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# Highway Crossing Structures for Wildlife: Opportunities for Improving Driver and Animal Safety

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Cover: A wildlife overpass near Snoqualmie Pass that is part of a network of crossings designed for safe passage across Interstate 90 by a variety of species, such as elk, cougars, and river otters, that call Okanogan-Wenatchee and Mount Baker-Snoqualmie National Forests home. Photo by Atkinson Construction.

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Robert Ament, Sandra Jacobson, Renee Callahan, and Marta Brocki, Editors

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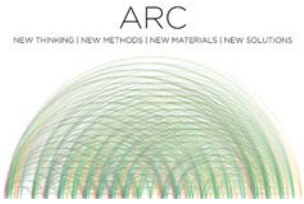


## Abstract

**Ament, R.; Jacobson, S; Callahan, R.; Brocki, M., eds. 2021.** Highway crossing structures for wildlife: opportunities for improving driver and animal safety. Gen. Tech. Rep. PSW-GTR-271. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 51 p.

Wildlife crossing infrastructure is a tool for mitigating the disruption of native wildlife resulting from the extensive U.S. road network, a source of wildlife-vehicle collisions that also threatens motorist safety. This report explores the opportunity to renovate this network from one that is designed to serve the needs of people to one that also proactively accounts for the needs of wildlife, while increasing the safety of both. The many challenges to implementing a systematic approach to wildlife mitigation are explored, including how long-range transportation plans often lack information on wildlife needs, the lack of early coordination of wildlife concerns in transportation plans and projects hinders effective mitigation, agency missions often fail to align, easily implementable opportunities are often missed, and no overarching policy requires inter-agency integration for mitigating wildlife-vehicle collisions and wildlife connectivity. Acknowledging these challenges, this report further highlights opportunities and a wide variety of support for wildlife crossings. In addition, measures are enumerated to further strengthen support for the deployment of wildlife crossing structures, and suggestions for a path forward are mapped out.

Keywords: road ecology, wildlife-vehicle collision, landscape fragmentation, wildlife crossing infrastructure, transportation network.

## Executive Summary

Developed collaboratively by a team of engineers, ecologists, biologists, landscape architects, and policy experts, this report summarizes the benefits and challenges to investing effort and funding to support a nationwide commitment to a systematic network of wildlife crossing structures to increase driver and animal safety. Specifically, this report addresses two key issues:

1) Illuminates the safety, ecological, economic, and social benefits of highway crossing structures for wildlife
2) Identifies funding mechanisms, partnerships, and policy implications that hinder or facilitate the standard practice of constructing wildlife crossing structures where they are needed

### The High Cost of Wildlife-Vehicle Collisions

The United States has a road network of more than 4,000,000 miles to transport people and goods. While an asset overall, this network presents a safety issue for drivers and is a major source of disruption for native wildlife, as evidenced by an estimated 1 to 2 million collisions that occur each year involving motorists and wildlife in the United States. These collisions result in 26,000 human injuries and 200 human fatalities at an annual cost to Americans of $8 billion (Huijser et al. 2008). In addition to the human toll, millions of animals die each year in collisions with vehicles, and others are prevented from accessing important parts of their habitat, jeopardizing our rich wildlife heritage (sec. 1).

### The Myriad Benefits of Wildlife Crossing Structures

Unlike many large-scale problems facing society today, there are proven solutions to reduce wildlife-vehicle collisions and reweave native habitats. Wildlife crossing structures designed or retrofitted to provide safe passage for wildlife above (overpasses) or below (underpasses) a roadway, coupled with fencing, have been shown to reduce wildlife-vehicle collisions by up to 97 percent (Huijser et al. 2009) (sec. 2.1). Indeed, where the total economic cost associated with wildlife-vehicle collisions along a given highway segment exceeds the expense of building a wildlife crossing structure to allow animals to safely cross the road, **it actually costs society less to solve the problem of wildlife-vehicle collisions than it costs to do nothing (sec. 2.2).**

In addition to increased highway safety for people and animals, wildlife crossings provide these benefits:

- Sustained ecosystem integrity due to connected habitats at a local scale
- The opportunity to retain or improve intact ecosystems at a landscape scale when structures are built where they are needed.

- Greater likelihood of viable wildlife populations and adaptability to climate change
- Priceless social values, including stewardship over public resources, education, and citizen engagement (sec. 2.3)

Every highway project is unique when it comes to determining what is necessary to mitigate its effect on wildlife. As a result, standardized designs for wildlife crossings are generally not available. Nonetheless, despite being a relatively new field of applied science, two decades of research reveal some consistent findings:

- Wildlife crossing structure design, size, and placement influence how different species respond to structures
- Some species prefer large, open structures, while others prefer smaller structures with less light
- Wildlife crossing structures designed for multiple species maximize biodiversity conservation
- Because animals often exhibit a learning curve of several years to find and habituate to wildlife crossings, performance evaluations need to be longer term to reliably assess effectiveness
- Land management surrounding wildlife crossings is a key factor in determining their effectiveness; therefore, coordination in the short and long term between transportation and land management agencies is essential
- Fencing keeps animals off the highway and directs them to structures, thus enhancing the effectiveness of wildlife crossing structures; in contrast, fencing alone (without crossing structures) creates a barrier that can keep animals away from crucially important habitat areas (sec. 2.4)

Planning and prioritization are also essential to focus limited resources on locations exhibiting the highest collision risk and conservation priority. By prioritizing conservation improvements as early as possible using data-based planning, state transportation agencies can more effectively address state and regional conservation needs in the short and long term (sec. 2.5).

## Challenges to Transforming the U.S. Road Network

One of the key challenges to adopting a systematic approach to mitigating wildlife impacts from highways is the fact that no single agency is responsible for ensuring that animals are able to move freely across the landscape. There are also additional challenges to implementation:

- Federal and state transportation and land management agencies have missions, approaches, and priorities that may not overlap
- Long-range transportation plans generally do not include wildlife mitigation or crossing provisions
- Federal and state natural resource agencies are often too resource or time constrained to effectively participate in early coordination with transportation agencies
- Timelines vary greatly among agencies and schedules for planning, and projects and funding are often misaligned, causing mitigation opportunities to be missed
- While federal funds can pay for construction of wildlife crossing structures, states bear the cost burden of maintenance
- Agencies are not required to integrate mitigation to maintain or improve wildlife connectivity, except for certain wildlife or fish species listed under the federal Endangered Species Act or an equivalent state law

In the face of these challenges, the most successful projects have resulted from partnerships among agencies, nongovernmental organizations, and other stakeholders using interdisciplinary principles of engineering, ecology, and design (sec. 3).

## New and Existing Support for Wildlife Crossing Structures

The current transportation law provides explicit authority for federal, state, municipal, and tribal managers to reduce the number of motorist collisions with wildlife and to ensure connectivity among habitats disrupted by roads. It also requires state and metropolitan long-range transportation plans to address potential environmental mitigation; and it permits planners to develop programmatic mitigation plans at various scales to encompass multiple resources, such as wildlife habitat or aquatic resources. Although these statutory provisions may be used to support the construction of wildlife crossing structures, they do not require it (sec. 4.1).

In addition to existing support for wildlife crossing structures, a variety of other policy and funding improvements and activities could further enhance motorist safety, reduce wildlife mortality, and conserve habitat connections:

- Develop a standardized methodology for collecting and reporting wildlife-vehicle-collision and carcass data and ensure public access to that data
- Provide technical assistance and peer learning opportunities, including programs to work with and increase capacity for transportation agencies and local governments
- Consider novel mechanisms to fund the costs of constructing wildlife crossing structures

- Include an inflationary adjustment for public lands funding, and enhance the flexibility of federal land management agencies to mitigate wildlife-highway conflicts
- Consider developing a demonstration program to prioritize and fund high-profile wildlife mitigation infrastructure projects nationwide
- Develop guidelines to identify and prioritize wildlife mitigation projects
- Encourage all jurisdictional levels of transportation agencies to manage for wildlife connectivity across highways
- Coordinate a common path forward by encouraging top-ranking officials to aid in aligning the goals and objectives of agencies involved in transportation planning and projects
- Support investment in research and development by assuring an adequate percentage of each highway program is allocated to innovative wildlife mitigation solutions
- Establish a standard performance metric to ensure that investments in wildlife mitigation lead to reductions in wildlife-vehicle collisions and improvements in habitat connectivity
- Work to increase awareness and understanding among key groups in society of the need for a more permeable transportation network
- Educate and cross-train students and professionals by expanding educational opportunities related to road ecology principles and practices for current and future workforces (sec. 4.2)

## Benefits of a National Commitment

As scientific evidence of the harmful cumulative effects of habitat fragmentation, introduced invasive and exotic species, climate change, and pollution mounts, the window of opportunity to curtail our road network's detrimental effects on wildlife is closing (Alamgir et al. 2017, Grooten and Almond 2018, Heller and Zavaleta 2009). Fortunately, the foundation for a transportation system capable of coexisting with nature already exists today in the United States; and it may be strengthened even more by considering and applying this report's findings. By building upon successful efforts already underway at the federal, state, local, and tribal levels, we may prevent the fatalities of up to 200 drivers projected to occur this year as a result of wildlife-vehicle collisions, not to mention the tens of thousands of injured motorists, billions of dollars in property damage, and millions of wildlife deaths (Huijser et. al. 2008, 2009). (sec. 5)

## Contents

# Chapter 1: Do We Need to Transform the U.S. Road Network to Meet 21st Century Challenges?

A quick glance at a United States road map reminds us that it is an amazing example of engineered infrastructure. Stretching from coast to coast and Canada to Mexico, with additional routes woven across Hawaii and Alaska, this network of more than 4,000,000 miles allows us to transport ourselves and our goods to sustain our collective way of life. Forming a vast and relatively seamless conglomeration of municipal, state, tribal, and federal roads, the U.S. public road network is a source of American pride.

