Abstract: Roads are one of the leading causes of habitat destruction and loss of connectivity throughout the world and particularly in the United States. An increase in direct human-animal interactions through road travel furthermore generally creates negative consequences for both humans and animals. Species most vulnerable to habitat fragmentation are those with large home ranges and low population numbers, including large mammals and, in particular, carnivores. Since road construction is not ending and vehicular travel is only becoming more popular in the United States, we must find ways in which to mitigate the effects of transportation on wildlife in order to ensure healthy wildlife populations for generations to come. By keeping small populations connected through corridors, studies have shown decreased extinction levels, increased species diversity and increased genetic diversity within species. Although there are some disadvantages to connecting populations through corridors, such as the spread of disease and exotic species and an increased exposure to humans, many areas have experienced success through different types of structures used to connect populations. The goal of this paper is to outline case studies in which mitigation measures (underpasses, overpasses, fencing) have been used to reduce the impacts of transportation on wildlife throughout Europe, Canada and the United States. According to the U.S. Federal Highway Administration International Technology Scanning Team, habitat loss due to fragmentation by roadways is one of the leading factors of wildlife mortality in Europe. The Europeans developed some of the first mitigation measures to decrease the effect highways have on wildlife, due in great part to the overwhelming human population sizes and accompanying habitat loss. Overall, Europeans have found that overpasses, especially those greater than 60m wide, are very effective, particularly for large mammals. Following are specific examples of mitigation projects used in five European countries (Slovenia, Switzerland, Germany, France, The Netherlands.)
Highways and Wildlife: Review of Mitigation Projects throughout Europe, Canada and the United States

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“What is huge, conspicuous, and avoided by ecologists? The road network etching the land appears to be the only spatial element that essentially all landscapes have in common.”
(Forman 1998)

The loss of biodiversity is one of the most important issues facing conservationists today. According to Haas (2000), habitat fragmentation directly leads to loss of biodiversity. This decrease in biodiversity is linked to connectivity—without it populations cannot weather events to which they normally would be resilient (McKelvey et al. 2002). The total population size and the range that a population can occupy are increased by connectivity between small populations. Without this connection, populations may experience local extinctions due to stochastic, or “chance”, events, such as drought or fire. In addition, inbreeding in small, isolated populations can cause the entire population to become more susceptible to disease and, along with lower reproduction and higher mortality, can cause these populations to become extinct (McKelvey et al. 2002). However, if small populations maintain connectivity with other small populations, these negative effects can essentially be eliminated because it increases both total population size and range of the organism, as well as allowing for breeding between populations. Thus, structures that eliminate connectivity as well as decrease habitat quality are extremely destructive to small populations that are already threatened (McKelvey et al. 2002).

Roads are one of the leading causes of habitat destruction and loss of connectivity throughout the world and particularly in the United States. In 1999, more than 89% of all trips...
taken by Americans were made in vehicles (Turrentine et al. 2001). That number equates to more than 200 million vehicles driving 5 trillion miles in one year in the United States (Cerulean 2002). This fact is not surprising when considering that the U.S. road system contains 3.9 million center lane and 8.2 million total lane miles (Turrentine et al. 2001) and covers approximately 2% of the total U.S. land area (Cerulean 2002). Obviously, as Turrentine et al. (2001) states, “the road vehicle system is a mature and essential system that is unlikely to be replaced in the near future.” Driving is the most popular form of transportation in the U.S.; however, it does not come without consequences. In the U.S. alone, 4.8 million hectares of land have been directly destroyed by road construction (Trombulak and Frissell 1999). This is land that used to support flora and fauna that are now experiencing the effects of habitat fragmentation and unnatural threats such as roadkill (Trombulak and Frissell 1999). In fact, in order to determine the actual amount of suitable habitat for wildlife, one must superimpose a map of the road system in the U.S. on the areas that seem to be suitable habitat; almost always, habitat boundaries are dictated by road locations (Devlin 1998). Along with this increase in road construction and use comes an increase in development and resource extraction in areas that were formerly undisturbed habitat (Cerulean 2002). An estimated 15-20% of the United States is affected by roads (Jackson). Thus, it is not surprising that, according to Bill Ruediger, director of the U.S. Forest Service’s threatened, endangered and sensitive species program in Montana and Idaho, “[the impact of highways on wildlife] is the conservation issue of the 21st century” (Devlin 1998).
An increase in direct human-animal interactions through road travel generally creates negative consequences for both humans and animals. One million vertebrates are killed every day on roads in the United States (Lowy 2001). The cost of the enormous amount of roadkill to society and the economy is staggering. Two-hundred people are killed and 29,000 are injured in the United States each year in deer-vehicle collisions alone (Conover et al. 1995). According to the Insurance Corporation of British Columbia (ICBC), the societal cost of a human fatality is $4.17 million, while an injury costs approximately $97,000 (Sielecki 2000). Between 1997 and 2000, ICBC paid approximately $67 million in wildlife-related claims. In some states in the U.S., 6 to 8 cents of every insurance dollar goes toward paying for wildlife-related claims (Lowy 2001). Beyond the cost of human fatality and injury are the maintenance costs of removing carcasses from highways. Ministry Maintenance Contractors in British Columbia spent about $600,000 on personnel and equipment to remove dead wildlife in 2000 (Sielecki 2000). In addition, the estimated value of a harvested deer is approximately $1,313, making the economic loss of deer killed by vehicles in the U.S. $1.7 billion annually (Jackson). Furthermore, the British Columbia Ministry of Water, Land and Air Protection estimated that about $392 million was spent in 1996 on direct wildlife activities (Sielecki 2000), an industry that is almost solely based on large mammals that have low reproductive rates and large home ranges.

