US 93 NORTH POST-CONSTRUCTION WILDLIFE-VEHICLE COLLISION AND WILDLIFE CROSSING MONITORING ON THE FLATHEAD INDIAN RESERVATION BETWEEN EVARO AND POLSON, MONTANA

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Final Report

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FEDERAL HIGHWAY ADMINISTRATION

November 2016

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RESEARCH PROGRAMS

MDT

US 93 North Post-Construction Wildlife-Vehicle Collision and Wildlife Crossing Monitoring on the Flathead Indian Reservation between Evaro and Polson, Montana

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16. Abstract
The US Highway 93 North reconstruction project on the Flathead Indian Reservation in northwest Montana represents one of the most extensive wildlife-sensitive highway design efforts to date in North America. The reconstruction of the 56 mile (90 km) long road section included the installation of wildlife crossing structures at 39 locations and approximately 8.71 miles (14.01 km) of road with wildlife exclusion fences on both sides. The mitigation measures were aimed at improving safety for the traveling public through reducing wildlife-vehicle collisions and allowing wildlife to continue to move across the road. This report summarizes research conducted between 2002 and 2015. The research focused on the effectiveness of the mitigation measures in reducing collisions with large mammals, and the use of the crossing structures (specifically by white-tailed deer, mule deer, and black bear). In addition, the effectiveness of wildlife guards (similar to cattle guards), wildlife jump-outs and a human access point was evaluated. Finally, the researchers conducted cost-benefit analyses and formulated recommendations.

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ACRONYMS

AADT	Annual Average Daily Traffic
ANOVA	Analysis of variance
BA	Before-After analyses
BACI	Before-After-Control-Impact analyses
CI	Control-Impact analyses
CSKT	Confederated Salish & Kootenai Tribes
FHWA	Federal Highway Administration
MDT	Montana Department of Transportation
RITA	Research and Innovative Technology Administration
RSPA	Research & Special Programs Administration
WTI-MSU	Western Transportation Institute at Montana State University

DEFINITIONS

Carcass removal data	Animal carcasses reported by road maintenance personnel
Fenced	Road sections with wildlife fences designed for large ungulates (8 ft (2.4 m) tall, mesh size on upper half was 7 inches (17.8 cm) high, 12 inches (30.5 cm) wide). Some sections of wildlife fence include a dig barrier to reduce the probability that animals (e.g. coyotes) will dig under the fence.
Unfenced	Road sections without wildlife fences. Note that these “unfenced” sections still have right-of-way fences. Along US 93 North the right-of-way fences typically consist of wildlife friendly livestock fences (42 inches (107 cm) high, 4 strands). The upper and lower strands are smooth, the two middle strands are barbed. However, right-of-way fences are not considered a physical barrier to large wild mammal species.
Wildlife crash data	Wildlife crash data reported by law enforcement personnel. These data typically relate to the most severe collisions and have a minimum estimated vehicle repair cost of $1000.
Wildlife-vehicle collisions	Wildlife-vehicle crashes and carcass removal data

EXECUTIVE SUMMARY

Background

The US Highway 93 North (US 93 North) reconstruction project on the Flathead Indian Reservation in northwest Montana represents one of the most extensive wildlife-sensitive highway design efforts to date in North America. The reconstruction of the 56 mile (90 km) long road section included the installation of wildlife crossing structures at 39 locations and approximately 8.71 miles (14.01 km) of road with wildlife exclusion fences on both sides. The mitigation measures were aimed at improving safety for the traveling public through reducing wildlife-vehicle collisions while simultaneously allowing wildlife to continue to move across the road. The wildlife mitigation measures along US 93 North were an integral part of the reconstruction of this highway because the Confederated Salish and Kootenai Tribes (CSKT) required the reconstructed highway to be respectful of the land, the people and their culture, and wildlife. The Federal, State and Tribal governments agreed to reconstruct US 93 North based on the idea that "the road is a visitor and that it should respond to and be respectful of the land and the "Spirit of the Place". The "guiding philosophy" for the reconstruction of the highway was to "protect cultural, aesthetic, recreational, and natural resources located along the highway corridor and to communicate the respect and value that is commonly held for these resources pursuant to traditional ways of the Tribes".

The context sensitive design of US 93 North included wildlife fences and wildlife crossing structures along selected road sections and research to evaluate their effectiveness. The function of the wildlife fences is to keep wildlife from accessing the highway and to help guide wildlife towards the safe crossing opportunities. The wildlife crossing structures allow wildlife to cross the highway without being exposed to potential collisions with vehicles. Wildlife crossing structures can also help reduce intrusions of wildlife into the fenced road corridor as wildlife may choose to use the crossing structures rather than breach the wildlife fences to access the other side of the highway.

Human Safety

The mitigation measures in the three main study areas (Evaro, Ravalli Curves, and Ravalli Hill), reduced collisions with large wild mammals (mostly white-tailed deer) substantially when the increase in wildlife-vehicle collisions in the unmitigated "control" sections was taken into account: 71.44 percent based on carcass removal data and 80.04 percent based on wildlife crash data. However, the number of wildlife-vehicle collisions along the entire transportation corridor between Evaro and Polson (mitigated along 16.8 percent of its length) did not decrease. The human safety data from the unmitigated road sections along US 93 North are consistent with the findings of other studies. These showed that while wider lanes, wider shoulders, longer sight distances and more gentle curves improve human safety in general, wildlife-vehicle collisions are likely to increase.

Based on data from US 93 North and data obtained from the literature, wildlife fences proved most effective in reducing collisions with large mammals (almost always >80 percent reduction) if the fences and associated measures were installed over road lengths of at least 3.1 mi (5 km). When wildlife fences were implemented over relatively short road lengths (< 3.1 mi (<5 km)), the average effectiveness in reducing collisions with large mammals dropped to about 50 percent. The effectiveness of the wildlife fences was highly unpredictable for any specific mitigated road section shorter than 3.1 mi (5 km) in length. The reduced effectiveness of short fenced road sections was related to fence end effects that resulted in a concentration of collisions at and near fence ends. While fence end treatments (e.g. electric mats embedded in the pavement) can improve the effectiveness of short fenced road sections it is also important to explore if wildlife fences can be extended to cover at least 3.1 mi (5 km) of continuous road length to reduce the fence end effects.

Additional analyses were conducted to investigate the effectiveness of the mitigation measures in reducing collisions for black bear and grizzly bear. Black bear carcasses along US 93 North continued to be recorded after highway reconstruction and there was no evidence that the mitigation measures in Evaro, Ravalli Curves, and Ravalli Hill reduced the number of reported black bear carcasses. This was likely related to the relatively short road lengths equipped with mitigation measures, the design of the wildlife fence, and the gaps in the wildlife fence at access roads and steep slopes. There were six grizzly bear carcasses reported between 2002 and 2015. Five of these grizzly bears were hit after highway reconstruction and the associated implementation of the mitigation measures. Three of these were reported from the reconstructed highway sections with short sections of wildlife fences and wildlife underpasses in selected locations. The data showed that grizzly bear continued to be hit by traffic after highway reconstruction.

Habitat Connectivity

After reconstruction, 29 crossing structures were monitored with wildlife cameras to record wildlife use. The cameras recorded 95,274 successful crossings in total or 22,648 successful crossings per year which can be described as substantial. The vast majority of the crossings were by white-tailed deer (69 percent). Mule deer and domestic dogs and cats each represented about 5 percent of the successful crossings. In addition, there were 1,531 successful crossings by black bear. The crossing structures were successfully used by 20 different species of medium sized or large sized terrestrial wild mammals. Depending on the type and dimensions of alternative crossing structures in an area, white-tailed deer used bridges, overpasses and large culverts more than expected. Small culverts were not used or barely used by this species. Mule deer also used bridges and large culverts more than expected. Similar to white-tailed deer, mule deer did not use or barely used small culverts. Black bear used a wider variety of structures, bridges, large culverts and small culverts, more than expected. Grizzly bears exclusively used large culverts. However, within the area known to be used regularly by grizzly bears this is the most common type of structure. Elk and moose mostly or exclusively used the wildlife overpass.

The data showed that there was a learning curve for deer (white-tailed deer and mule deer combined) and black bear. These species used the structures more frequently with increasing age of the structures. While deer and black bear use can be considered high one year after construction, both species showed an increase in successful crossings for at least five years after construction. This suggests that wildlife use, specifically by deer and black bear, is likely to continue to grow.

Deer highway crossings (white-tailed deer and mule deer combined) either remained similar or increased after highway reconstruction. Black bear highway crossings remained similar after highway reconstruction. Since there was no indication of an increase in deer population size after reconstruction compared to preconstruction, the researchers conclude that the highway reconstruction and the associated mitigation measures did not reduce habitat connectivity for deer. Instead, when the learning curve is considered, habitat connectivity for deer across the highway actually increased in the mitigated road sections. The researchers did not have data on potential changes in black bear population size before and after highway reconstruction. Assuming there were no substantial changes in the black bear population size, habitat connectivity for black bear across the highway was at least similar before and after reconstruction in the mitigated road sections. This suggests that, even though wildlife could no longer cross the highway anywhere, the mitigation measures maintained or improved habitat connectivity for deer and black bear.

Large mammal use of large underpasses varied greatly, independent of the fence length associated with the underpasses. The data showed that the presence of wildlife fences and longer fence lengths did not necessarily guarantee higher wildlife use. Similarly, the absence of fences or the presence of very short sections of fences did not always result in low use of an underpass by large mammals. This suggests that large mammal use of underpasses is heavily influenced by other factors. These factors likely include the location of the structure in relation to the surrounding habitat, wildlife population density, and wildlife movements. Note that while wildlife use of underpasses is highly variable - probably mainly because of differences between locations -, an individual underpass may still have higher wildlife use if that underpass is connected to wildlife fences and if the fence length is long rather than short.

Wildlife Guards

Wildlife guards are similar to cattle guards. Wildlife guards were installed at selected access roads along US 93 North to discourage wildlife, specifically ungulates, from accessing the fenced road corridor at access roads. Wildlife guards were a very substantial barrier to deer (1.26 percent permeability for white-tailed deer and 0.45 percent permeability for mule deer). On the other hand, the wildlife guards were quite permeable for mountain lion (94 percent), bobcat (73 percent), black bear (53 percent), domesticated cats (46 percent), and raccoon (34 percent). When bears (black bear or grizzly bear), mountain lions or bobcats are the target species the researchers strongly recommend measures other than wildlife guards.

Wildlife Jump-Outs

Wildlife jump-outs are earthen ramps within the fenced right-of-way. They allow wildlife caught in between the fences to walk up a slope at the fence line and then jump down to the safe side of the fence. Jump-outs should be low enough so that wildlife will readily jump down to the safe side of the fence. However, jump-outs should also be high enough so that wildlife will not or rarely jump into the fenced road corridor where they may be hit by vehicles. This implies that the optimal height of the wildlife jump-outs depends on the target species and their ability and willingness to jump up or down. While there are no established standards for the performance of wildlife jump-outs, the use by white-tailed deer was very low (about 7 percent use to access the safe side of the wildlife fence). Mule deer were more able or willing to use the jump-outs to access the safe side of the wildlife fence (about 32 percent use). As no deer were observed jumping up into the fenced road corridor, the researchers suggest experimenting with gradually lowering the wildlife jump-outs. However, the researchers strongly suggest accompanying this with further research and monitoring as lower jump-outs may also result in an increasing number of animals jumping up and accessing the fenced road corridor with the associated risk of wildlife-vehicle collisions.

Human Access Point

Wildlife fences are not only a barrier to large mammals, but also to people. At one location a human access point was provided that allows humans to pass through the wildlife fence (in the Ravalli Curves area, just north of Spring Creek or RC 381, west side of the highway). The access point consisted of a gap in the fence, large enough for people to walk through but the configuration is such that the designers hypothesized that it would be a barrier to large ungulates, including white-tailed deer. While the human access point received relatively little use by humans (only 9 human crossings in 3.5 years), white-tailed deer crossed frequently through the human access point over the same period (140 times). The data showed that the human access point was quite permeable to deer and allowed deer to access the fenced road corridor.

Cost-Benefit Analyses

The mitigation measures along US 93 North did not generate monetary benefits in excess of their costs, at least not based on human safety parameters alone. The costs were lowest for highway sections with long and continuous wildlife fences and wildlife underpasses (no wildlife overpass). The costs were highest for highway sections that had wildlife crossing structures but only very short sections of wildlife fences or no wildlife fences at all. Note that the cost-benefit analyses were almost exclusively based on human safety parameters. Parameters based on passive use values were not part of the cost-benefit analyses. Yet these passive use values were the principal reason the structures were built in the first place, reducing the direct applicability of this particular type of cost-benefit analysis as an evaluation tool for the mitigation measures along US 93 North. Examples of passive use parameters can include but are not limited to having viable wildlife populations or reduced probability of vehicles killing threatened or endangered species (e.g. grizzly bear).