Despite being an asset for people, this same network is a major source of disruption for native wildlife that coexist on the landscape with us. We know this tension exists. In 2005, the U.S. Congress, under the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFE-TEA-LU 2005) directed the Secretary of Transportation to conduct a national study that found that wildlife-vehicle collisions "are a growing problem and represent an increasing percentage of the accidents on our roads." (fig. 1). In 2012, Congress enacted a two-year reauthorization of the U.S. transportation act, known as Moving

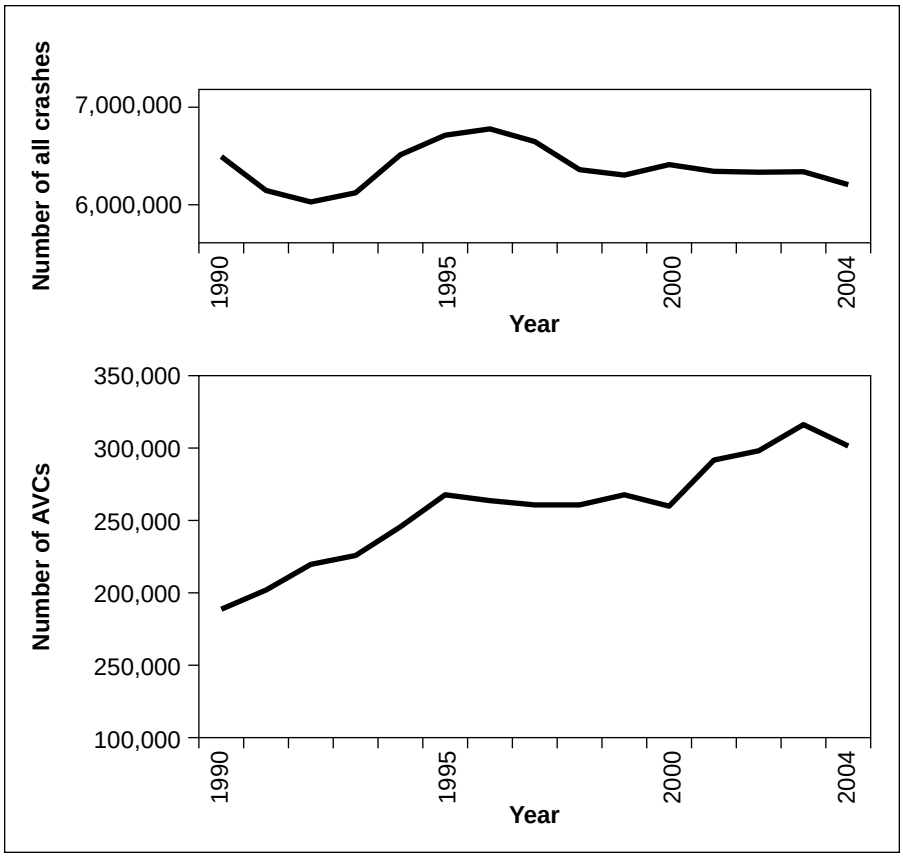


Figure 1— Nationally, as shown by the top chart, the total number of vehicle crashes has held roughly steady during the most recently reported 15-year period. Over the same time period, however, as shown by the lower chart, the number of animal-vehicle collisions (AVCs) rose by 50 percent, from roughly 200,000 to 300,000 (Huijser et al. 2008).

Ahead for Progress in the 21st Century Act (MAP-21), which expressly allows federal, state, municipal, and tribal highway officials to spend transportation dollars to reduce collisions between motorists and wildlife, and to maintain habitat connectivity across roadways (MAP-21 2012). These provisions were continued under the most recent transportation act, Fixing America's Surface Transportation Act (FAST Act 2015), enacted in December 2015.

To achieve fewer roadway casualties and allow wildlife to safely cross over, under, or at the same level as roadways, scientists and transportation practitioners have developed effective systems called wildlife crossing structures, or wildlife crossings. Realizing the greatest large-scale benefits of these structures requires the United States to transform its collective thinking as well as its road network. We can renovate this network from one that is exclusively designed to serve the movement needs of people to one that also proactively accounts for the movement needs of wildlife. This undertaking will require strong leadership, coordinated long-range planning among agencies, and adequate funding. Although there is no question we, as a nation, have the technological expertise and the financial wherewithal to make these changes, the more relevant question is, Will we choose to do so?

**This report presents the benefits and challenges to investing effort and funding toward a nationwide commitment to a systematic network of wildlife crossings.** Safer roads, healthy wildlife populations, and connected habitats are the goals. Well-designed wildlife crossing structures are the tools. The ultimate result: a transformed U.S. road network that benefits people and is sensitive to the needs of wildlife.

This is not a design manual, and we do not seek to replicate the growing body of work that substantiates the conservation value of wildlife crossing structures. Rather, this report represents a collaborative work of more than 15 engineers, ecologists, biologists, landscape architects, and policy experts from federal and state agencies, universities, nongovernmental organizations, and industry to accomplish the following:

1) Illuminate the safety, ecological, economic, and social benefits of wildlife crossing structures.
2) Identify funding mechanisms, partnerships, and policy implications that hinder or facilitate the standard practice of constructing wildlife crossing structures where they are needed

Many of the opportunities discussed here focus on federal land management agencies. As agencies responsible for preserving and enhancing wildlife connectivity, federal land management agencies manage millions of acres of wildlife habitat and run conservation programs with diverse partners. As national stewards

of wildlife at the federal level, federal land management agencies offer diverse opportunities to test new policies to enhance wildlife crossings. We have written this report in a collaborative effort to identify federal leadership opportunities on wildlife crossings.

Another critical piece of the puzzle is the Federal Highway Administration. Responsible for improving mobility on our nation's highways through national leadership, innovation, and program delivery, the Federal Highway Administration provided funding to develop this report.

At the same time, federal leadership will not succeed without the involvement and support of myriad other entities, including tribal and state transportation, natural resource and wildlife agencies, as well as local government, academic institutions, nongovernmental organizations, and members of the public. Each of these has an important role to mitigate the adverse effects of our nation's highways on wildlife.

**Why now?** Every year results in an additional 200 human fatalities and more than 26,000 injuries due to collisions involving wildlife, at an annual cost to Americans of more than $8 billion dollars in collision-related expenses, not to mention the millions of wildlife that die each year as a result of collisions (Huijser et al. 2008), jeopardizing our rich national wildlife heritage. Equally compelling is that, unlike many large-scale environmental issues we face, proven solutions exist: wildlife crossing structures with associated fencing have been shown to reduce collisions between motorists and wildlife by up to 97 percent (Huijser et al. 2008, 2009). With scientific evidence mounting regarding elevated extinction rates and loss of biodiversity stemming from habitat fragmentation, introduced invasive and exotic species, climate change, and pollution (Alamgir et al. 2017, Grooten and Almond 2018, Heller and Zavaleta 2009), now may be the time to build on the successful efforts of Congress, proactive transportation officials, and concerned and dedicated individuals, all of whom are working to curtail the detrimental effects of our road network.

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The idea for this report was born at the ARC Solutions' Crossings and Culture Forum held at the 2013 International Conference on Ecology and Transportation in Scottsdale, Arizona. The forum was comprised of international, interdisciplinary experts from multiple jurisdictions. A key issue that emerged was the lack of a systematic approach to reduce the effect of U.S. and other North American roads on wildlife and their habitats.

This report explores the issues, challenges, and benefits derived to the public of a systematic approach to reduce the adverse effects of highways on wildlife. The report is organized in sections that (1) illustrate the societal and ecological costs of the current approach to mitigation, (2) discuss the scientific basis for choosing

crossing structures as preferred cost-effective mitigation measures, and (3) explore opportunities to increase efficiencies and benefits of incorporating crossing structures into larger scale, systematic operations.

Darin Martens

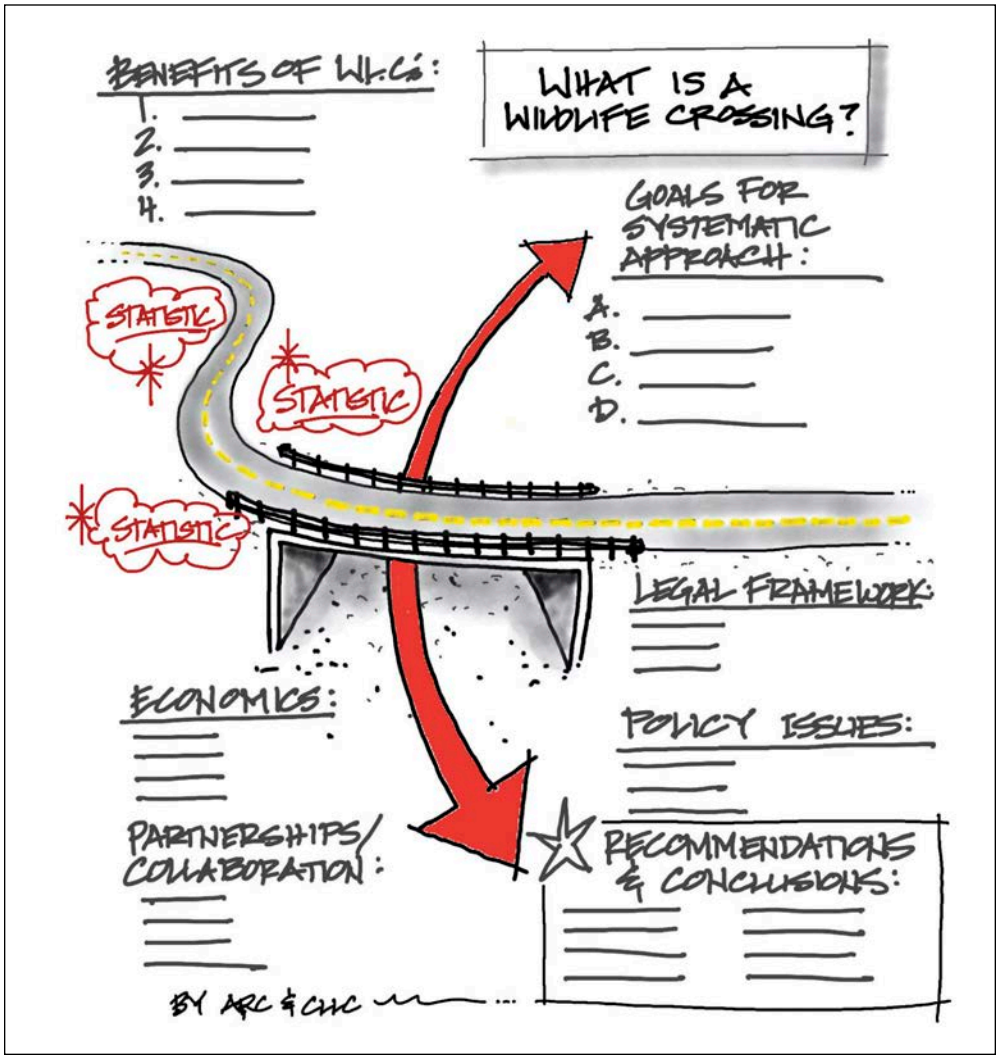


Figure 2—Getting started: a sketch capturing key components of a nationwide commitment to a systematic network of wildlife crossing structures.