Species most vulnerable to habitat fragmentation are those with large home ranges and low population numbers, including large mammals and, in particular, carnivores (Haas 2000). Some examples of species directly affected by roads are grizzly bears, black bears, gray wolves, Florida panthers, mountain lions, lynx, ocelots, snakes and desert tortoises. The loss of these top predators can have detrimental community-wide effects leading to an imbalance between predator and prey numbers that causes prey populations to explode (Haas 2000). The effects of
roads are so detrimental to connectivity, in fact, that studies have shown that gray wolves that migrated from Canada to reestablish in Montana stopped when they reached Interstate-90. Specifically, Defenders of Wildlife (2002) gives the following impacts of roads on wildlife:

1. Mortality from road construction
2. Mortality from collisions with vehicles
3. Modification of animal behavior
4. Alteration of the physical environment (including soil, temperature, light, etc.)
5. Alteration of the chemical environment (including metals, salts, nutrients, etc.)
6. Spread of exotics
7. Increased use of areas by humans.

In fact, as Trombulak and Frissell (1999) explain, it is often “difficult or impossible to separate the direct ecological effects of roads from those of the accompanying land-use activities.”

Since road construction is not ending and vehicular travel is only becoming more popular in the United States, we must find ways in which to mitigate the effects of transportation on wildlife in order to ensure healthy wildlife populations for generations to come. By keeping small populations connected through corridors, studies have shown decreased extinction levels, increased species diversity and increased genetic diversity within species (Haas 2000). Although there are some disadvantages to connecting populations through corridors, such as the spread of disease and exotic species and an increased exposure to humans (Haas 2000), many areas have experienced success through different types of structures used to connect populations. The goal of this paper is to outline case studies in which mitigation measures have been used to reduce the impacts of transportation on wildlife throughout Europe, Canada and the United States.

WILDLIFE MITIGATION STRUCTURES

The following mitigation measures are thought to be the most effective in reducing the impact of transportation on wildlife. However, other methods do exist, including non-structural
approaches such as olfactory repellents to raise animal awareness, ultrasound, road lighting, population control through hunting and habitat modification (i.e. undesirable vegetation planted near roadways to reduce feeding) as well as structural approaches such as reflectors that transfer light from car headlights into adjacent habitat, noise barriers and signs. Most of these methods have seen limited success in Europe, where they have been most extensively studied. Some, such as noise barriers, even increase fragmentation. However, signs combined with speed limits and flashing lights have had a more positive impact upon reducing wildlife-vehicle collisions (Bank et al. 2002). Yet, signage is still not as successful as the following mitigation structures.

_Underpasses_

Underpasses are structures used to funnel wildlife below roadways. Common types of underpasses include metal or pipe culverts for small animals, concrete box culverts, viaducts and open-span bridges to accommodate larger animals and concrete trenches for amphibians (Bank et al. 2002, Highway Service Center). These measures range in price from $50,000 for a small circular culvert to $350,000 for a box culvert (Highway Service Center). Underpasses are sometimes preferred because of their lower cost, suitability for aquatic and burrowing species and ability to be less conspicuous. However, they are also more confined than overpasses and can have altered light levels and climatic conditions (Giving Wildlife Safe Passage).
Overpasses

Overpasses, also known as “land bridges”, are created by building a bridge over a highway and using fencing to guide animals toward the overpass. These are the most expensive mitigation measures, costing around $1.5-2 million (Highway Service Center). Some benefits of overpasses include: used by many species, roads can be “hidden”, use natural vegetation, less noise and possibly more natural movement of animals. However, drawbacks include cost and the inability of aquatic and burrowing species to use them (Giving Wildlife Safe Passage).