Measures of Effectiveness

The three governments (Federal, State and Tribal) agreed on measures of effectiveness for the wildlife mitigation measures implemented along US 93 North. They agreed on specific parameters and thresholds that had to be met to consider the wildlife mitigation measures a success. Almost all the measures of effectiveness were met, specifically those that related to habitat connectivity for deer and black bear and the functioning of the wildlife crossing structures. Some of the measures of effectiveness that related to human safety were met, but others were not. This was because road enhancements that included wider lanes, wider shoulders and longer sight distances were associated with an increase in wildlife-vehicle collisions. In addition, short road sections with wildlife fences (which characterize US 93 North) were, on average, less effective in reducing collisions with large mammals than long fenced road sections (> 3 mi (> 5 km) in road length). This is new knowledge that was partially based on the results of the US 93 North research project. One could argue that this was yet another possible measure of "success": investing in research resulted in important new knowledge that can be directly applied to the policies and practices of highway and wildlife management agencies.

Recommendations

Based on the results of the US 93 North research project and the current state of knowledge, the researchers formulated recommendations for the implementation of mitigation measures aimed at reducing wildlife-vehicle collisions and at providing safe crossing opportunities for large mammals. In addition, the researchers formulated specific recommendations for the maintenance and retrofits of the mitigation measures along US 93 North. These include:

- Putting a wildlife fence inspection and maintenance program in place.
- Increasing the length of the fenced highway sections.
- Implementing effective fence end treatments.
- Implementing specific measures to reduce grizzly bear-vehicle collisions between St. Ignatius and Ronan and surrounding areas (e.g. longer fences and possibly electric mats (not wildlife guards) at access roads).
- Removing the human access point that currently allows white-tailed deer to enter the fenced road corridor.
- Retrofitting the wildlife guards so that the concrete ledges are no longer accessible to wildlife when they attempt to access the fenced road corridor.
- Retrofitting the connections between wing walls of certain crossing structures and the retaining walls of certain jump-outs that have trapped and caused the death of large mammals on occasion.
- Conducting vegetation maintenance at the top and bottom of the jump-outs to physically allow wildlife to escape the fenced road corridor.
- Carefully reducing the height of the jump-outs to increase the use by deer, especially white-tailed deer.
- Initiating research into a potential hazard of wildlife guards for ungulates (e.g. potential for broken legs).
- Initiating research aimed at developing better functioning jump-outs for ungulates while not jeopardizing human safety.

- Initiating research into the effectiveness of electric mats at deterring wildlife at access roads and fence ends, specifically with regard to keeping grizzly bears from accessing the fenced road sections.

1. INTRODUCTION

1.1. Background

The US Highway 93 North (US 93 North) reconstruction project on the Flathead Indian Reservation in northwest Montana represents one of the most extensive wildlife-sensitive highway design efforts to date in North America. The reconstruction of the 56 mile (90 km) long road section included the installation of wildlife crossing structures at 39 locations and approximately 8.71 miles (14.01 km) of road with wildlife exclusion fences on both sides of the highway (Figures 1 and 2, Appendices A1 and A2). This is excluding the future mitigation measures in the Ninepipe wetland area.

The mitigation measures were aimed at improving safety for the traveling public through reducing wildlife-vehicle collisions and allowing wildlife to continue to move across the road. Other examples of relatively long road sections in North America with a high concentration of wildlife crossing structures and wildlife fences are I-75 (Alligator Alley) in south Florida (24 crossing structures over 40 mi; Foster and Humphrey 1995), the Trans-Canada Highway in Banff National Park in Alberta, Canada (24 crossing structures over 28 miles (phase 1, 2 and 3A); Clevenger *et al.* 2002), State Route 260 in Arizona (17 crossing structures over 19 miles; Dodd *et al.* (2006)), US 93 South in Montana (19 crossing structures over 37 miles; Cramer *et al.* (2015), and I-90 at Snoqualmie Pass East in Washington State (about 30 crossing structures planned over 15 miles; WSDOT 2007). Both the road length and number of wildlife crossing structures of US 93 North on the Flathead Indian Reservation made it among the most extensive mitigation projects of this kind in North America to date.

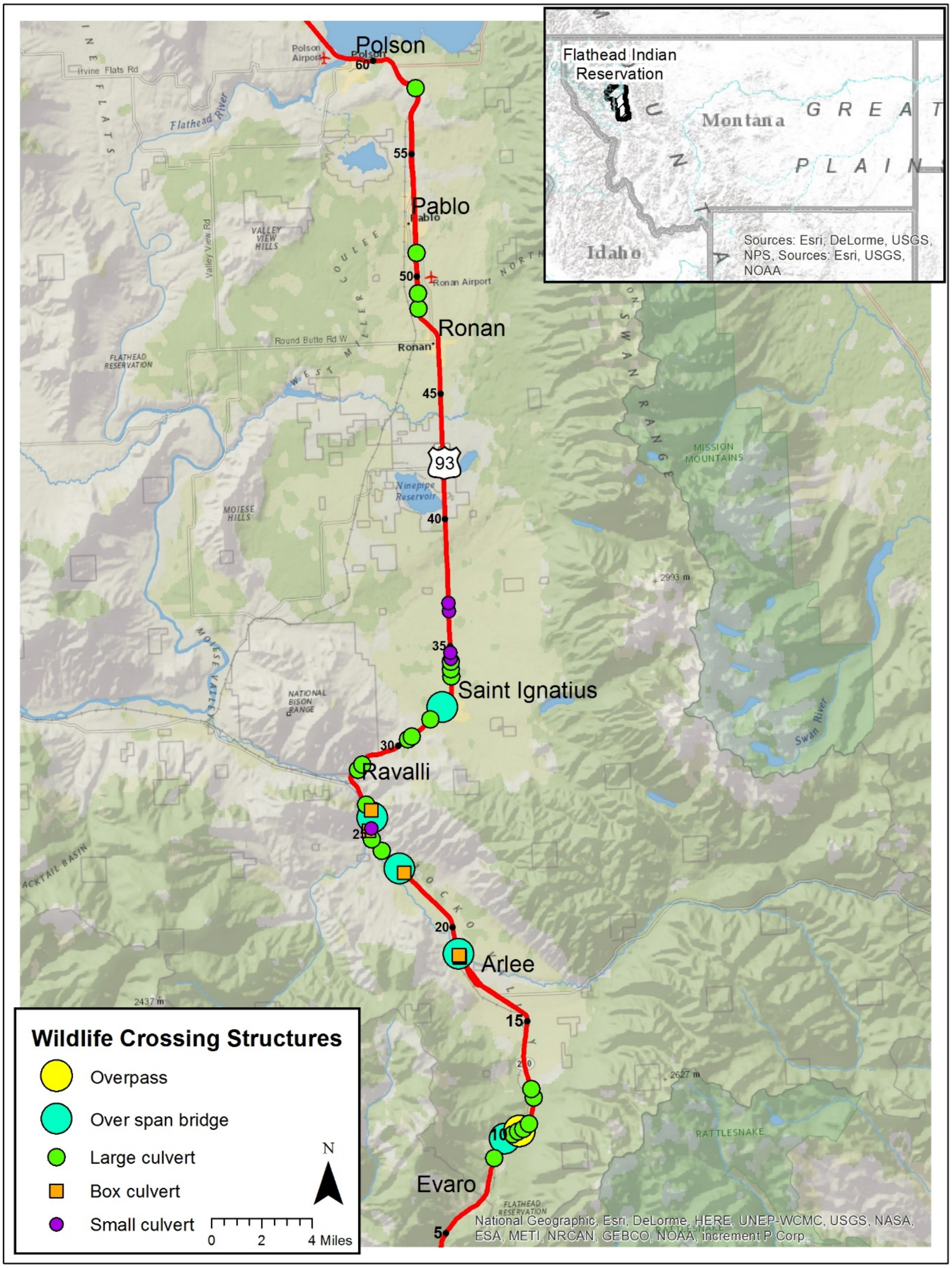

Figure 1: The location of the 39 wildlife crossing structures considered suitable for medium and large sized mammals along US 93 North on the Flathead Indian Reservation in northwestern Montana. See Appendix A1 for structure names, structure dimensions and other characteristics.

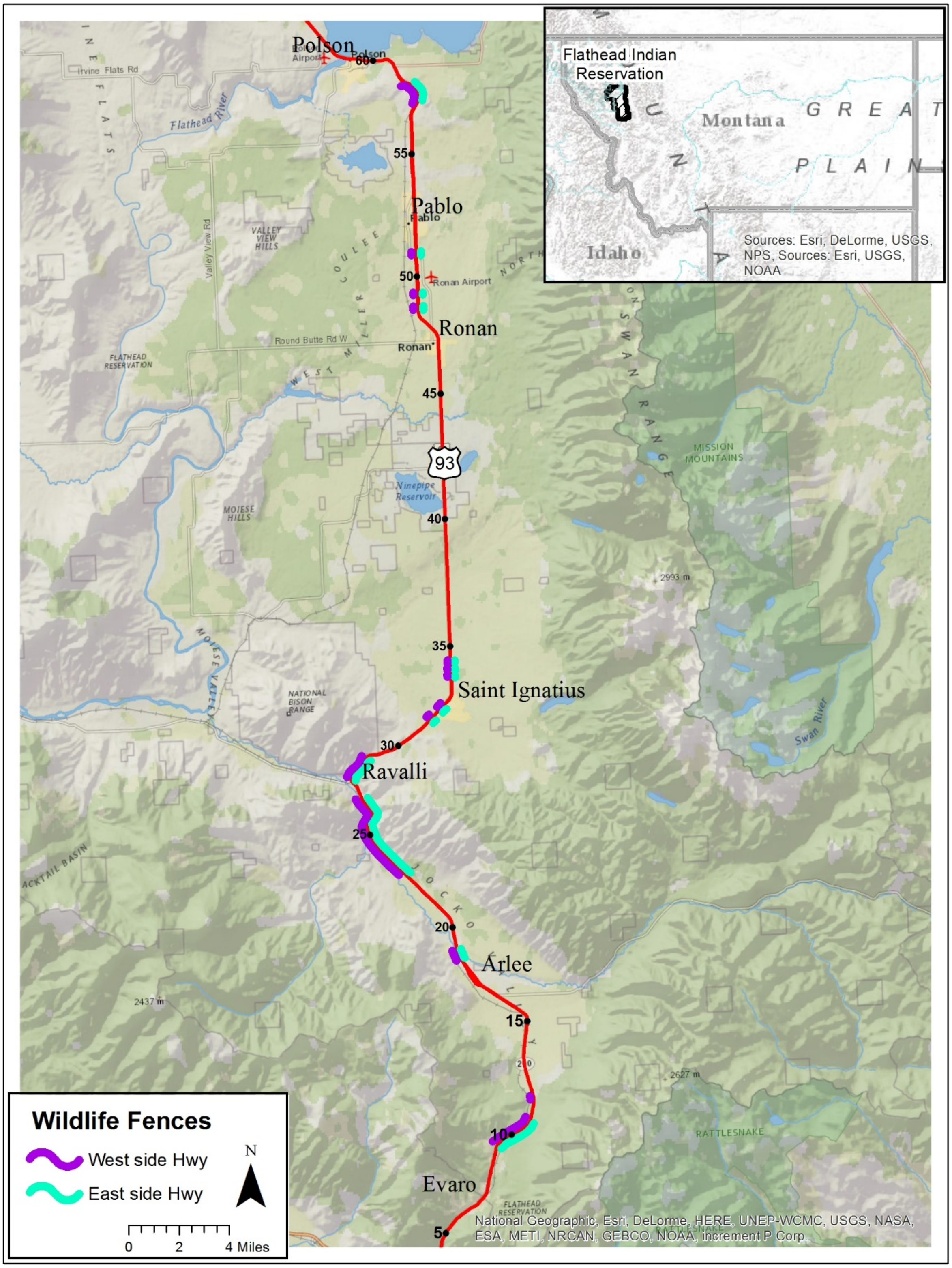

Figure 2: The location of the wildlife fences along US 93 North on the Flathead Indian Reservation in northwestern Montana.
See Appendix A2 for details on the start and end points for the wildlife fences.

The wildlife mitigation measures along US 93 North were an integral part of the reconstruction of this highway because the Confederated Salish and Kootenai Tribes required the reconstructed highway to be respectful of the land, the people and their culture, and wildlife (Becker and Basting 2010). Without approval and collaboration of all three governments (i.e. Federal, State and the Tribal government), the highway reconstruction project could not have been initiated (Becker and Basting 2010). After many years of negotiations, the three governments reached an agreement in 2000 (FHWA *et al.* 2000). This agreement is based on the idea that "the road is a visitor and that it should respond to and be respectful of the land and the "Spirit of the Place". The "Spirit of the Place" encompasses the entire Mission Valley, Mission and Salish Mountains, Jocko Valley, and Rattlesnake Divide. This broader environmental spectrum continuum has distinct landscapes like large outdoor rooms, which the existing road bisects" (US 93 Design Discussions Project Committee 2000a). The design of the reconstructed highway needed to "be influenced by, and respond to the land" so that it would "increase the perception that the road is integrated with the land rather than slicing through it" (US 93 Design Discussions Project Committee 2000a). "The guiding philosophy for modification of U.S. 93 is to protect cultural, aesthetic, recreational, and natural resources located along the highway corridor and to communicate the respect and value that is commonly held for these resources pursuant to traditional ways of the Tribes" (FHWA 2001). Values related to culture, landscape, and natural resources are not uniquely Native American. These values are present in almost any society. However, in the specific context of the reconstruction of a highway on a Native American reservation, these values were actually made an integral component of a context sensitive approach to redesigning a highway.