## Recommended Reading

**Huijser, M.P.; McGowen, P.; Fuller, J.; Hardy, A.; Kociolek, A.; Clevenger, A.P.; Smith, D.; Ament, R. 2008.** Wildlife-vehicle collision reduction study. Report to Congress. No. FHWA-HRT- 08-034. Washington D.C.: U.S. Department of Transportation, Federal Highway Administration. 232 p. http://www.fhwa.dot.gov/publications/research/safety/08034/index.cfm.

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**Jacobson, S. L.; Bliss-Ketchum, L.L.; de Rivera, C. E.; Smith, W.P. 2016.** A behavior-based framework for assessing barrier effects to wildlife from vehicle traffic volume. Ecosphere 7(4):e01345. 10.1002/ecs2.1345.

# Chapter 2: The Basics, Costs, and Benefits of Wildlife Crossing Structures

For many years, transportation planners and wildlife biologists have sought effective solutions to address wildlife-vehicle collisions and the barrier effect of highways on wildlife movement. Initial attempts at solutions included simple warning signs that advised drivers to be cautious, but these were found to be generally ineffective at modifying driver behavior. Another early proposed solution was to fence the highway to keep animals off the road. Although this resulted in fewer collisions, it also prevented animals from accessing important habitats and resources necessary for survival.

Because the public and many biologists originally believed that most animals would not use wildlife crossing structures, transportation departments were initially reluctant to invest taxpayer funds to build crossings with no guarantee that animals would use them. However, in the past 20 years, studies have increasingly shown the successes of wildlife crossing structures in reducing wildlife-vehicle collisions and allowing wild animals to safely cross highways.

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Road ecology is the study of the interaction between human-built infrastructure and the natural environment. It is a constantly evolving science that melds the interests and missions of multiple disciplines and agencies.

## 2.1 What Is a Wildlife Crossing Structure?

The term "wildlife crossing structure" describes a variety of structures that are designed or retrofitted to provide safe passage for wildlife above or below a highway. Although wildlife crossing structures do not have standardized designs, they can be categorized as two major types: overpasses and underpasses. The most appropriate type of crossing infrastructure to implement in a given situation can vary based on site (e.g., topography) and procedural (e.g., funding) constraints. Structures are usually built in combination with fencing to increase their effectiveness.

Wildlife crossing structures range from the expansively obvious to the small, obscure, and hardly noticeable to drivers. They are designed for a diverse suite of wildlife, from grizzly bears, moose, and bobcats to frogs, squirrels, and salamanders; in some locations, they are designed for slow-moving species such as turtles. Each is designed to serve the target species for a specific location, or to accommodate the majority of species in an area. Wildlife crossing structures also may be designed for target species from a motorist safety standpoint: large ungulates such

as moose, elk, or deer; or for species with the highest conservation concern, such as the Florida panther or Canada lynx.

Generally, the larger the underpass, the greater the diversity of wildlife able to use it. Large underpasses are effective for deer, elk, moose, bears, and wolves. Medium underpasses typically accommodate foxes, badgers, and raccoons, although larger animals such as bears can also use them. Small underpasses are used by species such as frogs, salamanders, and squirrels; it may be the only safe way to cross a highway, especially for slower moving species.

It is a common misconception that wildlife crossing structures can be prey traps where predators lurk at the entrances and have easy access to prey. Although predators and prey may use the same crossing structures, research suggests that predation does not typically occur in part because they use the structures at different times (Ford and Clevenger 2010, Clevenger and Barrueto 2014).

**Case History 1**

Idaho's State Highway 21 near Lucky Peak Reservoir was identified as a high-priority wildlife migration and habitat corridor. In an effort to increase driver safety and reduce motorist crashes involving wildlife, the Idaho Transportation Department, Idaho Department of Fish and Game, and other project partners built a wildlife underpass and associated fencing at a key crossing site. Almost immediately, deer and elk began using the structure to cross safely under the highway, reducing the number of collisions dramatically.

*Idaho Transportation Department*

Figure 3— Idaho State 21 wildlife underpass.

## Wildlife Overpasses

Wildlife overpasses are some of the most visible crossing structures to the traveling public. When well-designed and implemented, they are generally considered to be one of the most effective means of reconnecting habitat fragmented by roads. Overpasses mimic surrounding habitats by including natural elements such as local vegetation and link habitats by allowing for the movement of a wide range of wildlife, from large mammals to reptiles to mice and insects. Even forest-dwelling birds have been shown to cross highways using overpasses more than areas without overpasses.

## Wildlife Underpasses

A wildlife underpass is essentially a wildlife passage below a roadway in the form of either a bridge or a culvert. Existing bridges and culverts can be replaced or retrofitted to enhance passage by terrestrial or aquatic species. Long-span bridges typically span at least 20 ft (6.09 m) across a waterway. Culverts come in many shapes, sizes, and materials; some have natural open bottoms. Both bridges and culverts can be placed on waterways, which serve as important passages for both terrestrial and stream-dwelling wildlife, including fish.

*Betsy Howell*

Figure 4—Unlike wide-ranging species, this rough-skinned newt moves relatively short distances in its search for food and mates. However, it must have precise habitat conditions, or it will dry out and perish.

Darin Martens

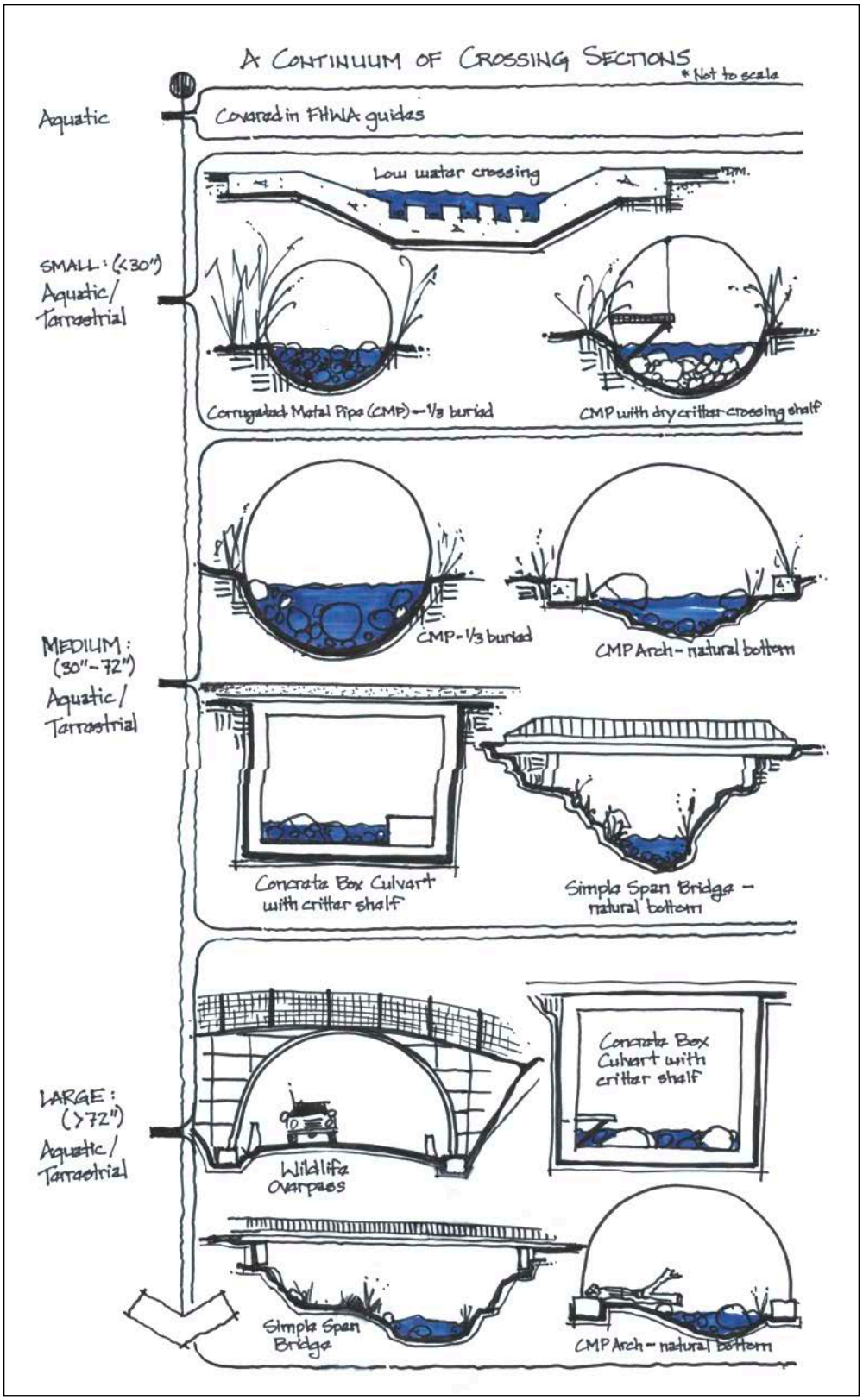


Figure 5—A sketch of examples of the wide range of wildlife crossing solutions.

**Some species require very specialized crossing structures:**

Flying squirrels are true forest-dwellers, rarely touch the ground, and travel by trees. Canopy crossings consist of rope or steel cables that span across roads and link forested habitats separated by roads.

Some salamanders require a view of the night sky to navigate. A grated culvert with a partially open top surface allows for the same ambient conditions the salamander would encounter in its natural habitat.

**Case History 2**

These extended bridges accommodate both vehicle traffic and wildlife. The road accesses a visitor center and has the highest amount of foot traffic during summer days when most animals are not active. Courtesy of Oregon Department of Transportation.

## 2.2 The High Cost of Doing Nothing

### Direct Monetary Costs of Ungulate Vehicle Collisions

In North America, deer, elk, and moose are the source of more than 90 percent of wildlife-vehicle collisions with large animals and related costs. Table 1 shows the average cost per collision that ranges from $6,617 (for deer) to $30,760 (for moose).