Overpass

Dual-Use Overpass

Fencing

Fencing is used both as a barrier between wildlife habitat and roadways as well as a funneling device to direct animals toward other structures such as underpasses and overpasses. Wildlife fences range from 2.4m to 2.8m high and often include fine mesh wire along the bottom to prevent small animals from entering the highway right-of-way. In some areas it is also necessary to include a buried portion of fence so that digging animals cannot enter the highway (Bank et al. 2002). A variety of gates are included with these fences, such as: one-way gates and jump-outs (i.e. ramps of soil) that allow animals to escape if they are caught on the highway; cattle gates to keep wildlife from entering the highway via road intersections; and double-swing gates and pedestrian gates that allow human access beyond the highway (Highway Service...
Center). Fencing costs between $35 and $90 per meter, depending upon the type of post (wood or steel) and if fine mesh wire is included along the bottom (Highway Service Center).

**Fencing with plastic apron**

![Fencing with plastic apron](http://www.hsctech-twinning.ca/mitigationmeasures1.htm)

**Jump-Out**

![Jump-Out](http://www.hsctech-twinning.ca/mitigationmeasures1.htm)

**One-Way Gate**

![One-Way Gate](http://www.hsctech-twinning.ca/mitigationmeasures1.htm)

### EUROPE

According to the U.S. Federal Highway Administration International Technology Scanning Team, habitat loss due to fragmentation by roadways is one of the leading factors of wildlife mortality in Europe (Bank et al. 2002). The Europeans developed some of the first mitigation measures to decrease the effect highways have on wildlife, due in great part to the overwhelming human population sizes and accompanying habitat loss. Overall, Europeans have found that overpasses, especially those greater than 60m wide, are very effective, particularly for large mammals. Following are specific examples of mitigation projects used in five European countries.

**Slovenia**

Slovenia is experiencing an increase in both forested regions and highway construction. Along with this unique combination of events, Slovenia is home to approximately 300-400 Eurasian brown bears—the only population of bears able to recolonize the depleted Alps population (USDOT 2000). Yet, because of its growing highway system, the primary migratory
route for the bears has been split with a road. Therefore, although in the past Slovenia has only used fencing and signs to mitigate the effects of transportation on wildlife, an increase in brown bear deaths has led to the construction of the first underpass (USDOT 2000).

In order to determine the most effective location for mitigation structures, geographic information systems (GIS), hunter information and radio tracking data were used (Bank et al. 2002). Currently, Slovenia houses eleven underpasses, five overpasses and two viaducts, along with numerous amphibian culvert systems. Underpasses greater than 25m wide and 3 to 5m high have been the most successful (i.e. box culverts). Size has been the determining factor in ungulate usage, wherein these animals tended to only use very large box culverts or overpasses. However, overall, fourteen focal species, including the brown bear, wolf and small mammals, regularly used all of the overpasses, underpasses and viaducts. Through their long-term monitoring programs—7300 days in 5 years—Slovenian researchers have determined that the frequency of use of the mitigation structures is negatively impacted by human traffic (Bank et al. 2002).

Slovenian Viaduct

Box Culvert

The Swiss have created many of the guidelines for overpass and underpass dimensions as well as location. According to their research, the most important factor influencing the efficacy of mitigation measures is location. The Swiss place their structures between prime habitat areas where populations of focal species are already found (Bank et al. 2002). In order to protect
habitat, the Swiss government gives financial compensation to those landowners who maintain greater than ten percent of their holdings as native habitat. Although location is the primary determinant for mitigation structures, the Swiss have found evidence that viaducts and overpasses are the most effective structures for the widest range of species (Bank et al. 2002). Therefore, more than twenty overpasses have been built throughout the country, with widths of 3.4 to 200m.

Landscape design is extremely important to mitigation structures in Switzerland, primarily because many of the overpasses are dual usage—both animals and humans use them to cross highways. Therefore, the Swiss plant habitat corridors along the highway and adjacent to human-use areas on overpasses to provide cover and habitat. Pipe culverts used for small animals are placed near hedgerows. Stumps are used for small animal habitat in viaducts. The Grauholz overpass, which crosses over six lanes of traffic, and a new 50m-wide overpass, have hedges, ponds, bushes, rocks and stumps in order to eliminate noise and light infiltration. Using infrared video technology, the Swiss have determined that overpasses narrower than 50m may cause some animals—especially ungulates—to become frightened (Bank et al. 2002). However, badgers, foxes, martens, roe and red deer use many of the smaller overpasses in Switzerland.