The context sensitive design of US 93 North included wildlife fences and wildlife crossing structures and research to evaluate their effectiveness (US 93 Design Discussions Project Committee 2000b, FHWA 2001, Hardy *et al.* 2007). The function of the wildlife fences is to keep wildlife from accessing the road where they may be hit by traffic (Clevenger *et al.* 2001) and to help guide wildlife towards the safe crossing opportunities (Dodd *et al.* 2007a, Gagnon *et al.* 2010). The wildlife crossing structures allow wildlife to cross the highway without being exposed to potential collisions with vehicles. Wildlife use of underpasses and overpasses can be substantial and meaningful at a population level (Clevenger and Waltho 2000, Sawyer *et al.* 2012, Sawaya *et al.* 2013). Wildlife crossing structures can also help reduce intrusions of wildlife into the fenced road corridor as wildlife may choose to use the crossing structures rather than breach the wildlife fence to access the other side of the highway. The wildlife crossing structures along US 93 North included one wildlife overpass in the Evaro area. The overpass was specifically targeted at grizzly bear (*Ursus arctos*) (US 93 Design Discussions Project Committee 2000b). This species uses wildlife overpasses much more frequently than wildlife underpasses (Sawaya *et al.* 2013). The reason the overpass was located in the Evaro area is that it "is the best possible location for linking grizzly bear populations to the east with the Bitterroot grizzly bear recovery zone to the west" (US 93 Design Discussions Project Committee 2000b).

The road sections where wildlife mitigation measures were implemented along US 93 North were not only selected based on a history of wildlife-vehicle collisions. Additional parameters included local knowledge and experience with regard to where wildlife was frequently seen on or near the road alive, low probability for changes in land use that could potentially negatively affect wildlife approaching the highway and the crossing structures (i.e. protected tribal, federal or state lands, or private land with easements), topography (e.g. road cuts (overpasses) or substantial road fills (underpasses)) and stream and river crossings (i.e. make a culvert or bridge across a stream or river also suitable for large terrestrial mammals).

Different sections of US 93 North were under construction at different times between 2004 and 2010 (Peccia & Associates 2015) (Appendix B). The road section between mile reference post 36.8 and 48.4 was not reconstructed. This road section bisects the Ninepipe wetland area and was subject to a supplemental Environmental Impact Statement (Federal Highway Administration 2001). As of 2016 the road section through the Ninepipe wetland area had not been reconstructed or mitigated yet.

1.2. Research

The magnitude of the US 93 North reconstruction project and associated mitigation measures provided an opportunity to evaluate to the extent these mitigation measures helped improve human safety through a reduction in wildlife-vehicle collisions, maintain habitat connectivity for wildlife (especially deer (*Odocoileus* spp.) and black bear (*Ursus americanus*)), and what the monetary costs and benefits were for the mitigation measures. In addition, the landscape along US 93 North is heavily influenced by human use, resulting in relatively short sections of wildlife fences and gates or wildlife guards at access roads. This is in contrast to the more natural vegetation along most of the other road sections that have large scale wildlife mitigation including continuous wildlife fences in North America. As the roads with most wildlife-vehicle collisions are in rural areas (Huijser *et al.* 2008), the results from the US 93 North project are likely to be of great interest to transportation and wildlife management agencies and other interested organizations and individuals throughout North America.

In 2002, prior to US 93 North's reconstruction, the Western Transportation Institute at Montana State University-Bozeman (WTI-MSU) was funded by the Federal Highway Administration (FHWA) and the Montana Department of Transportation (MDT) to initiate a before-after field study to assess the effectiveness of the wildlife mitigation measures. Pre-construction field data collection efforts were completed in the fall of 2005 and a final report on the preconstruction monitoring findings was published in January 2007 (Hardy *et al.* 2007). While the pre-construction research efforts (Hardy *et al.* 2007) are valuable on their own, their main purpose was to provide a reference for a before-after comparison with the post-construction data. The post-construction research was initiated in 2008 through a student project funded through the Western Transportation Institute at Montana State University (WTI-MSU) (U.S. Department of Transportation funds through its University Transportation Center program administered by the Research and Innovative Technology Administration (RITA) (Allen 2011). In 2010 MDT contracted with WTI-MSU to conduct the post-construction research with regard to the effectiveness of the mitigation measures. For this post-construction project, the Confederated Salish and Kootenai Tribes (CSKT) acted as a subcontractor to WTI-MSU.

1.3. Objectives

Consistent with the direction provided by Montana Department of Transportation (MDT), the project had the following objectives (Huijser *et al.* 2009a):

- Investigate the effect of the mitigation measures on human safety through an anticipated reduction in wildlife-vehicle collisions;
- Investigate the effect of the mitigation measures on the ability to maintain habitat connectivity for wildlife (especially for deer (white-tailed deer [*Odocoileus virginianus*] and mule deer [*Odocoileus hemionus*] combined) and black bear (*Ursus americanus*) through the use of the wildlife crossing structures; and
- Conduct cost-benefit analyses for the mitigation measures.

2. MITIGATION MEASURES AND HUMAN SAFETY ALONG THE ENTIRE CORRIDOR AND IN THREE SELECTED ROAD SECTIONS (EVARO, RAVALLI CURVES, AND RAVALLI HILL)

2.1. Introduction

Wildlife-vehicle collisions affect human safety, property and wildlife. The total number of large mammal-vehicle collisions has been estimated at one to two million in the United States and at 45,000 in Canada annually (Conover *et al.* 1995, Tardif & Associates Inc. 2003, Huijser *et al.* 2008). These numbers have increased even further over the last decade (Tardif & Associates Inc. 2003, Huijser *et al.* 2008). In the United States, these collisions were estimated to result in 135-211 human fatalities, between 26,647 and 29,000 human injuries and over one billion US dollars in property damage annually (Conover *et al.* 1995, Khattak 2003, Centers for Disease Control and Prevention 2004, Huijser *et al.* 2009b; Langley 2012). In most cases the animals die immediately or shortly after the collision (Allen and McCullough 1976). In some cases it is not just the individual animals that suffer. Road mortality may also affect some species on the population level (e.g. van der Zee *et al.* 1992, Huijser and Bergers 2000), and some species may even be faced with a serious reduction in population survival probability as a result of road mortality, habitat fragmentation and other negative effects associated with roads and traffic (Proctor 2003, Huijser *et al.* 2008). In addition, some species also represent a monetary value that is lost once an individual animal dies (Romin and Bissonette 1996, Conover 1997).

While this chapter focuses on the reduction of collisions with large ungulates, this group is not necessarily the most abundant or the most important species group hit by vehicles. Large mammals (e.g. deer size and larger) receive most attention because of the following reasons:

- A collision with a large mammal can result in substantial vehicle damage and poses a substantial threat to human safety;
- Large mammal carcasses on or adjacent to the road pose a safety hazard on their own as they can cause drivers to undertake evasive maneuvers, be a general distraction to drivers, and become an attractant to potential scavengers; and
- Some large mammal species are threatened, endangered or considered charismatic.

The preconstruction research along US 93 North found that deer (white-tailed deer [*Odocoileus virginianus*] and mule deer [*Odocoileus hemionus*] combined) were by far the most frequently recorded species group (Hardy *et al.* 2007). However, rare, threatened or endangered species may have been removed (legally or illegally) before agency personnel were able to record them, and small and medium sized species up to the size of a coyote, were inconsistently or rarely reported. It was notable though that the western painted turtle (*Chrysemys picta bellii*) was frequently hit by vehicles in the Ninepipe area (Griffin 2007).

This chapter focuses on the potential reduction in wildlife-vehicle collisions along US 93 North as a result of the implementation of the mitigation measures described in Chapter 1. Previous research has shown that wildlife fences in combination with wildlife underpasses and overpasses can reduce collisions with large wild ungulates by 79-97 percent (Reed *et al.* 1982, Ward 1982, Woods 1990, Clevenger *et al.* 2001, Dodd *et al.* 2007b).

2.2. Methods

2.2.1. Carcass Removal and Crash Data

Wildlife-vehicle collision data were obtained from MDT. The researchers defined wildlife-vehicle collision data as either carcass removal data or wildlife crash data, or both. Carcass removal data related to animal carcasses that were collected by road maintenance personnel whereas animal crash data related to reports by law enforcement personnel. Note that neither the crash data nor the carcass removal data included all animal-vehicle collisions that occurred (Huijser *et al.* 2007). Carcass removal data typically related to large common mammals only. Carcasses of small or medium sized species (e.g. coyote [*Canis latrans*] and smaller) were not or not consistently removed from the roadside. Carcasses of larger species that were not on the actual road surface and that were not highly visible from the roadway may also not have been removed and may thus have remained unrecorded. In addition, carcasses of any species may have been removed (legally or illegally) before road maintenance crews passed by. The crash data selected for this analysis included all reported crashes where the first or most harmful event involved animals. Animal crash data typically only represent a fraction of the carcass removal data because not all crashes are reported to law enforcement and because not all crashes meet the criteria of crash databases (e.g. minimum $1000 vehicle repair cost estimate) (Huijser *et al.* 2009b). However, crash data tend to relate to the more severe crashes (e.g. at least $1,000 in vehicle repair costs, presence of human injuries or presence of human fatalities) (Huijser *et al.* 2007). Regardless, both carcass removal and animal crash data sets can be very useful in detecting potential changes in collisions with large mammals, particularly the most common species. Note that it is not necessary to have recorded all animal-vehicle collisions to detect potential changes in the number of collisions as long as the search and reporting effort has remained consistent.

The two data sets ranged from 1 January 2002 through 31 December 2015. If more than one animal was recorded for one incident (either a crash or a carcass removal effort) each individual animal was counted and resulted in a separate record in one of the two databases. For the purpose of this report the researchers did not combine the crash data and the carcass removal data. Instead, the researchers used the two separate data sets to investigate the potential effect of the mitigation measures on the number of collisions with large mammals. The search and reporting effort for carcasses was relatively low until 2002 (Hardy *et al.* 2007). MDT maintenance personnel were instructed to improve consistent reporting from 2002 onwards (Hardy *et al.* 2007). Therefore the researchers restricted the data analyses to data from 2002 onwards. However, changes in personnel, higher priority tasks and other factors are likely to have resulted in some but unknown variation in the search and reporting effort for both the carcass removal data and the wildlife crash data.

The carcass removal data were typically recorded to the nearest 0.1 mile (160.9 m). Wildlife-crash data were typically recorded to a hundredth of a mile (16.1 m). For the purpose of the analyses the researchers assigned each carcass and each wildlife crash to the nearest 0.1 mile. However, for carcasses or wildlife-crashes that were near fence ends, the researchers used the original location descriptions when deciding whether a carcass or wildlife-crash was located just inside or just outside the mitigated road section.

The researchers investigated potential changes in the number of reported large mammal carcasses and wildlife crashes before and after highway reconstruction and associated mitigation measures. These data related to the entire highway section between Evaro and Polson (51.9 miles, 83.5 km) which included a mixture of fenced (8.7 mi, 14.0 km, 16.8 percent of road length) and unfenced or partially (one side of highway only) fenced road sections (43.2 mi, 69.5 km, 83.2 percent of road length) (Appendix A2). While 8 ft (2.4 m) tall wildlife fences could be expected to result in a reduction in wildlife-vehicle collisions, unfenced road sections that have been made wider with more gentle curves and longer sight distances may actually have higher numbers of wildlife-vehicle collisions after reconstruction (Vokurka and Young 2008). Since the road corridor between Evaro and Polson consisted of a mixture of fenced and unfenced road sections the researchers were not certain if wildlife-vehicle collisions would increase or decrease after reconstruction. Therefore the researchers applied a two-sided Mann-Whitney U test. Different road sections were under construction at different times and data from those years (2005 through 2010) were excluded from the analyses (Peccia & Associates 2015). The before data related to the years that none of the highway sections were under reconstruction (2002 through 2004) and the after data related to the years that reconstruction had been completed (2011 through 2015) (Appendix A1, Peccia & Associates 2015). Note that the road section through the Ninepipe area (mile reference post 37.4-47.7) was not reconstructed between 2002 and 2015 (Peccia & Associates 2015). The researchers conducted two analyses for the road corridor between Evaro and Polson; one including and one excluding the Ninepipe area.

The researchers also applied a Before-After-Control-Impact (BACI) study design to investigate the potential effect of the mitigation measures on the number of collisions with large mammals in the three areas that had relatively long sections of wildlife fences combined with wildlife crossing structures: Evaro, Ravalli Curves, and Ravalli Hill (Table 1). In this context Before-After related to the period before (2002 through 2005) and after (2011 through 2015) the highway reconstruction for these three areas. The Control-Impact related to road sections that did and did not have fences and associated mitigation measures implemented. Potential differences in the number of collisions based on a simple Before-After (BA) comparison (expressed as a percentage reduction) are not necessarily related to the implementation of the mitigation measures. They may also be influenced by other factors that changed after the mitigation measures were implemented (e.g. changes in road width, traffic speed, traffic volume, potential change in road avoidance behavior by large mammals and changes in the population size of large mammals) (van der Grift *et al.* 2013). Similarly, a simple Control-Impact (CI) comparison may also be influenced by other factors that are associated with the control or the impact sites. A BACI analysis is designed to address the potential influence of other factors that may have changed (other than the treatment), both in time and in space (Downes *et al.* 2002). BACI designs are especially recommended if the expected effect of the treatment is large, the changes as a result of the treatment can be expected to be permanent, and if the researchers are interested in detecting changes in the mean (rather than detecting changes in variability) (Schwarz 2012). In this case, the expected reduction in collisions as a result of wildlife fences was 79-97 percent (Huijser *et al.* 2009b), the reduction in collisions could be expected to be immediate and permanent as long as the wildlife fences remained intact, and the parameter of interest was the mean number of wildlife-vehicle collisions before and after implementation of the mitigation measures.