**In North America, deer, elk, and moose are the source of more than 90 percent of wildlife-vehicle collisions with large animals and related costs.**

**Table 1—Summary of the monetary costs (in 2007 U.S. Dollars) of the average wildlife-vehicle collision in North America for three common ungulates (adapted from Huijser et al. 2009).**

| Costs | Deer | Elk | Moose |
|---|---|---|---|
| Vehicle repair costs | $2,622 | $4,550 | $5,600 |
| Human injuries | $2,702 | $5,403 | $10,807 |
| Human fatalities | $1,002 | $6,683 | $13,366 |
| Towing, accident attendance, and investigation | $125 | $375 | $500 |
| Hunting value | $116 | $397 | $387 |
| Carcass removal and disposal | $50 | $75 | $100 |
| **Total** | **$6,617** | **$17,483** | **$30,760** |

### Case History 3

Highway 3 in the Crowsnest Pass of Alberta and British Columbia, Canada, has high rates of wildlife-vehicle collisions. A mitigation assessment using the cost-effectiveness thresholds described in section 2.2 found that half of the high-collision sites along Highway 3 have estimated annual costs in excess of the threshold cost. In these cases, installing a mitigation measure actually saves society money over the long run, compared to doing nothing. Similar highway mitigation assessments were conducted on the Trans-Canada Highway east of Canmore, Alberta, for three road segments in Jackson Hole, Wyoming, and for a highway segment in northern Idaho. All studies identified locations where the savings provided by investing in wildlife mitigation exceeded the costs of doing nothing.

In response to the perceived and actual expense of building wildlife crossings, the 2010 ARC International Wildlife Crossing Infrastructure Design Competition sought to develop the next generation of wildlife crossing designs to improve driver and wildlife safety, while reducing implementation costs. Since then, ARC has continued to build on the success of the competition by identifying and promoting leading-edge solutions to improve human safety, wildlife mobility and long-term landscape connectivity.

*Adam Ford*

Figure 6—The Wolverine Overpass on the Trans-Canada Highway in Banff National Park, part of the most studied series of wildlife crossing structures in the world.

## Cost Effectiveness Thresholds

For mitigation to be cost effective, it has to meet a break-even point or a dollar value threshold where the costs expended for the mitigation measure equal the expenses incurred due to the average costs of wildlife-vehicle collisions at that site. Because we know the cost of different mitigation measures per year (table 2) and their effectiveness at reducing wildlife-vehicle collisions (Huijser et al. 2009), we can calculate the break-even point for sections of highway with high wildlife-vehicle collision rates. Huijser et al. (2009) compared the number of deer-, elk-, and moose-vehicle collisions per kilometer per year to the actual cost of different mitigation measures. For structural mitigation measures (i.e., overpasses with fencing and jump-outs that allow animals that accidentally enter the roadway to exit to safety), the initial construction costs are amortized over their estimated 75-year lifespan, annual maintenance is accounted for, and the costs of fence replacement every 25 years is incorporated. The break-even threshold also takes into consideration the relative effectiveness of the mitigation measure. For example, underpasses with fencing and jump-outs reduce wildlife-vehicle collisions on average 86 percent; accordingly, this calculation assumes that 86 cents of each dollar invested in this mitigation measure is returned via wildlife-vehicle-collision cost reductions (Huijser et al. 2009).

**Table 2—Threshold values for different mitigation measures used to reduce deer-vehicle collisions by more than 80 percent. The discount rate used is 3 percent (adapted from Huijser et al. 2009).**

| Mitigation measure | $U.S. (2007)/Year | Threshold/Break-even point: Deer/kilometer/yr |
|---|---|---|
| Fence | $6,304 | 1.1 |
| Fence, underpass, and jump-outs | $18,123 | 3.2 |
| Fence, under- and overpass, jump-outs | $24,230 | 4.3 |
| Animal Detection System (ADS) | $37,014 | 6.4 |
| Fence, gap, ADS, and jump-outs | $28,150 | 4.9 |

Note: These values exclude values not easily monetized, such as the existence value of wildlife or peace of mind for motorists. Considering these values would lower the thresholds. Also, these threshold values are specific to one study area. Each mitigation measure has a different cost to implement and maintain, thus the appropriate mitigation measure should take into account the different safety and conservation goals as well as effectiveness in reducing wildlife-vehicle collisions.

Using this framework, managers are able to calculate cost-benefit thresholds for a variety of mitigation measures. For example, the average cost (in 2007 U.S. dollars) of building and maintaining a wildlife underpass with fencing for 75 years is $18,123 per year (table 2). A threshold of 3.2 deer-vehicle collisions per kilometer per year (5.2 deer-vehicle collisions per mile per year) is sufficiently costly to justify

installing one wildlife underpass with fencing, so that the annual savings from reduced collisions equals the annualized cost of constructing and maintaining the mitigation measure. The threshold value for collision rates with elk and moose are even lower, 1.2 and 0.7 collisions per kilometer per year (1.9 elk/mile/year and 1.1 moose/mile/year), respectively.

## 2.3 Do Wildlife Crossing Structures Work, and How Do They Benefit People?

Wildlife crossing structures have a proven track record of promoting safe passage for wildlife across highways in North America. Whenever an animal uses a wildlife crossing structure to cross the highway, it eliminates the possibility of being hit by a vehicle. Here are some examples:

- More than 15,000 crossings by 16 species of animals were recorded at six underpasses along State Route (SR) 260 in Arizona over a 7-year period (Dodd et al. 2012).
- More than 49,000 crossings by mule deer were recorded at seven large culvert underpasses along U.S. 30 in Wyoming in the first 3 years of post-construction monitoring (Sawyer and LeBeau 2011).
- More than 4,300 desert bighorn sheep crossings were observed on three overpasses on U.S. 93 in Arizona in just more than 2 years (ADOT 2015).
- More than 150,000 crossings by 11 species of large mammals were detected between 1996 and 2014 at more than two dozen crossing structures on the Trans-Canada Highway in Banff National Park, Alberta (Clevenger et al. 2012).

### Benefits of Wildlife Crossing Structures

**Increased motorist safety—**

Wildlife-vehicle collisions are a serious and growing source of human injuries, deaths, and tremendous property loss. There are an estimated 1 to 2 million wildlife-vehicle collisions with large animals each year in the United States, resulting in 26,000 human injuries and 200 human fatalities; the total economic impact exceeds $8 billion/year (Huijser et al. 2008). As such, motorist safety is the primary driver of many projects mitigating highway impacts to wildlife. Wildlife crossing structures (in combination with fencing) have a proven track record of reducing wildlife-vehicle collisions:

- Crossing structures and fencing on the Trans-Canada Highway in Banff National Park reduced wildlife-vehicle collisions involving all large mammals by more than 80 percent, and for those involving ungulates, by more than 94 percent, when comparing a 2-year preconstruction period to a 2-year postconstruction period (Clevenger et al. 2009, Woods 1990).

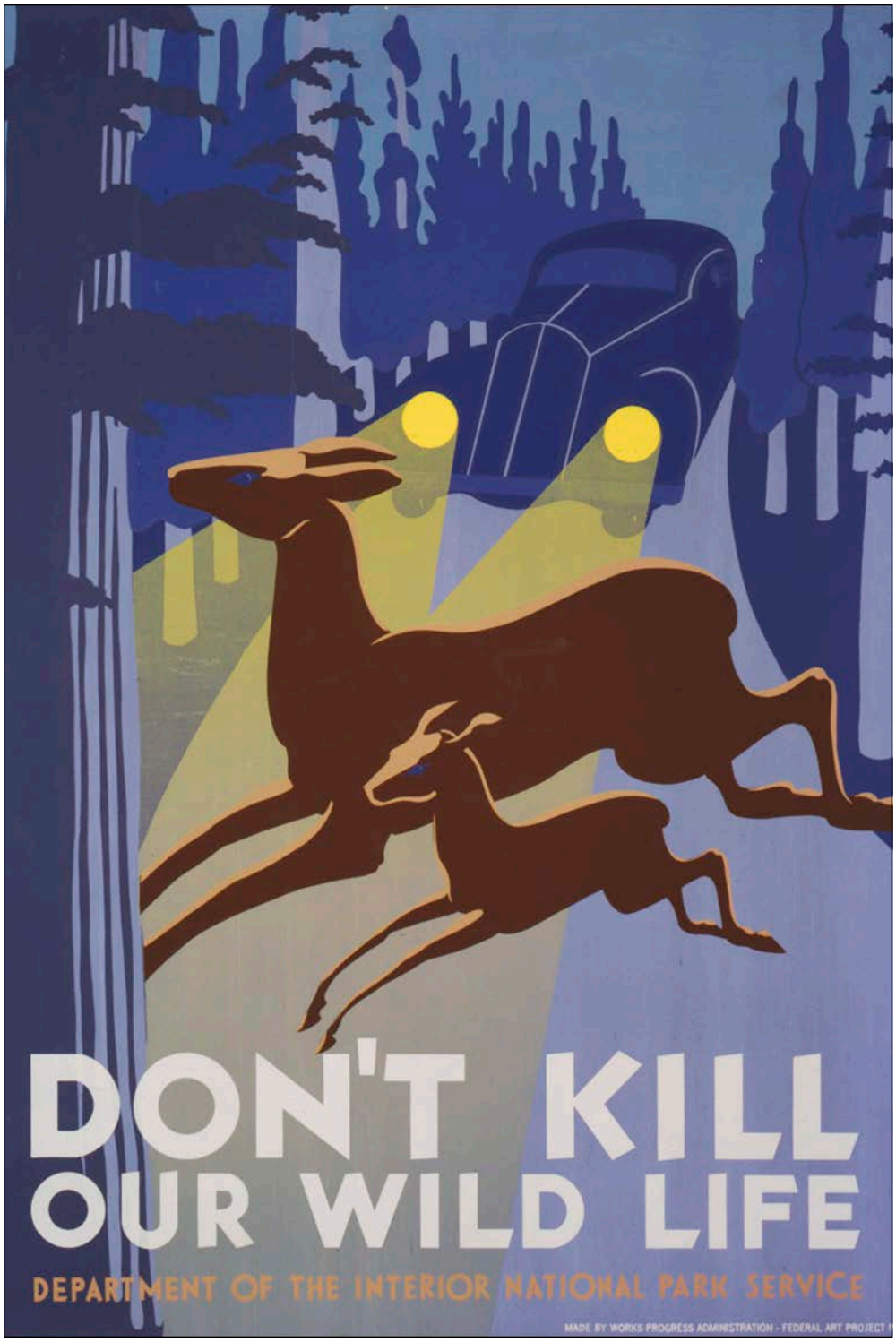


Figure 7—A poster created by the Works Progress Administration for the National Park Service in the 1930s.

- A retrofit fencing project linking three existing crossing structures on Arizona SR 260 reduced elk-vehicle collisions by 98 percent over a period of 6 years (Dodd et al. 2012).
- Seven small underpasses and fencing on U.S. 30 in Wyoming reduced mule deer-vehicle collisions by 81 percent 3 years post-installation (Sawyer and LeBeau 2011).

