway Administration, have prepared design guides for fish passage at newly constructed and at retrofitted crossings.[a]

In general, an assessment should be as accurate as possible—a culvert that is limiting passage should be identified as a problem. Many aquatic species in U.S. streams and rivers face daunting challenges for long-term survival and depend on connected habitats. Making the nation's road crossings passable for these species is important and can be achieved with proper assessment, decision making, design, and construction.

[a] For more information about *Hydraulic Engineering Circular 26: Fish Passage at Bridges and Culverts*, see www.fishpassage.wsu.edu/.

the Florida panther but also for all other species in the area. This was the first set of multiple passages for multiple species.

Passing many species with different movement abilities helps to promote permeability, the ability of a variety of wildlife to move across a landscape in the course of daily activities and during dispersal movements. To create a series of wildlife passages that provide permeability for multiple species is a goal of many transportation ecologists.

Several states and provinces have built multiple wildlife passages for a range of species. Whenever the Trans-Canada Highway is widened in its stretch through Banff National Park in Alberta, Canada—or to the east or west of the park—wildlife underpasses and overpasses are built. Multiple species of mammals from grizzly bear to pine marten traverse the 24-plus passages; researchers have documented more than 100,000 wildlife crossings in the past two decades (*10, 11*).

US-93 in Montana incorporates more than 55 wildlife passages, with another 20 or more planned. Remote trail cameras have revealed many species using these passages, including puma, white-tailed and mule deer, black bear, porcupine, great horned owl, and others. A series of three extended bridges along US-7 in Vermont—known as the Bennington Bypass—has proved effective in passing multiple wildlife species, from white-tailed deer and bobcats to small mammals. Future projects to create multiple passages for wildlife include Washington State's I-90 project, with 17 wildlife passages; and Colorado's I-70 passages, which will offer an overpass for wildlife.

Key Opportunities

Most wildlife crossings are created in conjunction with highway upgrades. Lane additions, bridge and culvert replacements, and other road improvements are key opportunities for transportation planners and wildlife ecologists to find ways to accommodate wildlife movement.

Stream flow is a major consideration when aging culverts are replaced. During these replacements, fill can be removed and a bridge installed to allow wildlife movement, especially along the riparian corridors, which are natural movement pathways for terrestrial and aquatic wildlife.

Culverts can be enlarged to allow for terrestrial movement along the sides of a stream. These upgrades allow terrestrial wildlife and anglers to pass under the road without having to negotiate water or large rocks that may be placed for rip rap. If planned correctly, these enlargements also facilitate more natural hydrologic flow, and can assist with storm water runoff, an important feature in preparation for hydro-

Photo: Z. Funkhouser, Idaho Transportation Department

Mitigation measures such as culverts help fish, like this steelhead, move under roadways.

logic changes associated with climate change.

Terrestrial structures can be retrofit or upgraded for wildlife permeability. For example, New Mexico DOT is improving wildlife structures along Interstate 40 and State Highway 333 in Tijeras Canyon. To make the roads more permeable for wildlife, New Mexico DOT is retrofitting a bridge underpass by widening a shoulder for wildlife pathways; clearing brush near three bridges to give deer and other prey better visual clearance; and installing wildlife-proof fences, as well as escape ramps and at-grade wildlife crossings with motorist warning systems.

Guidance and Tools

When designing new and upgraded transportation infrastructure, state and provincial transportation agencies are increasing their efforts to find thousands of opportunities to accommodate the needs for wildlife, fish, and ecological processes to move. With more than 6.4 million kilometers of roads in the United States (*1*), the opportunities are ample. States, provinces, and local entities are also finding that earlier consideration of wildlife and ecological needs in transportation planning offers more opportunities to avoid and minimize potential project impacts well in advance of the need for mitigation, saving time and money.

As these practices spread and the science develops, reports and tools are becoming available for planners and practitioners. For example, a recent National Cooperative Highway Research Program (NCHRP) project, Evaluating the Use and Effectiveness of Wildlife Crossings,[2] developed a website that includes a decision tool to assist road planners, engineers, and wildlife ecologists in mitigating roads for wildlife.[3] The tool is also available on the website of the American Association of State Highway and Transportation Officials' Center for Environmental Excellence.[4] In addition, the International Conference on Ecology and Transportation holds biennial meetings and publishes all papers presented.[5]

Photo: M. Watson, New Mexico Department of Game and Fish

New Mexico Department of Transportation is retrofitting a bridge underpass in Tijeras Canyon by widening a shoulder for wildlife pathways.

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[2] NCHRP Project 25-27 was the basis for this article.

[3] www.wildlifeandroads.org.

[4] http://environment.transportation.org/environmental_issues/wildlife_roads /decision_guide/manual/.

[5] www.icoet.net/.