The control sections were located adjacent to the impact sites (Figure 3-6). They were as similar in landscape as possible and similar in length to the impact sites. The total length of the impact (6.7 mi, 10.8 km) and control road sections (6.7 mi, 10.8 km) was identical (Table 1). Note that there was a gap of 0.2 mi (322 m) between the impact and control sections (Table 1). This gap allowed for potential "fence end runs" (see e.g. Clevenger *et al.* 2001; Chapter 4) within 0.2 mi (322 m) of a fence end without affecting the number of wildlife-vehicle collisions in the control road sections.

The wildlife-vehicle collision data were summarized for each of the three individual areas (Evaro, Ravalli Curves and Ravalli Hill) and also for the three areas combined (Appendix C). Since different road sections were under construction in different years, the years "before" and "after" construction were different for the three areas; Evaro 2002 through 2008 (before) and 2011 through 2015 (after), Ravalli Curves and Ravalli Hill 2002 through 2005 (before) and 2008 through 2015 (after). For the three areas combined the years before and after construction included in the analyses were 2002 through 2005 (before) and 2011 through 2015 (after). For the three areas combined the BACI effect was calculated $(\mu_{control,after} - \mu_{control,before}) - (\mu_{impact,after} - \mu_{impact,before})$. In addition, the carcass removal and the wildlife crash data for the three areas combined were transformed (ln(x+0.1)) to make the count variable resemble a normal distribution. This allowed for the investigation of a potential interaction of the before-after and fenced-control parameters through an ANOVA. If there was an effect of the treatment (i.e. the wildlife fences and the associated mitigation measures), the researchers expected the effect to result in fewer collisions rather than more. Hence our ANOVA was one-sided.

Table 1: The road sections that served as impact (with wildlife fences and crossing structures) and control (no wildlife fences and fewer crossing structures).
Data include the years that collision data (crash and carcass removal data) were available for, both before and after the highway reconstruction and the associated implementation of the mitigation measures. Note: the road sections include all 0.1 mile reference points listed.

Impact / Control	Road Section (mile reference post)	Length (mi)	Before reconstruction and mitigation measures	After reconstruction and mitigation measures	Crossing struct. (n)
Impact (fence)	Evaro (9.3 - 11.0)	1.7	2002-2008 (7 yrs)	2011-2015 (5 yrs)	6
Impact (fence)	Ravalli Curves (22.9-26.7)	3.8	2002-2005 (4 yrs)	2008-2015 (8 yrs)	9
Impact (fence)	Ravalli Hill (27.5-28.7)	1.2	2002-2005 (4 yrs)	2008-2015 (8 yrs)	2
Control (no fence)	Evaro (7.1-9.0)	1.9	2002-2008 (7 yrs)	2011-2015 (5 yrs)	1
Control (no fence)	Ravalli Curves (19.4-22.6)	3.2	2002-2005 (4 yrs)	2008-2015 (8 yrs)	0
Control (no fence)	Ravalli Hill (29.0-30.6)	1.6	2002-2005 (4 yrs)	2008-2015 (8 yrs)	1

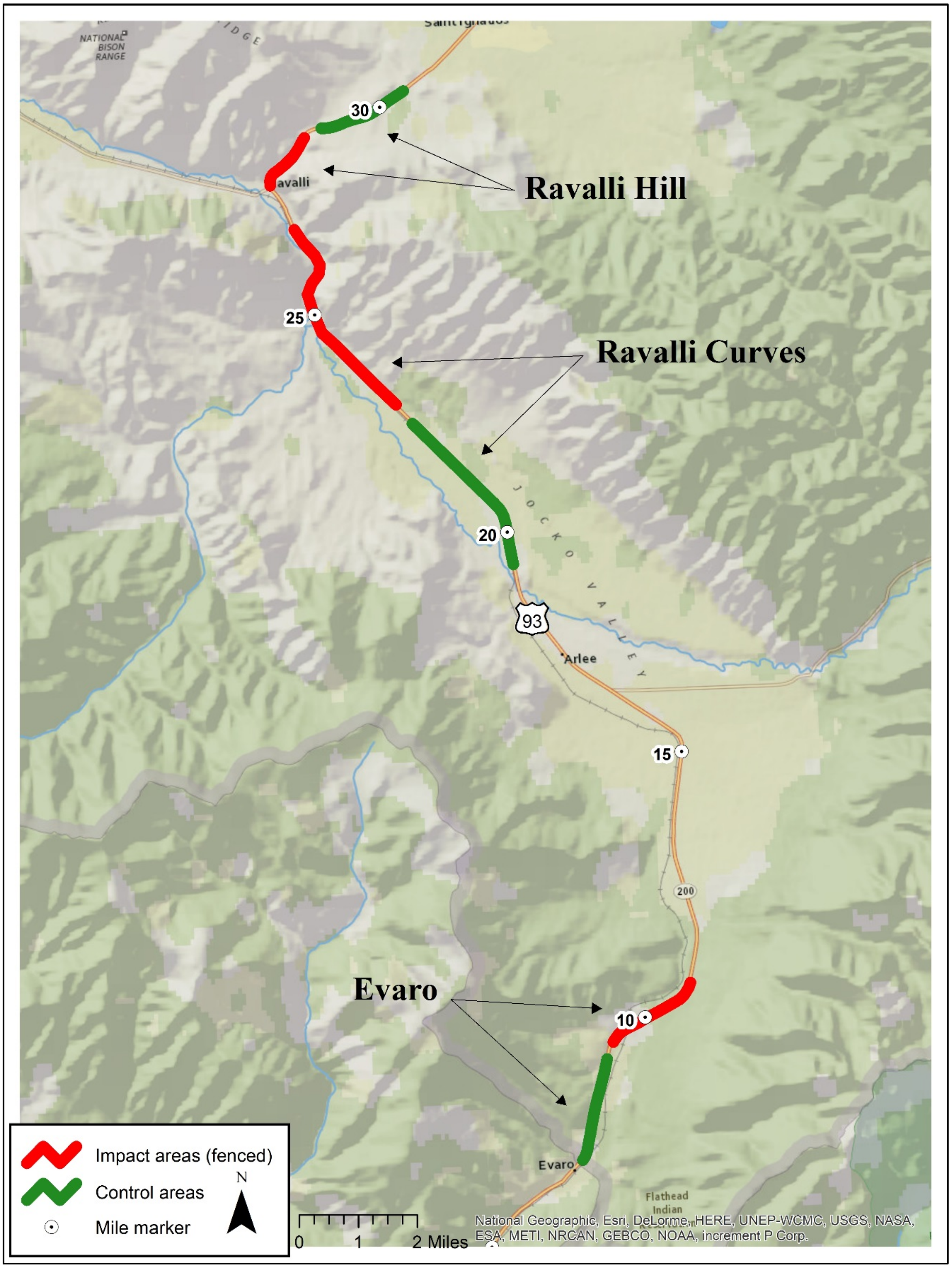

Figure 3: Impact road sections with wildlife fences (in red) and control road sections without wildlife fences (in green) in the Evaro, Ravalli Curves and Ravalli Hill areas.

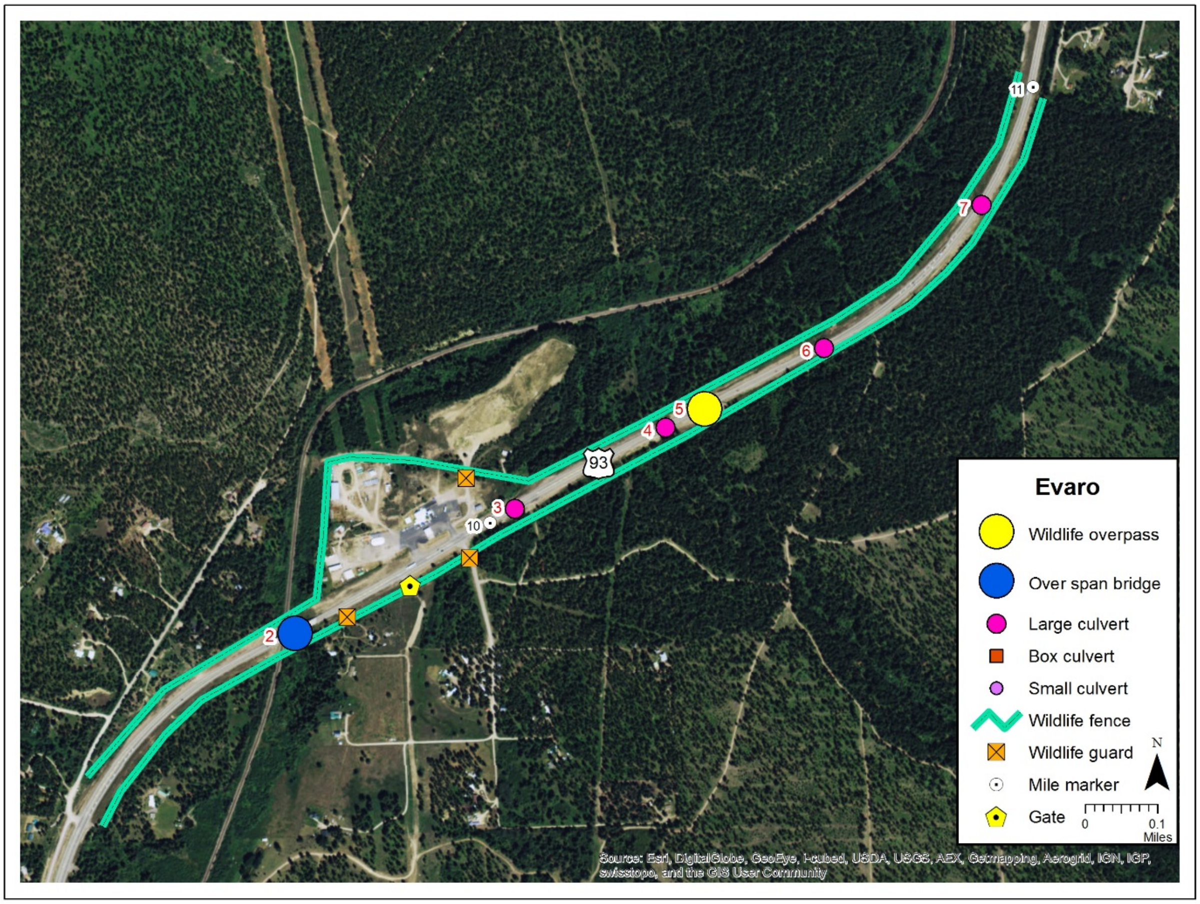

Figure 4: Mitigation measures in the Evaro impact road section.
The red numbers refer to the crossing structures (see Appendix A1).

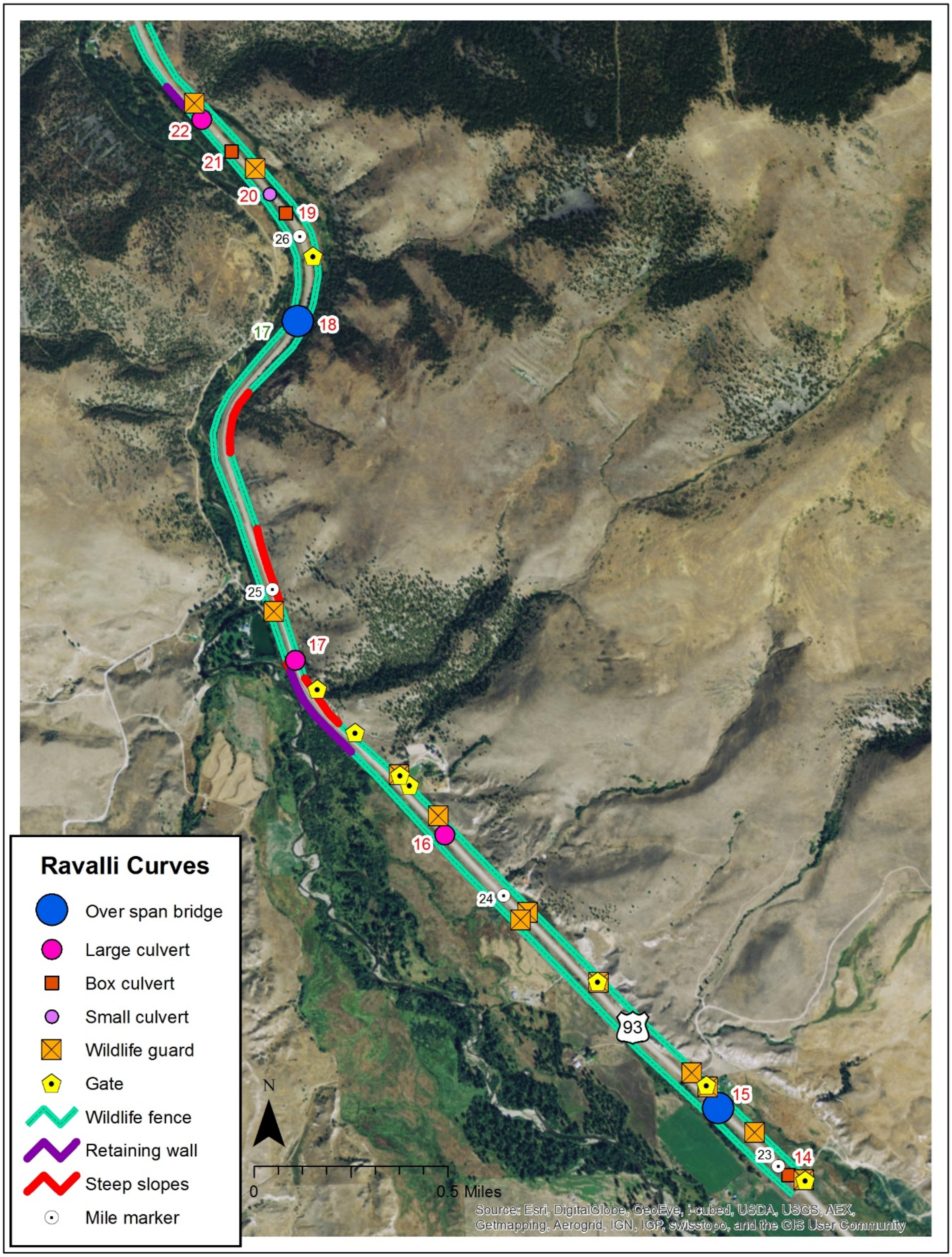

Figure 5: Mitigation measures in the Ravalli Curves impact road section. The red numbers refer to the crossing structures (see Appendix A1).