**Monetary savings—**

As the rates of wildlife-vehicle collisions have increased over the past two decades, agencies are increasingly seeking to mitigate highways in more cost-effective ways. Wildlife crossing structures reduce wildlife-vehicle collisions, thus effectively reducing the many costs to society, as discussed above. One study with well-known rates of wildlife-vehicle collisions before and after mitigation estimates the annual benefits from reduced wildlife-vehicle collisions have exceeded $200,000 per mile (Dodd et al. 2012). Another study on the Trans-Canada Highway found that mitigation reduced the annual average cost to society by 90 percent, resulting in CAD$110,773 savings per year on a 3-kilometer stretch of highway, or about CAD$22,940 per mile per year (Lee et al. 2013).

**Connected habitats—**

**Wildlife crossing structures and fencing can greatly lessen the impact of traffic because when combined they provide safe linkages across highways, helping ensure stable local and regional wildlife populations.**

Habitat connectivity is the degree to which habitats are linked across the landscape to facilitate wildlife movement and access to important resources such as water, food, and mates. Permeability is the degree to which the roadway features offer safe crossing opportunities for wildlife to access habitats on the other side. As traffic volume increases, a roadway will become an increasingly greater barrier to the movement of wildlife—either directly through road mortality or as a result of a deterrent effect that prevents some species from attempting to travel across roadways (Jacobson et al. 2016). While the volume of traffic that constitutes a complete barrier to wildlife movement varies by species (e.g., Coe et al. 2015), in either case, the barrier effect increases with the number of vehicles. Wildlife crossing structures and fencing can greatly lessen the impact of traffic because when combined they

**Case History 4**

Arizona State Route 260 research provides some of the best evidence that well-spaced crossing structures and fencing can actually promote permeability for white-tailed deer and elk, whereas fencing by itself constitutes a barrier to animal passage. Scientists believe this is because fencing helps animals find and use crossing structures. This research demonstrates how wildlife crossing structures and fencing function together to promote highway permeability and habitat connectivity (Dodd et al. 2012).

Road networks are a conspicuous human-made feature with significant impacts upon habitat fragmentation (Forman et al. 2003). Their environmental impacts extend well beyond what happens on the pavement, and have been estimated to affect nearly 20 percent of the U.S. land area (Forman 2000). Wildlife crossing structures protect individual animals from death or injury and help keep wildlife populations intact by allowing individuals free movement to access important habitats and resources, thus enhancing long-term survival and population viability.

provide safe linkages across highways, helping ensure stable local and regional wildlife populations.

**Wildlife protection—**
With 1 to 2 million large wild animals killed by vehicles every year in the United States, wildlife mortality can significantly impact populations and threaten long-term population persistence, especially for threatened and endangered species (Huijser et al. 2008). Highways are the leading cause of mortality for some wide-ranging mammals, such as the Florida panther and some bear and bighorn sheep populations. They are also responsible for population declines among many amphibian populations. By physically separating wildlife from traffic, crossing structures protect individual wild animals from death or injury.

**Genetically viable wildlife populations—**
Highways can act as barriers that isolate wildlife populations and alter gene flow and diversity. For example, grizzly bear populations across western Canada and the northern United States have been documented as being genetically isolated by highways (Proctor et al. 2012). A system of wildlife crossing structures can allow individual animals to disperse and mate with individuals in other populations, thereby promoting the genetic diversity needed for maintaining genetically viable populations.

Recent research conducted in Banff National Park along the Trans-Canada Highway provided compelling evidence that wildlife crossing structures are effectively helping maintain genetically healthy populations of black and grizzly bears that otherwise would be isolated by the bustling highway (Sawaya et al. 2014).

**Resiliency to climate change—**
With changing climatic patterns and increasingly frequent extreme weather events that wreak havoc on transportation infrastructure, especially drainage structures, wildlife crossing structures can help increase resiliency. The installation of oversized drainage structures can help accommodate increasingly frequent and large flood events, while at the same time serving as effective wildlife

*Confederated Salish & Kootenai Tribes; Montana Department of Transportation; Western Transportation Institute, Montana State University*

Figure 8—Black bear using an underpass on U.S. Highway 93 on the Flathead Indian Reservation in western Montana.

crossing structures that promote highway permeability and habitat connectivity. Increasing landscape connectivity has been recognized as the top strategy for helping species respond to a changing climate.

***Social values***—The trauma associated with wildlife-vehicle collisions, especially those with large ungulates like elk and moose, often transcends the tangible impact associated with human injury and economic impact (Huijser et al. 2008). Promoting safer highways can create a sense of motorist well-being and lessened worry when traveling on highways. Further, when surveyed, the public repeatedly places an intrinsic value on public investments where our natural resources are protected and preserved, especially in the context of creating environmentally sensitive transportation enhancements that meet the dual needs of safe highways and wildlife passage (FM3 and Public Opinion Strategies 2013). Additionally, the realm of citizen science, in which members of the general public participate in collecting and analyzing data about the natural world, is gaining traction as the general public takes an active interest in the outcomes from wildlife crossing structure projects, volunteering their time to monitor wildlife use of such structures. This citizen engagement can raise awareness and build public support for future projects.

## 2.4 What Type of Wildlife Crossing Structure Is Best?

It depends! The two main objectives of most, if not all, wildlife crossing mitigation efforts are to (1) reduce vehicle collisions leading to damage, human injury, and wildlife fatalities and (2) connect habitats for wildlife populations. That said, no two projects have exactly the same mitigation needs. Each project has its own unique set of components—wildlife species, landscapes, management objectives, and politics—that are specific to its locale; hence, there is no standardized design that engineers can implement.

After nearly two decades of monitoring and research, however, here are some lessons learned:

- Wildlife crossing structure design, size, and placement are important considerations that influence how different species respond to structures. There is no one- size-fits- all solution because many design considerations are site- and species-specific.
- Species exhibit preferences for certain types of crossing structures. Some species (grizzly bears, moose, wolves, elk, deer, desert bighorn sheep) tend to use large, open structures, while others (black bears, cougars) use more constricted structures with less light.
- Wildlife crossing structures designed and managed for multiple species help maximize biodiversity conservation.
- It takes time for wildlife to find, learn, and habituate to new crossing structures. This learning curve can be several years for even the most adaptable species such as deer. Thus, monitoring must be of sufficient duration to properly evaluate the effectiveness of wildlife crossing structures.
- How well a wildlife crossing structure performs is partly dependent upon the land management that surrounds it. Coordination in the short and long term between transportation and land management agencies helps ensure that tracts of suitable habitat are available adjacent to wildlife crossing structures in perpetuity.
- Fencing is a critical component of a successful mitigation strategy involving wildlife crossing structures, because it deters animals from entering the highway and directs them to the structures. Without fencing, crossings are much less effective. At the same time, fencing alone is typically not recommended because of the barrier effect.

**Case History 5**

Wildlife crossing structures have been a part of transportation projects as far back as the 1950s when one of the first underpasses in North America was built for black bears in Florida. The first wildlife overpass in the United States was built on the Watchung Reservation in response to plans to expand Interstate 78 in New Jersey.

## 2.5 Prioritizing and Planning

To be effective, wildlife crossing structures and fencing cannot be haphazardly or inexpertly placed. Prioritization is essential to focus limited resources on locations exhibiting the highest collision risk and conservation priority. Recent policy directives by the Western Governors' Association to "protect wildlife migration corridors and crucial wildlife habitat in the West" encourage western states to integrate future transportation planning across jurisdictional boundaries with wildlife habitat conservation at the systems level (Western Governors' Association 2017). State transportation departments are beginning to use west-wide Crucial Habitat Assessment Tools (CHATs) to more efficiently and effectively inform transportation and conservation planning across the West. Though wildlife movement data are better indicators for planning mitigation, when this data is not available, coarser data such as CHATs may need to suffice. Nonwestern state wildlife agencies possess similar tools and digital data in the form of wildlife habitat conservation maps.

Similar regional efforts are occurring elsewhere. For example, in August 2016, the New England Governors and Eastern Canadian Premiers adopted Resolution 40-3 on Ecological Connectivity, which encourages transportation and natural resource agencies to identify appropriate "design and size of transportation

State transportation departments commonly address habitat connectivity as a result of state laws mandating replacement of culverts that serve as fish barriers. Many states have significant backlogs of culvert maintenance and replacement projects due to high project cost. When these projects are funded, transportation departments could design culverts to accommodate other species groups. This would require advanced planning and technical assistance among these departments, wildlife agencies, and land management agencies. Although some culverts are too small to accommodate large animals, almost all culverts can be designed to improve wildlife connectivity for many species.

> "We spend $8 billion a year running over wildlife. If we took that cost and quartered it, we could build 200 animal crossings a year, and the problem of roadkill would disappear within a generation."
>
> –Ted Zoli, bridge engineer and MacArthur fellow

**Case History 6**

In a project that widened U.S. 97 to four lanes, adding two wildlife underpasses enabled the Oregon Department of Transportation and the U.S. Forest Service to mitigate three existing problems. Migratory deer cross U.S. 97 twice yearly from the high Cascade Mountains for the lush summer forage. Deer-vehicle collisions were common, so safety was an objective for this project. As the collisions increased, it became apparent that the interruption of deer movement and the high mortalities they suffered were also causing a decline in herd numbers. In contrast, although other animals in the area were common and not experiencing population declines from vehicle collisions, they could incur long-term genetic diversity losses due to the barrier effect of the highway. Ultimately, three project objectives were identified: (1) decrease deer-vehicle collisions as a safety measure, (2) restore the migratory deer herd to its former numbers by allowing it to make safe seasonal movements, and (3) provide concurrent but not specific passage opportunities for other species in the area to maintain genetic interchange.

infrastructure for movement of terrestrial and aquatic wildlife." Northeastern state wildlife agencies similarly possess comparable planning tools in the form of wildlife habitat conservation maps as well as other digital wildlife and habitat data.

In the case of smaller scale projects with shorter planning horizons, overlaying these habitat tools with a state's comprehensive list of planned surface transportation projects, or statewide transportation improvement program (STIP), may help facilitate the integration and coordination of transportation and wildlife habitat networks during subsequent planning. In the case of larger scale projects, which may take several years to decades to develop, engaging once a project is listed in the STIP will likely be too late. As a result, state leaders in wildlife mitigation are seeking opportunities to include wildlife considerations earlier, such as during pre-STIP planning, programming, project scoping, and development (Ament et al. 2015).

**By prioritizing conservation improvements as early as possible using consistent, data-based planning, state transportation departments can better and more cost effectively address state and regional conservation needs in the short and long term.**

By prioritizing conservation improvements as early as possible using consistent, data-based planning, state transportation departments can better and more cost effectively address state and regional conservation needs in the short and long term. Today, whether for motorist safety or wildlife conservation purposes, transportation and natural resource management agencies are increasingly integrating planning and implementation of crossing structures into their standard operating procedures.