Another structure used often in Switzerland is the one-way pipe. This structure moves amphibians from the terrestrial habitat on one side of a highway to ponds on the other side. Once they reach the wetland area and are able to reproduce, a one-way pipe going the opposite way leads them back to their terrestrial habitat (Bank et al. 2002). Once again, the Swiss use
hedgerows to lead animals to the pipes and provide cover. In addition, the Swiss have found
signs to be effective. Yet, the most effective at changing human behavior are those signs that are
triggered when animals are close to the highway and also contain lights (USDOT 2000).

One-Way Amphibian Pipe

Germany

With thirty-two overpasses currently in use, eight under construction and twenty more
planned, the German government and researchers undoubtedly believe in the efficacy of these
structures. Most German overpasses are dual-use, with part of the overpass being used as a farm
road and the other part planted with vegetation as cover for wildlife. Germans prefer overpasses
to culverts because they allow for the passage of larger animals in addition to small animals
(Bank et al. 2002). Therefore, most new roads are equipped with overpasses. These land bridges range in width from 8.7 to
870m, but most are between 30 and 50m wide. And, although most are dual-usage, bridges built specifically for wildlife
incorporate large boulders at the ends to block vehicles. Required monitoring has shown that
foxes use the actual road used by vehicles, while wild boar and deer use the vegetated area. In
addition, Germany uses steel barriers with a lip at the top to guide amphibians into larger
culverts that pass under the highway (Bank et al. 2002).

France
France has a total of 250 crossing structures with 125 overpasses, making them the primary mitigation measure used. The intent behind French crossing structures is not complete connectivity, but rather the exchange of enough genetic diversity to maintain hunting populations. Many of the overpasses are hourglass-shaped, with a narrow point of 8-15m. The French believe this construction technique reduces cost, while maintaining adequate cover for focal species (Bank et al. 2002). This practice is disputed by the Swiss, who believe the cost to be approximately equal to that of a straight overpass design.

Through required monitoring for one year post-construction with a five-year revisit, the French have determined that, in some projects, using multiple smaller overpasses is more effective than using one large overpass. In addition, they have begun to build high wooden fences along the edges of the overpasses to serve as a noise and visual barrier (Bank et al. 2002). With respect to amphibian crossing, in newer construction the French have chosen to use 3.5m pipe culverts and to incorporate a dry ledge along a wet culvert to maintain habitat for terrestrial species (Bank et al. 2002).

The Netherlands

The Netherlands is a leader in using models such as LARCH to create transportation infrastructure (Bank et al. 2002). These modeling programs allow researchers to incorporate aspects of the ecosystem and specific populations in order to create landscape scenarios and are used to support the construction of mitigation structures at specific sites. Modeling has led to the creation of four overpasses—both hourglass and straight-shaped—with widths from 17 to 50m.
In addition, the Dutch have modified some previously constructed bridges by covering one lane with vegetation and using fencing to direct animals toward it. The Dutch also use fine-mesh fence to direct small animals and amphibians toward 0.4- to 2m-wide circular or rectangular tunnels (Bank et al. 2002).

The most impressive success for wildlife in the Netherlands, however, has been the use of tunnels to increase the badger population. Until the early 1990’s, 20% of the badger population was killed on the highway each year (USDOT 2000). Then, the Dutch constructed five tunnels, with included escape gates, that connected the badger sets. Using infrared video cameras and tracks, the researchers determined that the tunnels were being used frequently. This claim was supported by an approximate doubling of the population after the construction of the tunnels. Now the tunnels are considered for every new highway project in the Netherlands (USDOT 2000).

**CANADA**

The Trans-Canada Highway (TCH) cuts directly through Banff National Park (BNP), bringing 4 million visitors per year to the park and allowing 5 million additional drivers per year, including semi-truck drivers, to travel through the area. Built directly through an area of pristine wilderness, this highway has been dubbed the “Berlin Wall” of BNP and has led to a mortality rate so great that biologists have called the Banff-Bow Valley a “wilderness ghetto”. At least 1,720 large animals were killed on the TCH and Canadian Pacific Railway between 1981 and 1999. Half of all wildlife deaths in Banff occur due to the TCH. During the height of tourist season 22,000 vehicles per day pass through BNP. Not surprisingly, the Bow Valley, through
which the TCH runs, is home to only four wolves when it should support twenty. In fact, in
BNP, 100% of grizzly bear mortality occurs less than 500m from roads (Clevenger 1998). In an
effort to mitigate the effects of transportation infrastructure on the wildlife in BNP, the Canadian
government chose to use a variety of mitigation structures.