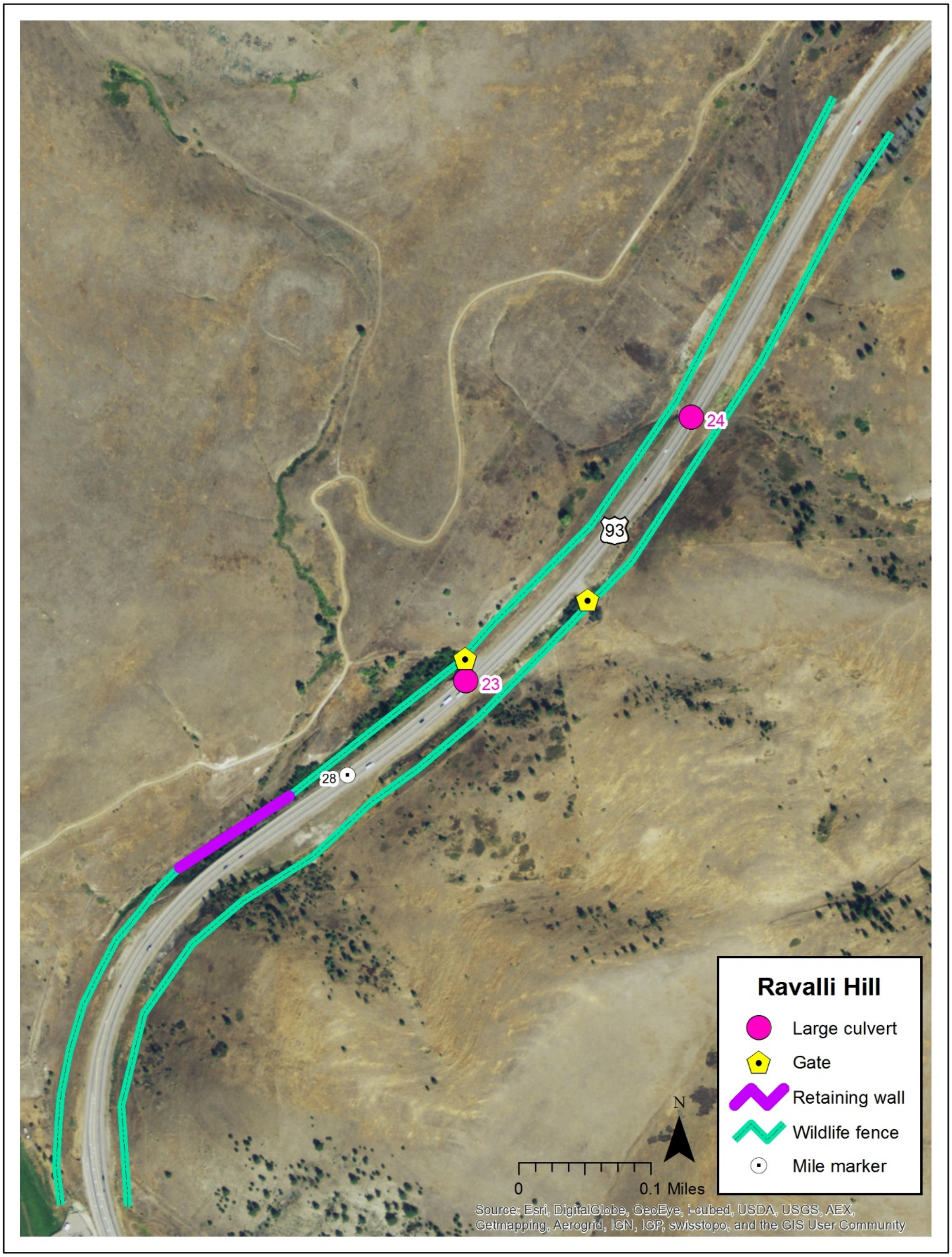

Figure 6: Mitigation measures in the Ravalli Hill impact road section. The red numbers refer to the crossing structures (see Appendix A1).

2.2.2. Deer Pellet Group Surveys

If there are more large mammals present in a certain year than in a previous year, an increase in large mammal-vehicle collisions can be expected. Similarly, reduced large mammal population sizes can be expected to result in fewer large mammal-vehicle collisions. Therefore it was important to have a measure for potential changes in large mammal population sizes before and after the mitigation measures were implemented. Between 2002 and 2005 white-tailed deer and mule deer represented 92 percent of all reported wildlife-vehicle collisions along US 93 North (Hardy *et al.* 2007). Therefore, the researchers were mostly interested in potential changes in the deer population size rather than potential changes in population size for other species.

Unfortunately, there were no deer population estimates or hunting statistics available for the Flathead Indian Reservation. Therefore the researchers conducted deer pellet group surveys which provided a relative measure for potential changes in deer population size. The surveys were located in the three areas with more or less continuous wildlife fences and associated measures: Evaro, Ravalli Curves, and Ravalli Hill areas. Since the researchers could not reliably distinguish between white-tailed deer and mule deer pellets, the results of the pellet group surveys related to deer in general (i.e. white-tailed deer and mule deer combined).

The researchers conducted pellet group surveys along 24-25 transects; 11-12 in the Evaro area and 13-14 in the Ravalli Curves and Ravalli Hill areas combined (Appendix D). The number of transects in each of the three areas was proportional to the fenced road length of each of the three areas (see Table 1). The location of each transect within an area was randomly chosen based on the (328 ft (100 m) road length units that were specified on the design plans (MDT 2002). A transect originated from the center of the selected 100 m road length unit along the highway and was located on one side of the road only (east or west side of the highway). The side of the highway was randomly selected for each transect. However, if no permission was obtained from private landowners to conduct a pellet group survey, the other side of the highway was surveyed. If no permission could be obtained for the other side of the highway either, a new 100 m road length unit was randomly selected. Note: If the same 100 m road length unit was randomly selected twice, the second transect was located on the opposite side of the highway of the first transect. The researchers allowed for a maximum of two transects per 100 m road length unit. In some cases permission from private landowners to survey an established transect could not be obtained in later years. In those cases an alternate transect location was selected if possible. The researchers typically surveyed the transects in August and September before falling leaves would have covered the pellets.

For each transect, the researchers set a compass bearing perpendicular to the highway. Each transect was 1640 ft (500 m) long and 3.3 ft (1 m) wide. The researchers used a 1 m long stick with a mark in the middle to delineate the 1 m wide transect. Since transects were not marked on the ground, the exact area surveyed varied between years. However, the same transect surveyed in different years always related to the same general area. The researchers only recorded deer pellet groups that were black in color as brown pellets may have been from a previous year. Some pellet groups were located only partially inside the 1 m wide transect. If the “center” of the pellet group was inside the 1 m wide transect the researchers included the pellet group. If the “center” of the pellet group was outside the 1 m wide transect the researchers excluded the pellet group.

The pellet group surveys were conducted in 2004 and 2005 (pre-construction), and 2008 through 2015 (post-construction). However, the post-construction surveys in the Ravalli Curves and Ravalli Hill areas (highway reconstruction in 2006-2007) were conducted in 2008 through 2012 whereas the post-construction surveys in the Evaro area (highway reconstruction in 2009-2010) were conducted in 2011 through 2015.

Potential differences ($P \leq 0.05$) in the average number of deer pellet groups per transect between years were investigated through an ANOVA and associated Tukey-Kramer-Multiple-Comparison test. The number of pellet groups in a transect (x) was first transformed to $\ln(x+0.1)$ to make the count variable resemble a normal distribution. Since the Evaro area (2011 through 2015) and the Ravalli Curves and Ravalli Hill areas (2008 through 2012) were partly surveyed during different years, separate analyses were carried out for the Evaro area and a combination of the Ravalli Curves and Ravalli Hill areas. A third analysis was carried out for the three areas combined. The latter analysis only included the years for which data were available for all three areas (i.e. 2004-2005 (before reconstruction) and 2011-2012 (after reconstruction)).

2.2.3. Traffic Volume

A change in traffic volume may affect the number of wildlife-vehicle collisions. Therefore the researchers investigated potential changes in traffic volume (Annual Average Daily Traffic (AADT)) before and after highway reconstruction. The traffic volume data (1991-2015) were recorded through an automated traffic counter (station names A-105 and A-008) about 0.5 mile south of Ravalli at mile reference post 26.3 (MDT 2007, 2016). Note that no traffic volume data were available for 2006-2008 as there was no traffic counter present due to highway reconstruction. Potential changes in traffic volume were investigated through a comparison of the before (2002-2005) and after (2011-2015) data (two-sided T-test).

2.3. Results

2.3.1. Species Recorded

The crash data did not specify the species, but the carcass removal data did identify the animal species. The species involved with animal-vehicle collisions along US 93 North between 1 January 2002 and 31 December 2015, based on carcass removal data, consisted mostly of large mammals. The category “domestic” (n=25) was excluded from further analyses as domesticated species, in this case dogs, cats, livestock and a mule, are – or should be - controlled by people and livestock fences rather than mitigation measures aimed at wildlife. “Unknown” species (n=4) were excluded as well. Relatively small wild species (n=13) were also excluded from further analyses as the species involved bobcat [*Lynx rufus*] (n=1), raccoon [*Procyon lotor*] (n=7), turkey [*Meleagris gallopavo*] (n=2), western striped skunk [*Mephitis mephitis*] (n=2), and coyote [*Canis latrans*] (n=2) because it is unlikely that they were consistently recorded and these species are too small to pose a substantial safety risk to humans. The remaining species were large wild mammal species and the vast majority of the removed carcasses were white-tailed deer (Figure 7).

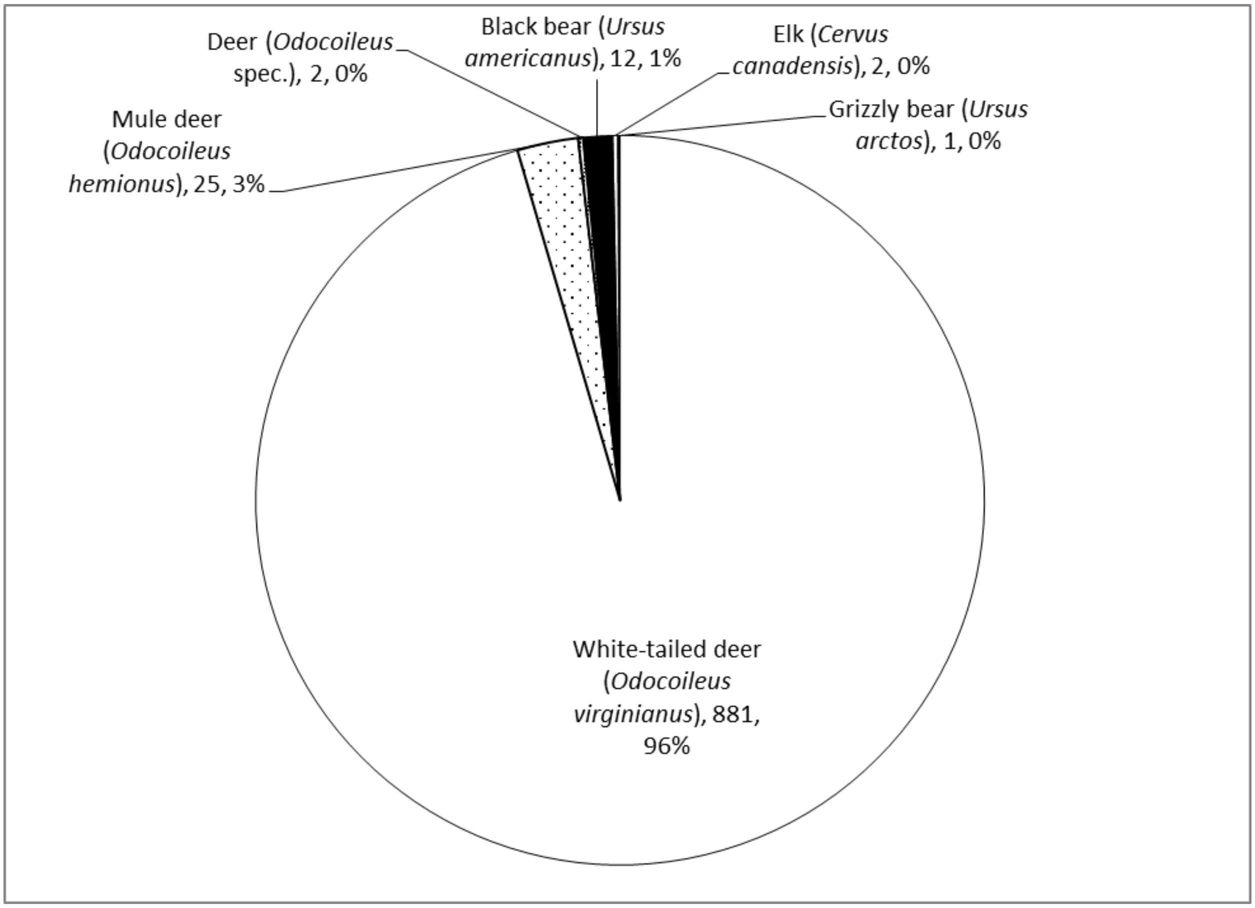

Figure 7: Large wild mammal species involved with animal-vehicle collisions (N=923).
The data are based on carcass removal data along US 93 North between Evaro and Polson between 1 January 2002 and 31 December 2015.