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# Chapter 3: What Are the Key Challenges to Transforming the U.S. Road Network, and How Can We Solve Them?

A systematic approach to mitigating wildlife impacts from highways is challenging because no single agency is responsible for sustaining movement of animals across the landscape, and most especially across multiple jurisdictions and land ownerships. Adhering to agency missions often creates a siloed approach, making it difficult for agencies to collaborate. To accomplish the goal of maintaining healthy wildlife populations through reduced vehicle collisions and improved habitat connectivity often requires local, state, tribal, and federal agencies to work collaboratively on projects. Table 3 includes a number of perceived challenges and possible solutions identified by a panel of international, interjurisdictional, and interdisciplinary experts at the ARC Solutions' Crossings and Culture Forum held at the 2013 International Conference on Ecology and Transportation in Scottsdale, Arizona.

**Table 3—Challenges and possible solutions for interagency collaborations to reduce wildlife-vehicle collisions and improve habitat connectivity, as identified by experts at the 2013 International Conference on Ecology and Transportation (continued)**

| Challenge | Possible solution |
|---|---|
| Federal land management agencies such as the U.S. Forest Service manage thousands of square miles of excellent wildlife habitat in the U.S. Although highways traverse national forests and other federal lands, they are at times managed by a local agency or a state transportation department, rather than by the federal agency. Federal and state transportation and land management agencies have missions and approaches that may not overlap. | Despite differences in missions, these agencies can create crucial partnerships to foster safe passage across highways. Each agency brings unique yet complementary skills to the table. State transportation departments specialize in the design and engineering of roads, while natural resource agencies are experts in the wildlife movement and behavior needed to design effective mitigation. Mission overlaps can be leveraged when agencies have both liaisons that understand other agencies' missions, and specialists in both engineering and wildlife disciplines. |
| Generally, long-range transportation plans do not include wildlife mitigation or crossing provisions. Similarly, federal land and resource management plans rarely include provisions for wildlife movement across highways. | These omissions could be overcome by implementing standardized wildlife conservation clauses in memoranda of understanding between transportation and land management agencies, and by incorporating provisions for safe passage within transportation and land/resource management plans. |
| Federal or state natural resource agencies are often too resource or time constrained to effectively participate in early coordination with transportation agencies, which delays the resource agency review until more complete plans are provided for permitting and regulatory purposes. | Early coordination among state and federal agencies could lead to more efficient scheduling of projects as well as increased opportunities for mitigation. States could encourage more timely and useful natural resource agency participation in the planning process by providing more easily interpretable statewide transportation improvement programs (STIPs). States could also identify and expand opportunities to consider wildlife earlier, such as during pre-STIP planning, programming, project scoping, and development. Another option would be to adopt a pre-screening process that requires consultation with federal and state wildlife or natural resource agencies and other affected stakeholders prior to a project's inclusion in the STIP. |

**Table 3—Challenges and possible solutions for interagency collaborations to reduce wildlife-vehicle collisions and improve habitat connectivity, as identified by experts at the 2013 International Conference on Ecology and Transportation (continued)**

| Challenge | Possible solution |
|---|---|
| Timelines vary greatly among agencies and schedules for planning, projects and funding are often misaligned, so opportunities are missed. | States that include wildlife connectivity goals in their state wildlife action plan may help align timelines and schedules among agencies and increase opportunities to identify and prioritize wildlife corridors that intersect with busy roads. |
| While federal funds can pay for construction of wildlife crossing structures, states bear the cost burden of maintenance. Because maintenance funding for new and aging infrastructure is increasingly limited, states are reluctant to add wildlife crossing structures to their maintenance workload. | Depending on their sufficiency rating, aging infrastructure may be eligible for rehabilitation funds under the surface transportation authorization legislation administered by the Federal Highway Administration. States could determine the present and future costs of maintaining wildlife crossing structures and include these costs in funding proposals for new construction, thereby funding future maintenance today, as feasible. This approach also may aid states with nonwildlife infrastructure. |
| Currently, no overarching policy or regulation requires interagency integration of mitigation to maintain or improve wildlife connectivity, except for certain wildlife or fish species listed under the federal Endangered Species Act. While guidance on, and incentives for, interagency cooperation do appear in various state and federal memoranda of understanding and agreements, such guidance is generally less binding than overall mission objectives, and may be contradicted by competing regulations. Although wildlife do not recognize jurisdictional borders, states have little incentive to work across state boundaries. Some may even be prohibited from working across borders. | Federal land management agencies have a major opportunity to help facilitate seamless coordination in multiple states much in the way the Western Governors' Association and its Wildlife Corridors Initiative sought to do for its member states. |
| Multiple agencies result in multiple missions and priorities. Agencies may have contradictory or conflicting laws, regulations, and mandates. | Agencies with good working relationships can creatively leverage current funding and related opportunities to accomplish implementation of wildlife crossings, although funding for planning and implementing highway projects may be vastly unequal among those agencies. |

Source: ARC Solutions, Crossings and Culture Forum, June 23, 2013 International Conference on Ecology and Transportation, Scottsdale, Arizona.

## 3.1 Melding Missions

Natural resource, land management, and transportation agencies do have several overlapping areas of interest where transportation goals dovetail with wildlife connectivity objectives, including the use of wildlife crossing structures. All agencies can agree that mitigating transportation corridors for wildlife serves the public through increased safety, reduced crashes, improved habitat connectivity, and more cost-effective use of taxpayer dollars—all of which enhance quality of life.

### Examples of Federal and State Agency Mission Statements and Focus Areas

**Federal Highway Administration**

**Mission:** To improve mobility on our nation's highways through national leadership, innovation, and program delivery.

**Focus:** Improving the transportation network, which may include fostering innovation to minimize impacts to wildlife/environment.

**U.S. Fish and Wildlife Service**

**Mission:** Working with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the nation.

**Focus:** Conserving wildlife and the environment; protecting wildlife from impacts of the transportation network.

**U.S. Forest Service**

**Mission:** To sustain the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations.

**Focus:** Forest and grassland management, with an emphasis on science-based decision making to foster wise and sustainable use of resources.

**National Park Service**

**Mission:** To preserve unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of current and future generations.

**Focus:** Natural and cultural preservation, while providing for visitor access via its transportation systems.

**State Departments of Transportation**

**Mission:** Vary from state to state, but typically emphasize safety, efficiency, cost effectiveness, quality of life, and sometimes explicit environmental responsibility.

**Focus:** A transportation system that maintains a safe and effective transportation network, which ties into quality of life and can include wildlife and the environment.

### Case History 7

In 2006, the Federal Highway Administration (FHWA), the Forest Service, U.S. Fish and Wildlife Service, and numerous other agencies embarked on an effort to help solve the many issues that arise from agencies working independently rather than collaborating. Eco-Logical is a process that encourages agencies to begin working together early on highway projects in a formalized manner that allows all stakeholder missions to be considered as part of the project objectives. Since its inception, the FHWA has encouraged interagency and public-private partnerships to engage in more frequent cooperative efforts, data sharing, and more streamlined projects with better environmental outcomes.

## 3.2 Power in Partnerships

Partnerships can be an effective tool to advance wildlife crossing structures. As the case histories throughout this document illustrate, collaboration is an essential ingredient in successful wildlife crossing projects. It is also crucial to identify and engage public and private stakeholders to expand awareness of and support for wildlife crossing structures as proven solutions to reducing wildlife-vehicle collisions and maintaining or improving habitat connectivity.

Several of the histories described in this document showcase the success of partnerships in planning for wildlife crossings on a large scale. While the highlighted examples were well-funded, funding to explicitly support such partnerships is becoming increasingly limited and thus is likely to constitute a growing challenge in the future.

Darin Martens

Figure 9—Togwotee Corridor reconstruction, 50’ diameter arch wildlife crossing structure during the flowering of yellow sweet clover (*Melilotus officinalis*).

**Case History 8**

A partnership process was developed for the Togwotee Corridor reconstruction, a 38-mile highway reconstruction at a major gateway to Yellowstone National Park. That project constructed five large wildlife crossing structures and seven smaller structures in addition to approximately 30 upsized and embedded culverts throughout the corridor. The partnership highlighted a number of successes:

- Willing transportation agencies (state and federal) made up of diverse specialists within the departments (i.e., environmental services, geology, bridge programs)
- Willing land management agencies (local, state, federal)
- A willing state wildlife management agency, in coordination with the U.S. Fish and Wildlife Service
- Local Chamber of Commerce/local interested business involvement
- Local nongovernmental organizations (i.e., wildlife interest groups, such as local development or conservation groups, as well as other interest groups, such as pathways or trail advocacy groups with potentially competing needs)
- Local county engineer and planning departments
- A local land trust group for conservation easements
- Neutral facilitator(s) and a core group to carry the process

In this case study, the core group/facilitators were a Wyoming Department of Transportation (WYDOT) environmental specialist and a U.S. Forest Service-WYDOT-federal highways project liaison.

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# Chapter 4: How Can We Enhance Existing Support for Wildlife Crossing Structures?

The previous chapters discuss the benefits of wildlife crossings as well as key challenges and possible solutions to a national commitment to deploy crossings where needed to increase driver and animal safety. This chapter begins by discussing opportunities and constraints presented by existing support for wildlife crossings. It then sets forth a range of activities that transportation officials, land managers, and wildlife experts may undertake to transform our road network in a way that benefits people and is sensitive to the needs of wildlife.