As 28 miles of the TCH that runs through BNP was widened, mitigation measures were
incorporated to increase the permeability of the highway to the wildlife. The first phase was
begun in the mid-1980’s and ran from the east park entrance to the Bow Valley Parkway. This
phase included the construction of eleven underpasses and a 2.4m high fence built adjacent to the
highway. Most of the underpasses were open-span bridges, but one 4m
metal culvert was also included (MountainNature.com). The second
phase of construction occurred in 1997 and widened the highway from
the Bow Valley Parkway to Castle Junction. Two 50m-wide overpasses
and eleven underpasses (nine culverts and two creek bridges) were built, along with fencing that
also included a fine-mesh wire “apron” along the bottom to discourage small animals from
entering the highway (MountainNature.com). On average, one
mitigation structure was constructed every 1.9km, with the
overpasses situated 9km apart (Highway Service Center). Berms
(raised sections of earth) were added to the underpasses and
overpasses to alleviate noise and light disturbance; openings were cut in concrete barriers to
allow small animals to cross the highway; one-way gates and jump-outs were included to allow
animals stuck on the highway right-of-way an opportunity to escape; and cattle gates are used to
keep animals from accessing the highway from road intersections (Highway Service Center).
In order to determine the effectiveness of these structures, a research program was launched in 1996 by Parks Canada. Early research indicated that the structures were effective for elk, deer and coyotes, but not for large carnivores, such as wolves, cougars, black bears and grizzly bears (MountainNature.com). This information, obtained through tracks and video surveillance, caused the designers to include two overpasses in phase two construction during 1997 (MountainNature.com). However, the definition of effectiveness changes depending on the goal. For some biologists, success is defined by a focal species using the structure. For conservation geneticists, one crossing per species per generation would counter the effects of genetic isolation. For wildlife ecologists, many crossings of many species would constitute success (Clevenger 1999).

Even with these different definitions, some promising numbers do exist. For instance, from 1996 to March 2001, animals crossed the structures 32,518 times. Different species have unique preferences with regard to structure type and location. For carnivores, including grizzly bears, wolves and cougars, the distance of the structure from the Banff Townsite is most important on influencing usage, with a positive correlation between distance and usage (MountainNature.com). Carnivore usage is also negatively correlated with human use, positively correlated with openness and length and highly associated with whether the structure is near a drainage (Clevenger 1998). Elk and deer prefer structures that are short in length, less than 7m wide, greater than 2.4m high, have a clear view of the entrance and have high human usage (MountainNature.com and Clevenger 1998). Bighorn sheep have yet to use the structures built in phase two, while moose prefer the overpasses built during this time (MountainNature.com). Martens use the culverts, possibly to avoid predation (MountainNature.com).
Although it is impossible to truly measure effectiveness without “pre-mitigation” numbers, these structures seem to be successful. Elk are the most frequent users of underpasses, followed by deer, coyotes, black bear, wolves and cougars. Elk, deer and coyotes have used all of the underpasses, while black bears have used nine, wolves have used six and cougars have used five (Clevenger 1998). Through-passage increased from 50% after the first year of monitoring of phase one structures to 83% after the second year of phase one monitoring. After the first year of phase two monitoring, through-passage was at 96% and by 1998 it had reached 98% overall (Clevenger 1998). These structures have also decreased roadkill in mitigated areas. Fencing alone cut ungulate roadkill by 96% (USDOT 2000). Since 1981, 75% of the wolves killed in BNP were killed in unmitigated and unfenced areas. Overall, only 30% of large carnivore roadkill deaths occurred in mitigated areas (Highway Service Center).

Along with these successes come some disappointments. For instance, the overpasses are “arched”, causing animals to have to travel into the “unknown” in order to cross. Researchers have suggested that locating the overpasses at the bottoms of gulleys could provide for better visibility (MountainNature.com). In addition, black bears and cougars are able to climb the fences, causing increases in roadkill even in mitigated sections. One suggested improvement is to eliminate dandelions from areas near the fences, as they are a delicacy for black bears. In addition, researchers are experimenting with mesh wire placed at a 90° angle from the top of the fence, acting much like the “lip” on amphibian trenches to discourage animals from climbing over the top of the fence (USDOT 2000). Although location is, according to Dr. Anthony Clevenger (1998), the “most critical factor in guaranteeing success,” overall limits on human activity in the area could greatly increase the usage of these structures by wolves, female grizzly
bears and other sensitive carnivore species (USDOT 2000). In the future, it is suggested that using only underpasses may be more economical and possibly as effective as the current design because of the comparatively small number of overpass crossings (MountainNature.com). However, Parks Canada biologist David Poll suggests that overpass use may surpass underpass use once the vegetation matures (USDOT 2000).