2.3.2. Crash and Carcass Removal Data for Entire Corridor

The number of large wild mammal carcasses reported for the entire corridor (mi reference post 7.1 through 59.0) increased by 5.38 percent after highway reconstruction (Figure 8). However, this increase was not significant (two-sided Mann-Whitney U test, P=1.000). The number of reported wildlife crashes along the entire corridor increased by 83.57 percent after the highway reconstruction (Figure 8) (two sided Mann-Whitney U test, P=0.036) (Figure 8). These carcass removal and wildlife crash data related to the entire highway section between Evaro and Polson (51.9 miles, 83.5 km) which included a mixture of fenced (16.8 percent percent of road length) and unfenced road sections (83.2 percent of road length). The wildlife crashes represented 62.80 percent of the large wild mammal carcasses for the years before and after reconstruction combined (42.64 before reconstruction, 74.28 after reconstruction). The percentage of the wildlife crashes that resulted in human injuries or human fatalities was similar before (5.83 percent) and after (5.51 percent) highway reconstruction.

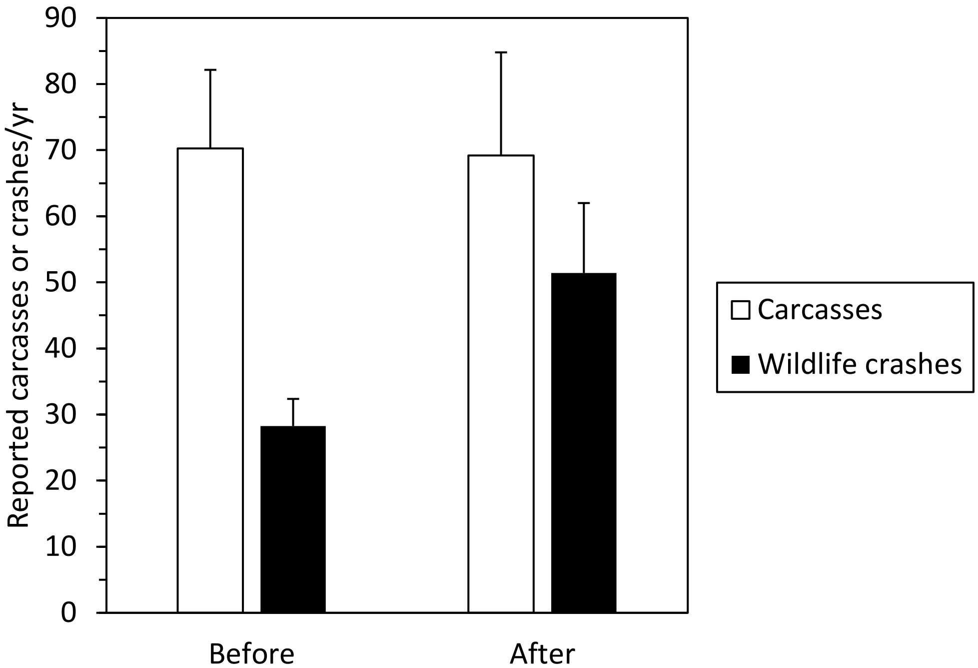

Figure 8: The average number and associated standard deviations for large wild mammal carcasses and wildlife crashes.
The data relate to the entire US Hwy 93 N corridor before (2002 through 2004) and after (2011 through 2015) highway reconstruction between Evaro and Polson.

When the non-reconstructed, non-mitigated Ninepipe area (mi reference post 37.4-47.7) was excluded, the number of large wild mammal carcasses reported for the entire corridor (mi reference post 7.1 through 59.0) increased by 76.22 percent after highway reconstruction (Figure 9) (two-sided Mann-Whitney U test, P=0.018). The number of reported wildlife crashes along the entire corridor increased by 53.70 percent after the highway reconstruction (Figure 9). While the latter increase was not significant (P≤0.05) it was trending towards significance (P≤0.10) (two sided Mann-Whitney U test, P=0.086) (Figure 9).

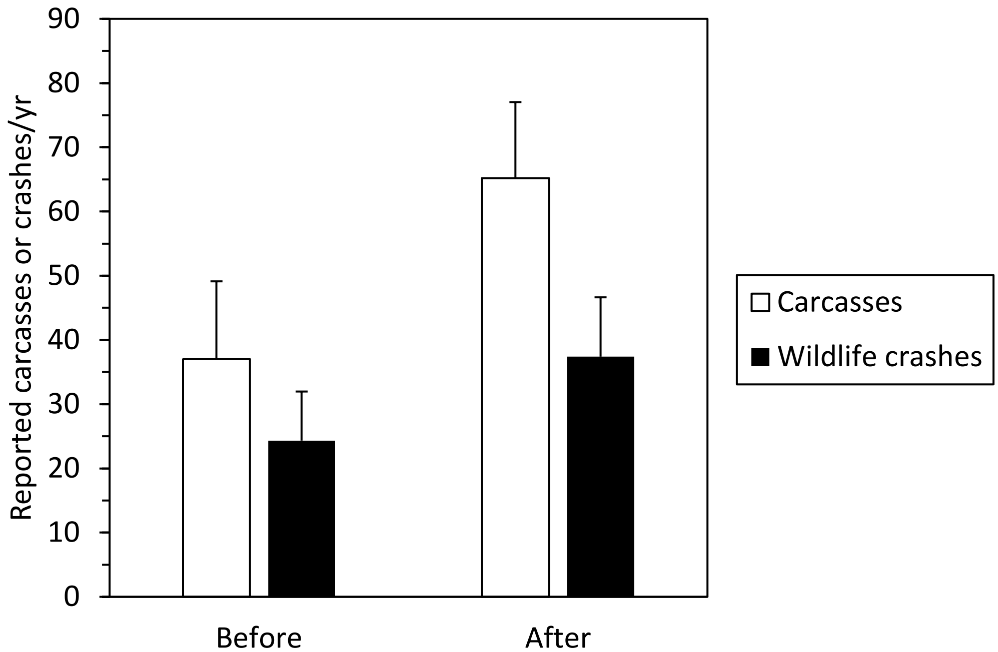

Figure 9: The average number and associated standard deviations for large wild mammal carcasses and wildlife crashes excluding the Ninepipe area.
The data relate to the entire US Hwy 93 N corridor before (2002 through 2004) and after (2011 through 2015) highway reconstruction between Evaro and Polson, but excluding the road section through the Ninepipe area (mi reference post 37.4-47.7).

2.3.3. Carcass Removal Data Evaro, Ravalli Curves and Ravalli Hill

Based on a simple "before-after" comparison for the mitigated road sections there was a 23.6 percent reduction in reported large wild mammal carcasses in Evaro, 25.0 percent reduction in Ravalli Curves, and an increase of 200 percent (or factor 3.0) in Ravalli Hill (Figure 10). Furthermore, the number of reported large wild mammal carcasses in the control road sections increased substantially (Figure 10). This suggests that if the road sections with mitigation measures would have remained unmitigated, they would have seen a similar increase in the number of large wild mammal carcasses. Yet, presumably because of the mitigation measures, the number of large wild mammal carcasses decreased in two of the three mitigated road sections (Evaro and Ravalli Curves) and increased less strong than in the control section in the third road section (Ravalli Hill).

When all three mitigated road sections were combined, a simple "before-after" comparison suggested a 5.19 percent reduction in large wild mammal carcasses; from 6.75 to 6.40 large wild mammal carcasses per year (Figure 10). Furthermore, the number of large wild mammal carcasses in the control road sections increased from 5.00 to 16.60 carcasses per year (increase of 232.00 percent or factor 3.32) (Figure 10). This suggests that if the road sections with wildlife fences and crossing structures would not have been mitigated they would have seen a similar increase in the number of large wild mammal carcasses. Yet, presumably because of the mitigation measures, the number of large wild mammal carcasses in the three mitigated areas decreased by 5.19 percent. An increase of 232.00 percent (or factor 3.32) would have increased the number of carcasses in the three mitigated road sections from 6.75 carcasses per year (actual number of carcasses before highway reconstruction) to 22.41 (theoretical number of carcasses after highway reconstruction). Thus, the percentage reduction in the three mitigated road sections combined, corrected for what would have happened should these areas not have been mitigated, was 71.44 percent (a theoretical reduction from 22.41 to 6.40 carcasses per year).

If the lines for the control and mitigated areas in Figure 10 would have been parallel it would have indicated a lack of effect of the mitigation measures on the number of large mammal carcasses. However, the lines for the control and impact areas were not parallel which indicated that the treatment (i.e. the fences and associated mitigation measures) did have an effect on the number of large mammal carcasses. For the three areas combined (6.7 mi), the Before-After-Control-Impact (BACI) effect was 11.95 large mammals per year (or 1.78 large mammals per mile per year or 1.11 large mammals per kilometer per year). The interaction of the before-after and mitigated-control parameters was significant (one-sided ANOVA $F_{1,14}$=3.782, P=0.036). This meant that the effect of the highway reconstruction (before-after) on the number of large mammal carcasses depended on the treatment (wildlife fences and wildlife crossing structures vs. no wildlife mitigation measures).

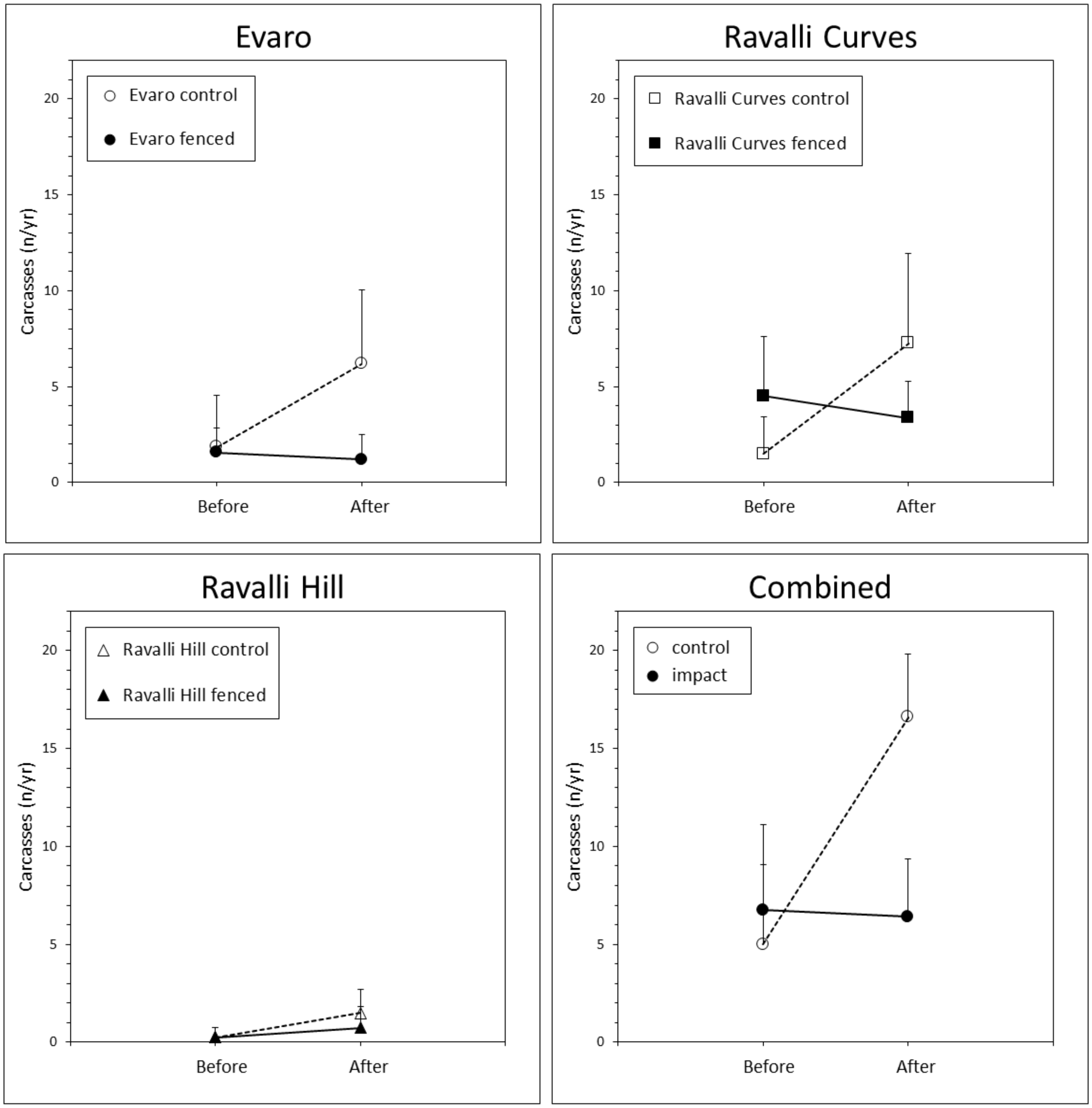

Figure 10: The average number of wild large animal carcasses per year and associated standard deviation reported in the three impact road sections (with wildlife fences) and the three control areas (without wildlife fences).
The graphs distinguish between before (4-7 years, different calendar years) and after reconstruction and associated mitigation (5-8 years, different calendar years). The combined data are based on the 4 years before (2002-2005) and 5 years after reconstruction (2011-2015).