## 4.1 Existing Support for Wildlife Crossing Structures

In 2012, Congress and President Barack Obama broke new ground when they enacted MAP-21 (MAP-21 2012: §§ 1101 et seq., 23 U.S.C. §§ 101 et seq., 2012); it was the first national transportation law to weave throughout its programs explicit authority for federal, state, municipal, and tribal managers to reduce the number of motorist collisions with wildlife and ensure connectivity among habitats disrupted by roads. **As summarized below, although these provisions may be used to support the construction of wildlife crossing structures, they do not require it.**

Indeed, neither MAP-21 nor its successor legislation, the Fixing America's Surface Transportation Act, Pub. L. 114-94, authorizes a dedicated source of funding for environmental mitigation, let alone for wildlife crossing structures (FAST Act 2015). This is consistent with the approach initially adopted in MAP-21 and continued in the FAST Act of consolidating federal aid highway programs into fewer, more flexible programs that accord states and other funding recipients greater discretion over the types of activities funded. In keeping with this approach, the following federal transportation programs permit managers to use program dollars to fund eligible wildlife-related mitigation, including the construction of wildlife crossing structures:

- Surface Transportation Block Grant Program (FAST Act 2015: § 1109, 23 U.S.C. § 133(b)(15)). Eligible transportation alternative projects include activities to reduce vehicle-caused wildlife mortality or to restore and maintain connectivity among terrestrial or aquatic habitats.
- Highway Safety Improvement Program (MAP-21 2012: § 1112, 23 U.S.C. § 148). Eligible projects include the addition or retrofitting of structures or other measures (including the construction of wildlife crossing structures) to eliminate or reduce wildlife-vehicle collisions.
- Tribal and Federal Lands Transportation Programs (MAP-21 2012: § 1119, 23 U.S.C. §§ 201-203). Funding from these two programs may be used to pay for environmental mitigation in or adjacent to tribal land or federal

public lands, respectively, (1) to reduce vehicle-caused wildlife mortality while maintaining habitat connectivity; or (2) to mitigate damage to wildlife, aquatic organism passage, habitat, and ecosystem connectivity, including constructing, maintaining, replacing, or removing culverts and bridges, as needed.[1]

- Federal Lands Access Program (MAP-21 2012: § 1119, 23 U.S.C. §§ 204). Funding from this program may be used to pay for environmental mitigation on land (owned or maintained by a state, tribal, or local government) in or adjacent to, or that provides access to, federal land to reduce vehicle-caused wildlife mortality while maintaining habitat connectivity.

U.S. Fish and Wildlife Service

The Texas Department of Transportation and the U.S. Fish and Wildlife Service (US FWS) have built a network of wildlife underpasses to mitigate the effect of state roads on one of the U.S.' last-known populations of ocelots, for whom roadways are a leading cause of known mortality events. US FWS has used the Federal Lands Access Program and Federal Lands Transportation funds to fund speed control measures on the entrance road to Laguna Atascosa National Wildlife Refuge in the Rio Grande Valley, South Texas.

[1] MAP-21 initially included a restrictive cap of $10 million per fiscal year for all eligible environmental mitigation activities under the Federal Lands Transportation Program (FLTP) (MAP-21 2012: § 1119). The FAST Act subsequently modified this cap so it restricts only those FLTP activities aimed at reducing wildlife mortality (FAST Act 2015: § 1119(1)(B), 23 U.S.C. § 203(a)(1)(D)).

MAP-21 also requires state and metropolitan long-range transportation plans to include a discussion of the types of potential environmental mitigation activities and potential areas to carry out these activities, including activities—such as constructing wildlife crossing structures—that may have the greatest potential to restore and maintain the environmental functions affected by the plan (MAP-21 2012: §§ 1201-1202, 23 U.S.C. §§ 134-135).

Programmatic mitigation plans are a relatively untested mitigation option under MAP-21 (MAP-21 2012: § 1311, 23 U.S.C. § 169). The statute provides that programmatic mitigation plans may be developed on a regional, ecosystem, watershed, or statewide scale and may focus on a specific resource, such as wildlife habitat. Therefore, it appears that a systematic approach to mitigate the effect of future transportation projects using wildlife crossing structures could be developed using this provision.

## 4.2 The Path Forward: Opportunities to Strengthen Support for Wildlife Crossing Structures

In addition to existing federal transportation policies and funding opportunities for wildlife crossing structures, there are a variety of other policy and funding improvements that could further enhance motorist safety, reduce wildlife mortality, and conserve habitat connections. These improvements would help balance the nation's goal of providing for the safe, efficient movement of goods and people, with its need to mitigate the effect of roads on valuable natural resources.

Federal land management agencies are responsible for preserving and enhancing wildlife connectivity, both through policies on the lands they manage and through conservation programs with partnering agencies. As national stewards of wildlife and their habitats at the federal level, many of the opportunities discussed in this section focus primarily on federal land management agencies' policies to enhance wildlife crossings. Nonetheless, it is important to recognize the critical role that tribal, state, local, and municipal agencies as well as the private sector and educational institutions play in ensuring that these Federal opportunities are successful.

The following measures suggest a range of activities that would lead to a transformed U.S. road network that benefits people and is sensitive to the needs of wildlife:

**Develop a standardized methodology for collecting and reporting wildlife-vehicle-collision and carcass data, and ensure public access to that data.**

Huijser et al. (2008) recommended to Congress that the U.S. consider implementing a systematic, nationwide approach to reducing wildlife-vehicle collisions. In some states, transportation agencies collect no wildlife-vehicle-collision or carcass data at all. In others, data are collected inconsistently and haphazardly, using different methods. As a result, none of the three national databases for collecting crash information provide a reliable, standardized assessment of wildlife-vehicle collisions. Improving the consistency, precision, and transparency of data collection on wildlife-vehicle collisions can help transportation agencies establish performance metrics to ensure that funds are utilized effectively. The development of a standardized methodology would also allow agencies to better adopt best practices between states and regions.

**Provide technical assistance and peer learning opportunities for agencies.**

Along with federal land management agencies, tribal and state agencies and their local government counterparts manage hundreds of thousands of miles of roadways that fragment wildlife habitat. While many agencies would like to strengthen their wildlife crossing programs, they have varying degrees of technical knowledge, internal coordination, management capacity, and partnership support to effectively plan for and construct wildlife crossings. Technical assistance programs that increase agency capacity, including programs that work with and increase capacity for local governments and transportation agencies, would both raise awareness and facilitate implementation of wildlife crossings. Technical assistance may include broad-scale outreach through webinars and websites, as well as peer exchanges and communities of practice to connect interested states with each other. Technical assistance would be a relatively low-cost activity that would allow practitioners to learn best practices, establish relationships, and identify new funding sources.

**While many agencies would like to strengthen their wildlife crossing programs, they have varying degrees of technical knowledge, internal coordination, management capacity, and partnership support to effectively plan for and construct wildlife crossings.**

**Consider novel funding mechanisms for construction of wildlife rossings**

Lack of funding is always raised as a major impediment to wildlife crossing construction. Under the current paradigm, wildlife mitigation competes with all other highway needs programs—replacement and maintenance of an increasingly aging infrastructure, safety improvements, road expansions—and numerous other priorities. Additionally, the Highway Trust Fund faces an ongoing shortfall because of stagnant gas tax revenues, forcing all funded programs to compete for fewer resources. Similarly, state transportation departments face increasingly tight budgets. Therefore, many agencies must focus on maintenance of existing infrastructure and postpone action on other needs.

One option for addressing funding could be to automatically allocate a set percentage of the total amount of funding for a program or an individual project

for wildlife mitigation. Since approximately 5 percent of all collisions in the United States involve wildlife (Huijser et al. 2008), an analogous starting point would be to devote a similar percentage of safety program dollars toward reducing and eventually eliminating this threat to motorist safety.

Given that wildlife-vehicle collisions cost U.S. drivers an estimated $8 billion each year (Huijser et al. 2008), having a highway wildlife program with funding at a level that allows transportation agencies to adequately address and reduce wildlife-vehicle collisions while providing for connectivity would appear to be a prudent and rationale investment of public funds. Indeed, at least one expert estimates that, if we were to take a fraction of the estimated $8 billion[2] incurred as a result of collisions with wildlife and invest it annually in building wildlife crossings, **then we could solve the problem in a single generation** (Zoli 2010). This would make the U.S. surface transportation system highly permeable and safer for wildlife and drivers, alike.

**One expert estimates that, if we were to take a fraction of the estimated $8 billion incurred as a result of collisions with wildlife and invest it annually in building wildlife crossings, then we could solve the problem in a single generation.**

In addition to Federal Highway Administration funding, other federal, state, and local agencies ideally would also share in the cost and responsibility for mitigating the effects of roads on wildlife. One possible revenue stream at the state level could be for the state to set up a wildlife mitigation fund and require insurance companies to collect and pay into the fund a portion of each claim (e.g., $10, $100) that was made due to a crash with an animal. Given that there are an estimated 1 to 2 million wildlife-vehicle collisions with large animals each year (Huijser et al. 2008), many resulting in insurance claims, this would have the potential to generate billions of dollars for wildlife mitigation over a generation. If such a program were implemented, the need for funding may decrease at the same time monies generated by wildlife-vehicle-collision insurance claims also decreased.

**Enhance agency flexibility and access to funding for wildlife-highway conflicts**

Federal, state, and local agencies have seen their transportation funding lose ground to inflation, budgetary cuts, and restructured or eliminated programs. Despite the fact that most agencies are managing the same amount of public lands, generally at increased visitation levels, recent transportation bills eliminated a number of discretionary funding sources, including projects eligible under the Transit in Parks, the Public Lands Highway Discretionary, and the National Scenic Byways programs, without a reciprocal increase in funding elsewhere. Lower funding levels limit the ability of federal, state, and local agencies to enhance driver and wildlife

[2] This estimate is based on a cost of $10 million to construct a wildlife crossing. While the costs of construction for wildlife crossing structures vary widely based on target species; site conditions, including number of lanes crossed; and type of structure, this is a conservative estimate of the impact that a dedicated investment in road crossing infrastructure for wildlife could generate. For example, wildlife overpasses in Banff National Park were estimated to cost approximately $1.75 million per overpass, while other wildlife overpass projects have been estimated to cost $1.5 to $2.4 million per structure (Huijser et al. 2008).

safety through their roads programs. Between 2005 and 2020, the cumulative rate of inflation based on the U.S. Consumer Price Index was more than 32 percent, reducing the buying power of agency transportation dollars even more.

In addition to diminished buying power, federal land management agencies are limited by a cap of $10 million per fiscal year for eligible activities aimed at reducing wildlife-vehicle collisions and improving connectivity under the Federal Lands Transportation Program. The program improves multi-modal access within national parks, forests, wildlife refuges, Bureau of Land Management lands, and U.S. Army Corps of Engineers facilities. It focuses on the transportation infrastructure managed and maintained by federal land management agencies and can be used to pay for environmental mitigation in or adjacent to eligible federal lands to improve public safety, reduce vehicle-caused wildlife mortality, and mitigate other harmful effects of roads. This funding cap further hinders the ability of federal land managers to mitigate wildlife-highway conflicts.

Including an inflationary adjustment for federal, state, and local program funding, and removing the funding cap on Federal Lands Transportation Program wildlife mitigation projects to reduce wildlife-vehicle collisions, will enable federal, state, and local land managers to better meet their agency missions by, among other things, reducing the effect of roads on wildlife.