UNITED STATES

The United States is behind Europe and Canada in the use of mitigation measures to decrease the effects of its extensive road system on wildlife. However, projects have been initiated in many states that address a variety of issues, from species-specific crossings to the connectivity of pristine habitat. Following is a summary of these projects, along with research results if available (although many projects are too new or funding is too small to produce extensive monitoring results).

Massachusetts

Each spring, spotted salamanders in Amherst, Massachusetts migrate to vernal pools in order to mate and lay their eggs. Because these pools become completely dry seasonally, salamanders can lay their eggs without fear of fish feeding on them (Roble). In many areas, however, roads are constructed between the salamanders and these breeding areas, causing massive casualties during migration season (USDOT 2000). In Massachusetts, volunteers carried the salamanders across the roads in buckets for years before contracting the project out to ACO Polymer, a private German company that specializes in amphibian
culvert construction. Along with the British Fauna and Floral Preservation Society, the company constructed two tunnels 200 feet apart under the roadway. Drift fences were used to guide the salamanders to the tunnels, and slotted tops were added to the tunnels to provide the appropriate light and moisture levels (USDOT 2000). Using mark-recapture techniques, the researchers discovered that the length of the fence did not affect the success of the salamander to reach the tunnel and, overall, the salamanders had a 75% success rate in crossing the road using the underground corridors. Researchers also included that the success of this project may be dependent upon the tunnels being located in primary movement corridors for the animals (USDOT 2000).

California

Similar methods were used in Palo Alto, California to aid in the movement of the California tiger salamanders from their homes to vernal pools, separated by a road. Approximately half of the population was killed during each migratory period, and the amphibian is now listed as a “species of special concern” in California. However, for a cost of $20,000, an asphalt barrier was constructed along the road to guide the salamanders into a 50-foot long metal tunnel with holes on top. No data has of yet been collected on the success of the project (D’Agostino 2001).

In the western Mojave Desert, the habitat of desert tortoises, a state and federally listed threatened species, was fragmented by a highway. In order to eliminate highway mortality due to tortoises entering the highway right-of-way, fencing was erected to keep the tortoises off the road and guide them toward two 1.6m by 66m corrugated metal culverts. Then, a multi-agency team of researchers tagged
172 tortoises with Passive Integrated Transponders (PIT). This system, which has been used to track fish in the past, was outfitted with solar panels and solar rechargeable batteries in order to keep it eco-friendly, while the receiver and antennae were buried to prevent damage (Boarman et al. 1998). By attaching the system to the tortoises, researchers were able to track their movements through the culverts. They recorded 75 passes by five tortoises from 1995 to 1996 and expect those numbers to grow as the tortoises become familiar with the culverts as a viable passage point (USDOT 2000).

Washington

The Washington State Department of Transportation first surveyed barriers to fish movement on state roadways in 1991. At that time, barriers and culverts were prioritized so that those yielding the greatest habitat benefits were corrected first. Since the beginning of the Fish Passage Barrier Removal Program, 1,459,448m² (179 miles) of salmonid habitat has been reclaimed (WSDOT 2001), and the Washington State Legislature has increased funding for the project from $2-4million per biennium to $9.3million for 1999-2001 (USDOT 2000). Twenty-two barriers are scheduled for retrofitting or replacement from 2001-2003.

The obvious success of this program lies in the research foci on the hydraulic conditions of culverts as well as the ecology of salmonids (WSDOT 2001). Within the 4,463 sites where highways cross fish streams, 500 have been identified as “problem culverts”, wherein the water is too shallow, the water velocity is too high or the outfall drop is too far. Two successful culvert conversions include Rasmussen and McDonald Creeks. At Rasmussen Creek, researchers have replaced two round culverts with one archway to decrease the velocity of the

water for fish swimming upstream. In so doing, they added 1324m fish habitat. Since the construction, both Coho salmon and cutthroat trout, along with numerous other species, have been seen in upstream areas—places they could not reach prior to the project (USDOT 2000). In McDonald Creek, a box culvert was constructed 6ft. above the streambed, making it impossible for fish to enter the culvert. Therefore, pool-and-weir fishways were created, allowing the fish to climb into the culverts. Stream habitat was increased by 1279m, and the number of fish doubled within a month (USDOT 2000).