2.3.4. Crash Data Evaro, Ravalli Curves, and Ravalli Hill

Based on a simple "before-after" comparison for the mitigated road sections there was a 74.5 percent reduction in reported wildlife crashes in Evaro, 50.0 percent reduction in Ravalli Curves, and 62.5 percent in Ravalli Hill (Figure 11). Furthermore, the number of reported wildlife crashes in the control road sections increased substantially (Figure 11). This suggests that if the road sections with mitigation measures would have remained unmitigated, they would have seen a similar increase in the number of wildlife crashes. Yet, presumably because of the mitigation measures, the number of wildlife crashes decreased in all three fenced road sections.

When all three mitigated road sections were combined, a simple “before-after” comparison suggested a 61.90 percent reduction in wildlife crashes; from 5.25 to 2.00 wildlife crashes per year (Figure 11). Furthermore, the number of wildlife crashes in the control road sections increased from 3.25 to 6.20 crashes per year (increase of 90.77 percent or factor 1.91) (Figure 11). This suggests that if the road sections with fences and crossings structures would not have been mitigated they would have seen a similar increase in the number of wildlife crashes. Yet, presumably because of the mitigation measures, the number of wildlife crashes in the three mitigated areas decreased by 61.90 percent. An increase of 90.77 percent (or factor 1.91) would have increased the number of wildlife crashes in the three mitigated road sections from 5.25 crashes per year (actual number of crashes before highway reconstruction) to 10.02 (theoretical number of crashes after highway reconstruction). Thus, the percentage reduction in the three mitigated road sections combined, corrected for what would have happened should these areas not have been mitigated, was 80.04 percent (a theoretical reduction from 10.02 to 2.00 crashes per year).

If the lines for the control and impact areas in Figure 11 would have been parallel it would have indicated a lack of effect of the mitigation measures on the number wildlife crashes. However, the lines for the control and mitigated areas were not parallel which indicates that the treatment (i.e. the fences and associated mitigation measures) did have an effect on the number of wildlife crashes. For the three areas combined (6.7 mi), the Before-After-Control-Impact (BACI) effect was 6.20 wildlife crashes per year (or 0.93 crashes per mile per year or 0.58 crashes per kilometer per year). The interaction of the before-after and mitigated-control parameters was significant (one-sided ANOVA $F_{1,14}$=4.486, P=0.026). This meant that the effect of the highway reconstruction (before-after) on the number of wildlife crashes depended on the treatment (wildlife fences and wildlife crossing structures vs. no wildlife mitigation measures).

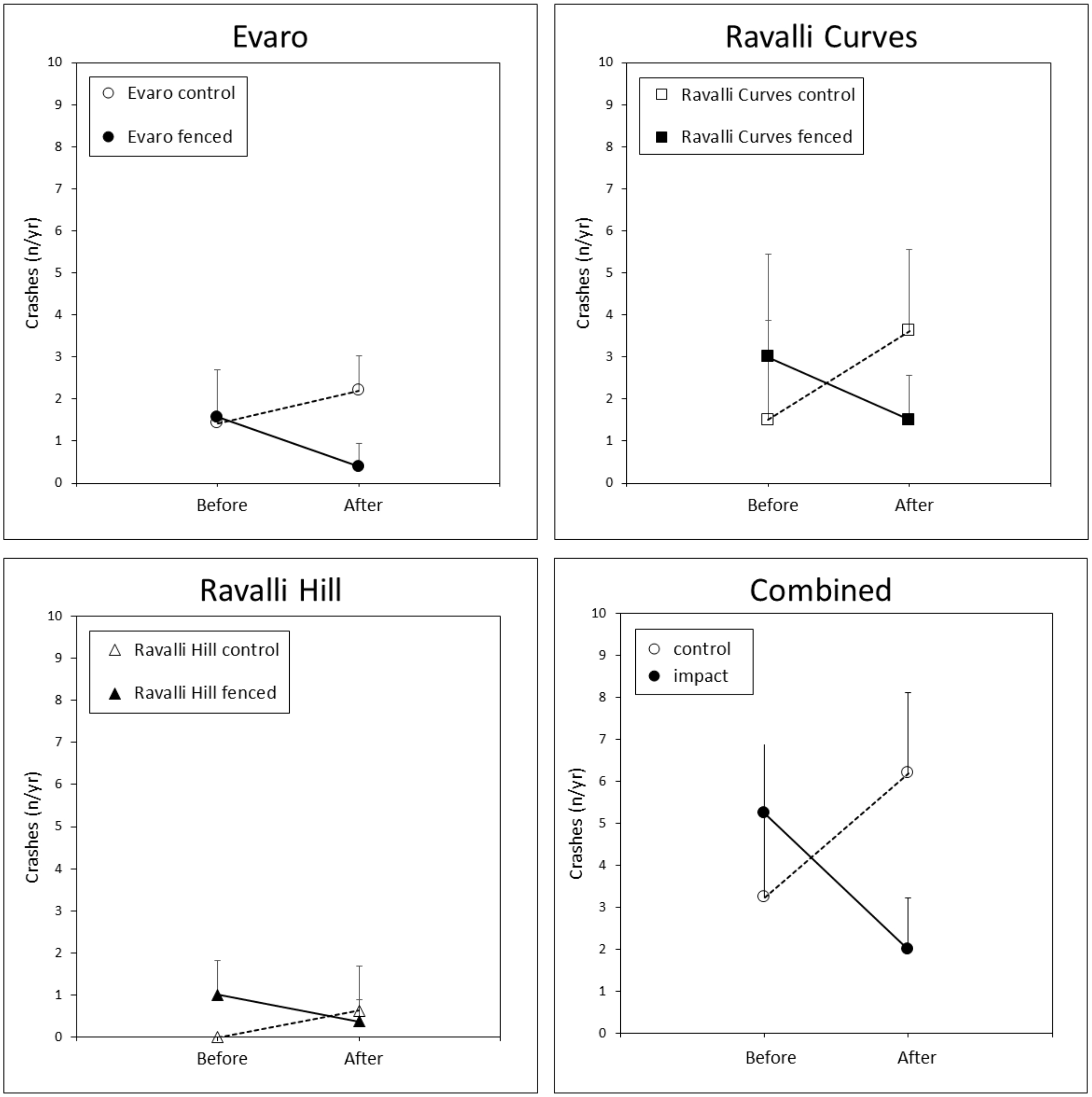

Figure 11: The average number of wildlife crashes per year and associated standard deviation reported in the three impact road sections (with wildlife fences) and the three control areas (without wildlife fences). The graphs distinguish between before (4-7 years, different calendar years) and after reconstruction and associated mitigation (5-8 years, different calendar years). The combined data are based on the 4 years before (2002-2005) and 5 years after reconstruction (2011-2015).

2.3.5. Deer Pellet Group Surveys Evaro, Ravalli Curves, and Ravalli Hill

The average number of black pellet groups per transect in the Evaro area was variable between the different years with relatively large standard deviations (Figure 12). There was no indication of a difference in the average number of deer pellet groups per transect in the years before and after highway reconstruction. However, the average number of deer pellet groups in 2011 was lower than in 2013 through 2015, and the average number of pellet groups in 2012 was also lower than in 2015 (Tukey-Kramer-Multiple-Comparisons test, $P<0.001$).

The average number of black pellet groups per transect in the Ravalli Curves and Ravalli Hill areas combined was variable between the different years with relatively large standard deviations (Figure 13). There was no indication of a difference in the average number of deer pellet groups per transect in the years before and after highway reconstruction. There were also no differences in the average number of deer pellet groups per transect between individual years (Tukey-Kramer-Multiple-Comparisons test, $P=0.28$).

The average number of black pellet groups per transect in the Evaro, Ravalli Curves and Ravalli Hill areas combined was variable between the different years with relatively large standard deviations (Figure 14). There was no indication of a difference in the average number of deer pellet groups per transect in the years before and after highway reconstruction. There were also no significant differences in the average number of deer pellet groups per transect between individual years, through there was a tendency for significant differences between individual years ($P<0.10$) (Tukey-Kramer-Multiple-Comparisons test, $P=0.058$).

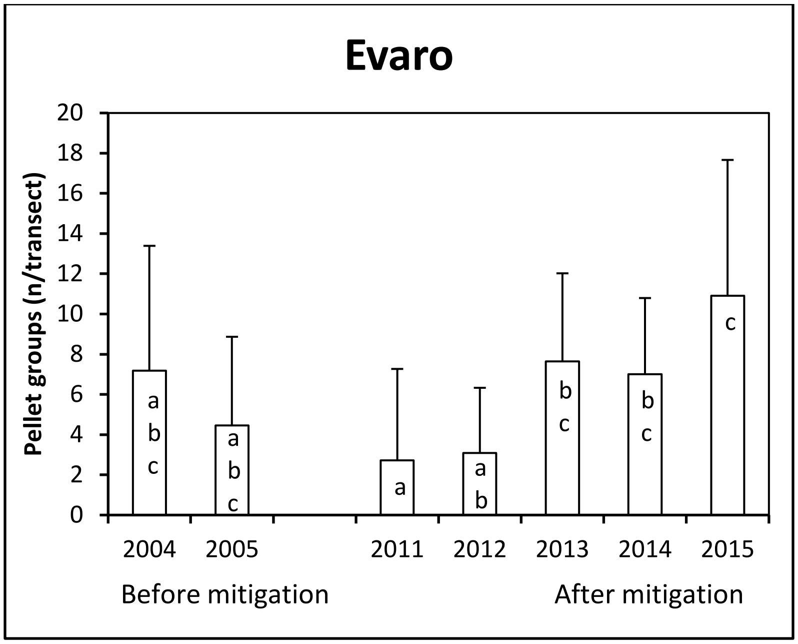

Figure 12: The average number of black deer pellet groups per transect and associated standard deviations per year in the Evaro area.
If the average number of pellet groups is similar between different years they share at least one letter. If different years do not share at least one letter, the average number of pellet groups is significantly different (P≤0.05) for these years.

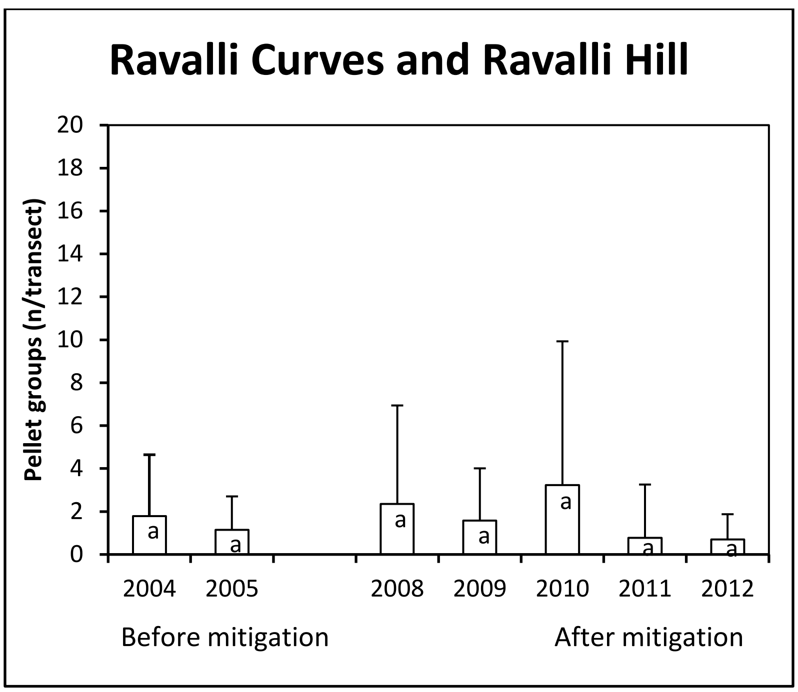

Figure 13: The average number of black deer pellet groups per transect and associated standard deviations per year in the Ravalli Curves and Ravalli Hill areas combined.
If the average number of pellet groups is similar between different years they share at least one letter. If different years do not share at least one letter, the average number of pellet groups is significantly different (P≤0.05) for these years.