**Consider developing a wildlife demonstration program**

From 1990 to 2004, the number of wildlife-vehicle collisions in the United States increased by 50 percent, from 200,000 to 300,000 annually – accounting for roughly 5 percent of all reported collisions (Huijser et al. 2008). To address this problem, agencies could consider developing a wildlife demonstration program that would prioritize and fund high-profile wildlife mitigation demonstration projects, with a preference for one project per state. Projects could entail, for example, wildlife underpasses or overpasses, bridges, culverts, or animal detection systems, as appropriate. Such a program may have myriad benefits, including reducing human fatalities and injuries; providing safe passage for wildlife; improving ecological connectivity; supporting local economies and jobs; leveraging federal investment with state, local, or private funding; encouraging development and research of innovative crossing technologies; and potentially saving taxpayer dollars over the lifetime of the crossing structures.

To be successful, such wildlife demonstration programs would need to appropriately select, prioritize, and locate mitigation measures to achieve the highest impact with the greatest cost effectiveness. In addition to considering the frequency of wildlife-vehicle collisions and the importance of wildlife habitat and its connectivity, selection criteria for the program could also consider the security of lands

adjacent to the structures. Land security—which can take different forms, including public ownership, conservation easements, and wildlife management agreements—helps minimize the likelihood of future human development that creates conflict with wildlife, thereby potentially diminishing use of crossing structures. Because land security is critical to ensuring that the long-term benefits of mitigation are maximized, it may be most beneficial to institute wildlife demonstration programs initially on federal and tribal lands. For example, a pilot program could be added to the Federal Lands Transportation Program, the Federal Lands Access Program, and the Tribal Transportation Program. Doing so will have the added benefit of empowering federal land managers, such as the Bureau of Land Management, National Park Service, Forest Service, and Fish and Wildlife Service to better fulfill their agency mandate to protect wildlife by improving connectivity for animals, both large and small, on and near federal lands. Upon completion of the pilot, successful elements of the program could be permanently adopted as additional revenue sources are identified.

**Develop guidelines governing deployment of wildlife crossing structures**

Science and research to date support the effectiveness of wildlife crossing structures, particularly when used in conjunction with appropriate fencing (Huijser et al. 2008, 2009). Development of guidelines to identify and prioritize wildlife mitigation projects would pave the way for deploying these proven solutions. Guidelines would further articulate the criteria for prioritizing problematic wildlife-vehicle collision areas, key wildlife habitat corridors and other important locations for wildlife mitigation. Inclusion of pre- and postconstruction monitoring and evaluation will enable policymakers to gauge the successes and failures of deployment and provide the information necessary to adjust and adapt strategies to realize an accountable and methodical approach for wildlife mitigation.

**Encourage all jurisdictional levels of transportation agencies to manage for wildlife connectivity across highways**

Both small- and large-scale connectivity projects are needed to maintain or restore wildlife movement because the road network is so extensive, and multiple small projects add up to large benefits to moving wildlife. The most prevalent recommendation by scientists and ecologists to help wildlife adapt to climate disruption is to maintain landscape connectivity, so they can move and adjust to changing circumstances (Gilbert-Norton et al. 2010, Heller and Zavaleta 2009). Policymakers can help combat the effects of our changing climate by ensuring that future transportation policies provide safe passage for wildlife across roads, no matter the jurisdiction.

**Coordinate a common path forward among agencies**

By providing direction and offering creative and inspired guidance, top ranking agency officials can aid in aligning goals and objectives of the many, often disparate, transportation, wildlife, land management, and environmental agencies involved in transportation planning and projects.

**Support investment in research and development of innovative mitigation strategies**

Assuring an adequate percentage of each highway program is allocated to support innovative advances in mitigating the effects of highway infrastructure on wildlife would likely reduce the cost to the public of future wildlife-vehicle collisions as well as the loss of wildlife biodiversity. Transportation ecology is an emerging field of applied science and innovation that is still in its early stages. Because most North American wildlife crossing structures were installed within the past 15 years, considerable opportunities for learning and innovation remain.

**Establish a standard metric to measure performance**

It is critical that increasing investments in a more permeable transportation network for wildlife lead to concomitant reductions in wildlife-vehicle collisions and improvements in habitat connectivity. Establishing standard metrics for assessing the performance of wildlife mitigation measures is a simple, transparent way to ensure that funds allocated to curb this mounting safety hazard are utilized effectively.

**Work to increase awareness and understanding across many key groups in society**

Broadly speaking, key groups, including administrative leaders, transportation experts, and the general public, would all benefit from a more complete understanding of the scientific, social, and economic advantages of a systematic approach to wildlife mitigation and the application of wildlife crossing structures as a proven solution to reducing wildlife-vehicle collisions and improving connectivity. Among other things, the public would benefit from a greater understanding of the science underpinning biodiversity, and thus the ways mitigation may enhance biodiversity, including by reducing vehicular mortality to wildlife.

*Renee Callahan*

Figure 11—A herd of elk crossing over Dry Creek Road less than 1 mile from U.S. Highway 89 in Paradise Valley, Montana. U.S. 89 provides access to the iconic Roosevelt Arch entrance to Yellowstone National Park.

**Educate and cross-train students and professionals**

Educational opportunities and workforce training regarding wildlife mitigation are inadequate. Such opportunities need to be expanded not only for the current professional staff, for whom such training is sparse and sporadic, but also for engineers and natural resource students preparing for their careers at U.S. universities and other institutions of higher learning who have access to few if any courses or sessions dedicated to road ecology principles and practices.

## Recommended Reading

**Fixing America's Surface Transportation Act [FAST Act] of 2015.** Pub. L. 114-94, §§ 1109, 1119(1)(B); 23 U.S.C. §§ 133(b)(15), 203(a)(1)(D) (2015).

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**Moving Ahead for Progress in the 21st Century Act of 2012.** §§ 1112, 1119, 1201-1202, 1311; 23 U.S.C. §§ 134-135, 148, 169, 201-204 (2012).

# Chapter 5: Benefits of a National Commitment

As scientific evidence of the harmful cumulative effects of habitat fragmentation, introduced invasive and exotic species, climate change, and pollution mounts, the window of opportunity to curtail our road network's detrimental effects on wildlife is closing (Alamgir et al. 2017, Grooten and Almond 2018. Heller and Zavaleta 2009).

New technologies, such as onboard pedestrian, bicyclist, and animal detection systems and self-driving cars, may help greatly in the coming decades to reduce crashes with large animals. However, self-driving cars may take decades to deploy nationwide, and animal-detection systems currently focus on larger animals that pose a danger to motorists, rather than small and medium-sized wildlife. Similarly, increased deployment of mass transit systems, while helpful in reducing the number of cars on our roads, may not be sufficient to eliminate the vast majority (89 percent) of wildlife-vehicle collisions estimated to occur on two-lane roads (Huijser et al. 2008). A national commitment to increase driver and animal safety would not only advance evolving technological solutions, but also build upon successful efforts already underway at the federal, state, local, and tribal levels to reduce wildlife-vehicle collisions.

Everyone has a role to play in transforming the U.S. road network. From the concerned individual to the engaged scientist or engineer, to all manner of experts and interested parties in between, everyone has a stake, and everyone can make a difference. It is also the responsibility of agencies in the

**Everyone has a role to play in transforming the U.S. road network. From the concerned individual to the engaged scientist or engineer, to all manner of experts and interested parties in between, everyone has a stake, and everyone can make a difference.**

*Darin Martens*

Figure 12—Pronghorn antelope using overpasses at Trappers Point near Pinedale, Wyoming.

road-wildlife-landscape interface to consider and work toward mitigating the impacts of roads on wildlife. A variety of state and national policies already support the use of transportation dollars for this purpose. A dedicated funding stream would build on the investments already made and may make it easier for more transportation experts and agencies to join in partnership toward a new norm of building wildlife crossing structures as a standard practice wherever they are needed across the United States.

Creating a transportation system capable of coexisting with nature is a powerful gift to our nation's—and the world's—future. The foundation for such a system has already been developed in our nation's policies and direction, and it can be increasingly effective by considering and implementing these recommendations by experts in the field.

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# Appendix 1: Glossary of Terms

**biodiversity—**The variety of species in a particular habitat or ecosystem.

**break-even threshold—**Threshold where the costs expended for the mitigation measure equal the expenses incurred due to the average costs of wildlife-vehicle collisions at that site. (Huijser et al. 2009)

**citizen science—**The collection and analysis of data relating to the natural world by members of the general public (Oxford Dictionary Press 2016).

**culvert—**A tunnel carrying a stream or open drain under a roadway. Culverts come in many shapes, sizes, and materials; some have natural open bottoms (Oxford Dictionary Press 2016).

**ecological integrity—** Maintaining the diversity and quality of ecosystems and enhancing their capacity to adapt to change and provide for the needs of future generations. (IUCN n.d.)

**habitat connectivity—**The degree to which habitats are linked across the landscape to facilitate wildlife movement and access to critical life resources such as food, water and mates..

**habitat fragmentation—**The division of large, continuous habitats into smaller, more isolated, habitats.

**permeability—**The degree to which a roadway offers safe crossing opportunities for wildlife to access habitats on the other side.

**road ecology—**The study of the interaction between human-built infrastructure and the natural environment.

**statewide transportation improvement program (STIP)—**A statewide prioritized listing of transportation projects for 4 years that is consistent with long-range state and metropolitan transportation and transportation improvement plans, and is required for project funding eligibility under federal highway and transportation codes (titles 23 U.S.C. and 49 U.S.C. Chapter 53). (23 C.F.R. § 450.104).

**wildlife crossing structure—**A structure designed or retrofitted to provide safe passage for wildlife above or below a roadway.

**wildlife overpass—**A bridge or other structure that allows wildlife to pass over a roadway.

**wildlife underpass—**A tunnel or other structure that allows wildlife to pass under a roadway.

# Appendix 2: Scientific and Common Names of Animal Species

| **Scientific name:** | **Common name:** |
|---|---|
| *Alces* | Moose |
| *Antilocapra americana* | Pronghorn antelope |
| *Caudata* | Salamander |
| *Cervus canadensis* | Elk |
| *Glaucomys sabrinus* | Northern flying squirrel |
| *Lynx canadensis* | Canada lynx |
| *Lynx rufus* | Bobcat |
| *Odocoileus hemionus* | Mule deer |
| *Ovis canadensis* | Bighorn sheep |
| *Procyon lotor* | Raccoon |
| *Puma concolor* | Florida panther |
| *Taricha granulosa* | Rough-skinned newt |
| *Taxidea taxus* | American badger |
| *Terrapene carolina* | Box turtle |
| *Ursus americanus* | Black bear |
| *Ursus arctos* | Grizzly bear |
| *Vulpes vulpes* | Red fox |

# Appendix 3: Workshop Participants

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