Washington is also in the process of dealing with a complex issue of highways and animal corridors in relation to Interstate-90. The state is planning to widen the road to a six-lane freeway in order to increase safety and travel comfort in an area that averages 24,400 vehicles per day (USDOT 2000). However, the Cascades Conservation Partnership (the Partnership) has detailed three reasons the I-90 corridor is so important to wildlife: 1) it creates a bottleneck for movement of animals and is the most narrow east-west point from the Canadian border to northern California; 2) it is an important east-west corridor due to its low elevation at Snoqualmie Pass; and 3) it is positioned between a number of important wilderness areas, lakes, old-growth forests and a national park. Thus, according to the Partnership, widening the highway will essentially eliminate this important north-south and east-west corridor in the Cascade Mountains (Fisher Consulting Services 2000). The U.S. Forest Service has already stated that, under current land use, the area will never see more than 50% old-growth forest. In addition, wolverines, grizzly bears, gray wolves and spotted owls all use the four critical corridors that run through the area (Fisher Consulting Services 2000). In fact, according to the Northwest Forest Plan, “the area is a critical connective link in the north-south movement of organisms in the Cascade Range” (Singleton). Although full funding for the highway
construction has not yet been obtained, researchers with the U.S. Forest Service are using GIS, 
snow tracking and cameras to determine important crossing areas. They have identified fifteen 
species that use the area as an important corridor and are now lobbying for funds to include 
wildlife crossings in the highway construction (USDOT 2000).

Wyoming/Yellowstone National Park

The Wyoming Department of Transportation is implementing wildlife mitigation 
measures, although little funding is available for monitoring their effectiveness. Wildlife fences 
have been installed at a cost of 30% higher than normal fences, but have shown little need for 
maintenance. Jump-outs and one-way gates have also been included to allow animal escape 
from the highway, and some underpasses have been constructed with recorded usage by elk and 
deer. Yet, their most important accomplishment may be buying easements to protect land around 
the Yellowstone National Park-to-Cody Road during its reconstruction (Bonds).

In addition, researchers in Yellowstone National Park (YNP) have begun to investigate 
the effects of road reconstruction within the park on the wildlife. Roads in the park were 
constructed over old horse trails that were created without consideration of the ecological 
impacts on terrain, vegetation or wildlife. Now, however, the roads are being rebuilt as wider, 
straighter roadways that can accommodate wide recreational vehicles and SUV’s. With an 
average of 2,972,227 visitors per year, the effects of vehicles on wildlife populations are sure to 
be substantial. In a study conducted from 1989-96, researchers recorded 936 mammal deaths. 
Included in this number are 375 elk, 286 mule deer, 79 bison, 66 coyote, 19 antelope, 11 beaver, 
9 white-tailed deer, 5 bighorn sheep, 5 black bear, 3 wolves, 2 grizzly bears and 1 raccoon 
(Gunther et al.). Of these 936 deaths, 85% occurred in areas with speeds above 45mph, and the
number killed was significantly more in areas with speed limits of 55mph. One reason for this result could be that vehicles exceeded the speed limit, on average, by 17mph in 55mph zones. What concerns researchers most, though, is that when identical stretches of highway were compared before and after construction, vehicles traveled, on average, 5mph faster on the newer section. According to Gunther et al., this could result in an increase in wildlife-vehicle collisions as park roads continue to be rebuilt.

*Florida*

Florida is among the states leading the way in wildlife-transportation mitigation. Unfortunately, with a human population that has increased from 1.7 to over 14million since 1936, many of the natural wildlife corridors have been developed and mitigation techniques are the only option (Hartmann). The first land bridge constructed in the U.S. was completed on September 30, 2000 over Interstate-75 in Florida (Berrios, personal communication). The overpass is 16m wide with a 5m trail created down the middle and 5.5m planters on each side. The overpass uses U-beams, which are supposed to make it more visually appealing to the 50,000 drivers that pass under the land bridge each day (USDOT 2000). The project cost $3.4million and, although no monitoring is currently being conducted, designers hope to install infrared cameras for night monitoring of animal passage (Berrios, personal communication).

Another mitigation project constructed on U.S. 441 was meant for amphibians and reptiles crossing the highway. Within a two-mile section of the road, the highest number of documented roadkills occurred, with 80 species
being killed (USDOT 2000). Therefore, a 1.1m high concrete wall with a 6 inch “lip” was constructed to guide the animals to culverts and also to prevent vertical assaults. However, unexpectedly, the wall also discouraged mammals from jumping over to enter the highway and, instead, served the same purpose in funneling the animals toward nearby underpasses (USDOT 2000).

In addition to the massive numbers of amphibians and reptiles being killed on Florida’s roads, the state’s threatened and endangered species are at a high risk of being killed on highways that are constructed through their main habitat corridors. One example is the Florida black bear. Decades ago, 12,000 individuals occupied the state; today, there are 1500 or fewer, with 50 being lost to roadkill each year (USDOT 2000). State Road 46 runs through one of their primary habitat corridors. Therefore, the Florida Department of Transportation and the Florida Fish and Wildlife Conservation Commission (FWC) decided to elevate the road over a box culvert, giving the bears a clear view of the 40 acres of secured habitat that lies on the other side of the 14.3m long, 7.3m wide and 2.4m high box culvert. Pine trees were also planted to guide the bears into the culverts. According to researchers, not only are bears using the culvert, but so are twelve other species (USDOT 2000).

Another federally listed species whose population has severely declined because of vehicle collisions is the endangered Florida panther. Between 1972 and 2001, 44 panther deaths were recorded by the FWC. Panther-vehicle collisions account for 24% of panther deaths. Therefore, during the conversion of State Road 84 to Interstate-75, fencing and crossings (at a cost of about $500,000 each) were constructed to mitigate the impacts vehicles have on the panther population (Florida Fish and Wildlife Conservation Commission 2001). Also, night speed limits were
lowered in 1985 in an attempt to decrease panther-vehicle collisions. Although 65% of the panther deaths by vehicle during this time occurred outside of the speed zones, some panthers were struck by vehicles traveling less than 25mph (Florida Fish and Wildlife Conservation Commission 2001). Although some sources say female panthers rarely use corridors and are reluctant to use any crossing that is connected to poor habitat (Gucinski et al. 2000), according to the FWC fencing and crossings have completely eliminated collisions in those mitigated areas (Florida Fish and Wildlife Conservation Commission 2001).

**Montana**

Montana has more public road miles than there are interstate miles in the entire U.S. (Defenders 2002). It is no wonder, then, that, according to the Western Forest Carnivore Committee, for a carnivore to use a landscape that extends from west-central Wyoming to mid-British Columbia and Alberta (the ideal home range size of most carnivores), it would have to cross “four highways in Wyoming, 17 highways in Idaho (including two interstates), 23 in Montana (including two interstates) and 17 in British Columbia and Alberta (including the TCH) (Devlin 1998). However, one mitigation project has been successfully completed and one major project is on its way in Montana.

Mountain goats living in Glacier National Park have been visiting a natural salt lick located south of what is currently U.S. Highway 2 for years. However, when an avalanche destroyed the highway in 1979, the Montana Department of Transportation (MDT) used Federal Highway Administration (FHWA) funds to...
build a safe goat passage under the new highway and bridge. During construction, crews worked special hours, lowered speeds and stopped vehicles for any goat wanting to cross in order to disturb the natural crossing as little as possible (USDOT 2000). Meanwhile, they placed metal screening on bridge rails and planted trees to guide the goats to the newly dug trails. After only one year, 99.4% of the goats used the underpass, less than half showed signs of fear and the number of individual salt lick visits doubled. Within three years, all goats used the new trails and some extended their lick visits into the fall and winter (USDOT 2000).

The Confederated Salish and Kootenai Tribes of Montana, the MDT, Missoula and Lake counties and the FHWA hope their mitigation plan for U.S. Highway 93 works just as well. A section of the two-lane road that stretches from Evaro to Polson is scheduled to be widened to handle increasing traffic and accompanying safety concerns (Giving Wildlife Safe Passage). Because this highway fragments important corridors in the region, a mixture of mitigation projects is being planned for the 56.3 miles. This is the most extensive mitigation program to be undertaken—outside of a national park—in North America and, because it is intended to serve the ecological community rather than be species-specific, a mixture of passage types are being used. According to Bill Ruediger, “U.S. Highway 93 can be a realistic prototype of how to build a ‘regular’ highway in the U.S. and the rest of the world” (Giving Wildlife Safe Passage). A number of large vertebrates will be affected by this project, including grizzly bears, wolves, deer, elk, moose, mountain lions, painted turtles, lynx and bull trout. In addition, some species of special concern include the endangered bull trout, threatened grizzly bear, threatened lynx and vulnerable painted turtles (Giving Wildlife Safe Passage). A total of forty-two crossings are currently planned with eight to twenty more being constructed in the Ninepipe section. The locations of these crossings are based upon roadkill data, tracking data, migratory patterns and
sighting records (Giving Wildlife Safe Passage). Of the forty-two crossings, ten are 4’x6’
corrugated metal or concrete box culverts, twenty-three are 12’x22’ corrugated metal or concrete
box culverts, one is a multi-span bridge, seven are open-span/multi-span bridges and one is a
wildlife overpass. Along with 23.7km of fencing, the total for all of these mitigation measures is
approximately $9.2million (Giving Wildlife Safe Passage). In addition, fencing and vegetation
will guide animals toward the crossings, and jump-outs and one-way gates will allow animals
that enter the highway to escape.
LITERATURE CITED


Giving wildlife safe passage across US Highway 93: a case study of a mitigation plan developed by the Confederated Salish and Kootenai Tribes, Montana.


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