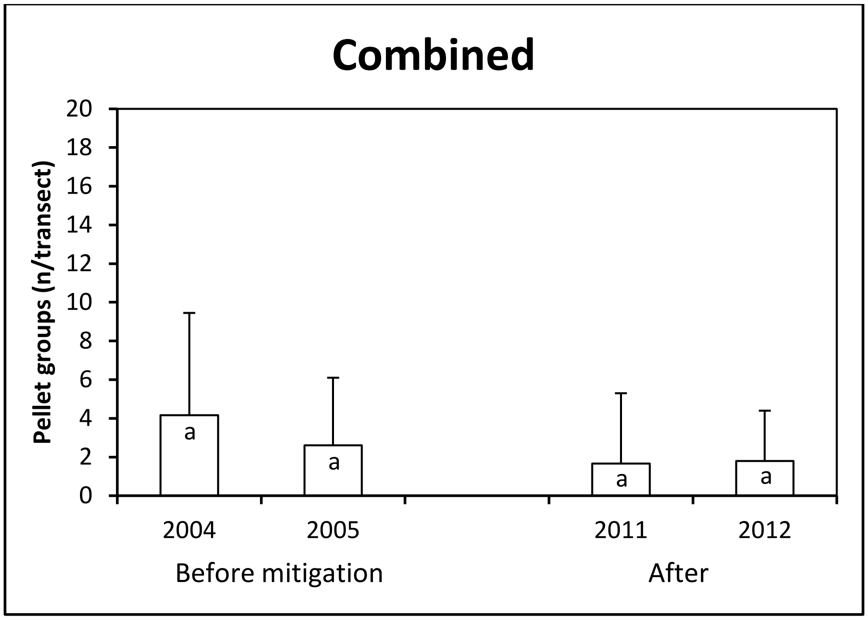

Figure 14: The average number of black deer pellet groups per transect and associated standard deviations per year in the Evaro, Ravalli Curves and Ravalli Hill areas combined.
If the average number of pellet groups is similar between different years they share at least one letter. If different years do not share at least one letter, the average number of pellet groups is significantly different (P≤0.05) for these years.

2.3.6. Traffic Volume

Traffic volume increased throughout the 1990s but stabilized after 2000 (Figure 15). Average AADT was 7,423.5 (SD=115.5) before highway reconstruction (2002-2005) and 7,119.6 (SD=252.4) after highway reconstruction. However, the potential decrease in traffic volume was not significant (T-value = -2.2072, P=0.063, two-sided T-test).

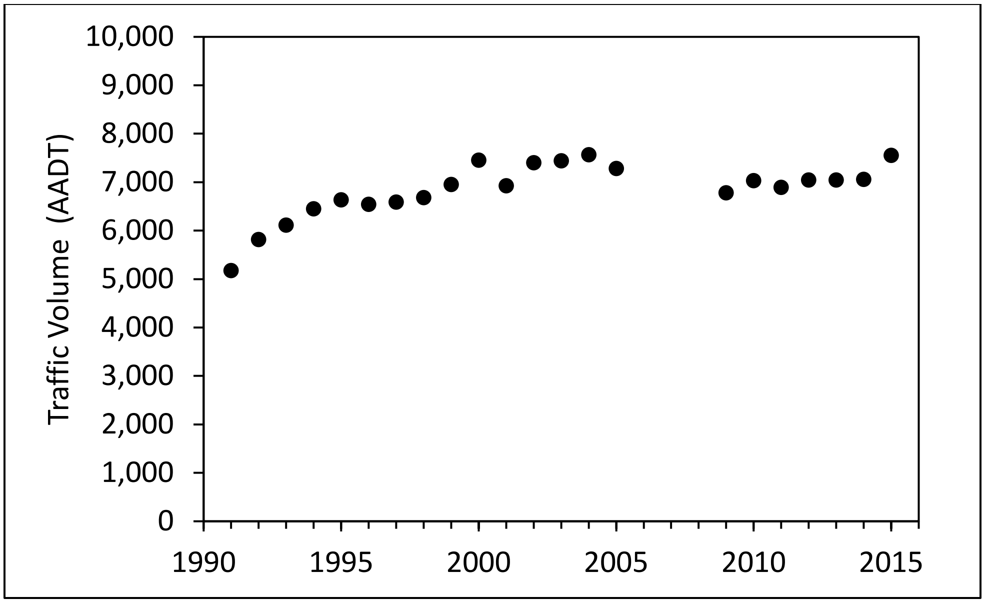

Figure 15: The Annual Average Daily Traffic (AADT) along US 93 North.
The data are from an automated traffic counter 0.5 mi south of Ravalli (mile reference post 36.3) between 1991-2015. Note: There were no data available for 2006-2008 as there was no traffic counter present due to highway reconstruction.

2.4. Discussion and Conclusion

The reconstruction of US 93 North improved human safety in general along the entire transportation corridor between Evaro and Polson (Peccia & Associates 2015). The total number of reported crashes (all types of crashes combined) decreased by approximately 33 percent (Peccia & Associates 2015). In addition, the number of reported crashes with incapacitating human injuries and human fatalities decreased by 73 and 58 percent respectively (Peccia & Associates 2015). However, the number of reported wildlife-vehicle collisions did not decrease over the entire length of the highway between Evaro and Polson. Based on a before-after comparison, the number of large wild mammal carcasses remained similar, and the number of wildlife-vehicle collisions increased by 83.57 percent. The increase in the reported number of crashes may be related to the increased design speed of US 93 North. This may have resulted in an increase in estimated vehicle repair costs and meeting or exceeding the minimum threshold of $1000 in estimated vehicle repair costs more frequently. Note that only 16.8 percent of the highway corridor between Evaro and Polson had wildlife fences on both sides of the highway and that the potential effect of wildlife fences in reducing wildlife-vehicle collisions was heavily diluted. At the same time the pellet group counts indicated that deer population size in selected areas around US 93 North was similar before and after reconstruction. Furthermore, the traffic volume did not increase after highway reconstruction. In summary, the highway reconstruction resulted in fewer crashes and fewer severe crashes in general (all types of crashes combined), but wildlife-vehicle collisions remained similar (carcass removal data) or increased (wildlife-crash data). This is consistent with another study by Vokurka and Young (2008) who found that wider lanes, wider shoulders, more gentle curves and longer sight distances for rural highways in Wyoming reduced crashes (all types combined). However, they also reported an increase in one specific type of crash; wildlife-vehicle collisions. The increase in wildlife-vehicle collisions on reconstructed rural highways may be related to wider highways (it takes longer for the animals to cross) and higher vehicle speeds (the design speed has increased).

Based on a simple before-after comparison, the number of reported wildlife-vehicle collisions decreased by 5.19 percent (carcass removal data) or 61.90 percent (wildlife crash data) for the mitigated road sections in the Evaro, Ravalli Curves and Ravalli Hill areas combined. However, the number of reported wildlife-vehicle collisions in the control road sections did not remain constant after the road reconstruction; they increased by 232.00 percent (carcass removal data) and 90.77 percent (wildlife crash data). This suggests that if the road sections with mitigation measures would not have been mitigated they would have seen a similar increase in the number of large wild mammal carcasses and crashes with animals. Yet, presumably because of the mitigation measures, the number of reported large wild mammal carcasses and crashes with animals decreased by 5.19 percent (carcass removal data) and 61.90 percent (wildlife crash data). When the substantial increase in collisions in the control sections was taken into account, the collisions in the three fenced areas were reduced by 71.44 percent (carcass removal data) and 80.04 (wildlife crash data). Based on the Before-After-Control-Impact analyses these reductions were significant.

The increase in wildlife-vehicle collisions in the control road sections without mitigation measures is not associated with a potential increase in the deer population size. The deer pellet group surveys indicate that the deer population size was similar before and after the implementation of the mitigation measures. Therefore, the increase in wildlife-vehicle collisions in the control road sections after reconstructing the highway appears to be associated with having a wider highway, in some areas also more travel lanes, and a likely increase in vehicle speed as a result of an increase in design speed (similar to the findings of Vokurka and Young 2008). While wider lanes, wider shoulders, smoother curves and longer sight distances tend to reduce the total number of crashes (all types of crashes combined), one specific type of crash, i.e. wildlife-vehicle collisions, can actually increase if no mitigation measures are implemented (Vokurka and Young 2008). This also seems to apply to the reconstruction and widening of US 93 North. This suggests that the decision process for the potential inclusion of wildlife mitigation measures as part of a road reconstruction project should not only be based on historic wildlife-vehicle collision data. It is advisable to also include the expected increase in wildlife-vehicle collisions for unfenced reconstructed road sections.

Wildlife fences for large ungulates are most effective at reducing collisions (at least about 80 percent reduction) if the fences and associated measures are installed over road lengths of at least 3.1 mi (5 km) (Huijser *et al.* 2016). If fences are implemented over relatively short road lengths (< 3.1 mi, <5 km), the average effectiveness in reducing collisions with large mammals may drop to about 50 percent and is highly unpredictable for any specific fenced road section (Huijser *et al.* 2016). This is likely related to fence end effects (Huijser *et al.* 2016). The three fenced road sections along US 93 North (Evaro, Ravalli Curves and Ravalli Hill) were 1.7 (2.73 km), 3.8 (6.11 km) and 1.2 mi (1.93 km) long respectively. This means that the effectiveness of the Evaro and Ravalli Hill areas could be expected to be relatively low (about 50 percent on average) and very variable (range 0-94 percent) whereas the effectiveness of the Ravalli Curves section could be expected to be higher with less variation (typically at least 80 percent reduction).

3. MITIGATION MEASURES AND HUMAN SAFETY FOR ALL FENCED ROAD SECTIONS ALONG US 93 NORTH

3.1. Introduction

In this chapter the researchers report on the effectiveness of wildlife fences and associated mitigation measures in reducing wildlife-vehicle collisions for all the fenced road sections along US 93 North.

3.2. Methods

The researchers selected all fenced road sections (N=13) with wildlife fences on both sides of US 93 North (Appendix A2). Highway sections with wildlife fences on one side of the highway only were excluded from the analyses (i.e. Schley Creek). The researchers calculated the percentage reduction in large wild mammal carcasses and wildlife crashes for each fenced road section based on a before-after comparison (Appendix E). The effectiveness of the wildlife fences and associated measures was based on large wild mammal carcass observations (collected by road maintenance personnel from the Montana Department of Transportation) and wildlife crashes (collected by law enforcement personnel). If the wildlife-vehicle collision data (either the carcass removal data or the wildlife crash data) showed an increase in collisions in the mitigated road sections rather than a decrease, the percentage effectiveness for the mitigated road section concerned was set at zero (i.e. no reduction in wildlife-vehicle collisions). If there were no wildlife-vehicle collisions (carcasses or crashes) observed before and after highway reconstruction the researchers did not calculate the effectiveness of the road section concerned and the road section was excluded from the analysis. Finally, the researchers calculated the average reduction in wildlife-vehicle collisions based on carcasses and wildlife crashes. These were the data used in the analyses.

In addition to the effectiveness data for the fenced road sections along US 93 North, the researchers also included effectiveness data from other fenced highway sections in North America and Europe (N=17) (Huijser *et al.* 2016). These data were obtained through a literature review (Huijser *et al.* 2016). The literature review was focused on reductions in large mammal-vehicle collisions, with an emphasis on mitigation measures that were designed for large ungulates (e.g. deer (*Odocoileus* spp., *Capreolus capreolus*), elk (*Cervus* spp.) and moose (*Alces* spp.)). Most of the fenced highway sections also included underpasses or overpasses designed for large mammals. The combined data (from both US 93 North and the literature review, N=30) were used to investigate the potential effect of the fenced road length on the percentage reduction in large mammal-vehicle collisions.

3.3. Results

After highway reconstruction, large wild mammal carcasses were on average 17.79 percent lower in the fenced road sections along US 93 North (Table 2). Wildlife crashes were 50.62 percent lower on average (Table 2). Wildlife-vehicle collisions (average of the carcass and crash data) were reduced by 33.52 percent (Table 2).

Table 2: The reduction in large wild mammal carcasses, wildlife crashes and wildlife-vehicle collisions (average of carcass and crash data) based on before-after comparison in the fenced road sections along US 93 North (fences on both sides of the highway).
See Appendix E for the raw data.

	Mean (%)	SD	Median (%)	Range (min-max) (%)	N
Large wild mammal carcasses	17.79	32.48	0.00	0.0-100.0	12
Wildlife crashes	50.62	42.08	50.0	0.0-100.00	13
Wildlife-vehicle collisions	33.52	27.96	32.5	0.0-100.0	13

The reduction in wildlife-vehicle collisions (based on either large wild mammal carcasses or wildlife crashes or the average of the two) based on either Before-After (BA) or Before-After-Control-Impact analyses (BACI) was dependent on the length of the fenced road section (Figure 16). Short road sections with wildlife fences (≤3.1 mi (5 km) road length) were, on average, less effective (46.59 percent reduction on average) than long road sections (>3.1 mi (5 km) road length) (82.97 percent reduction on average) (Table 3). In addition, the effectiveness was much more variable for individual short fenced road sections (range 0.0-100.0 percent) compared to long fenced road sections (typically >80 percent) (Figure 16, Table 3).

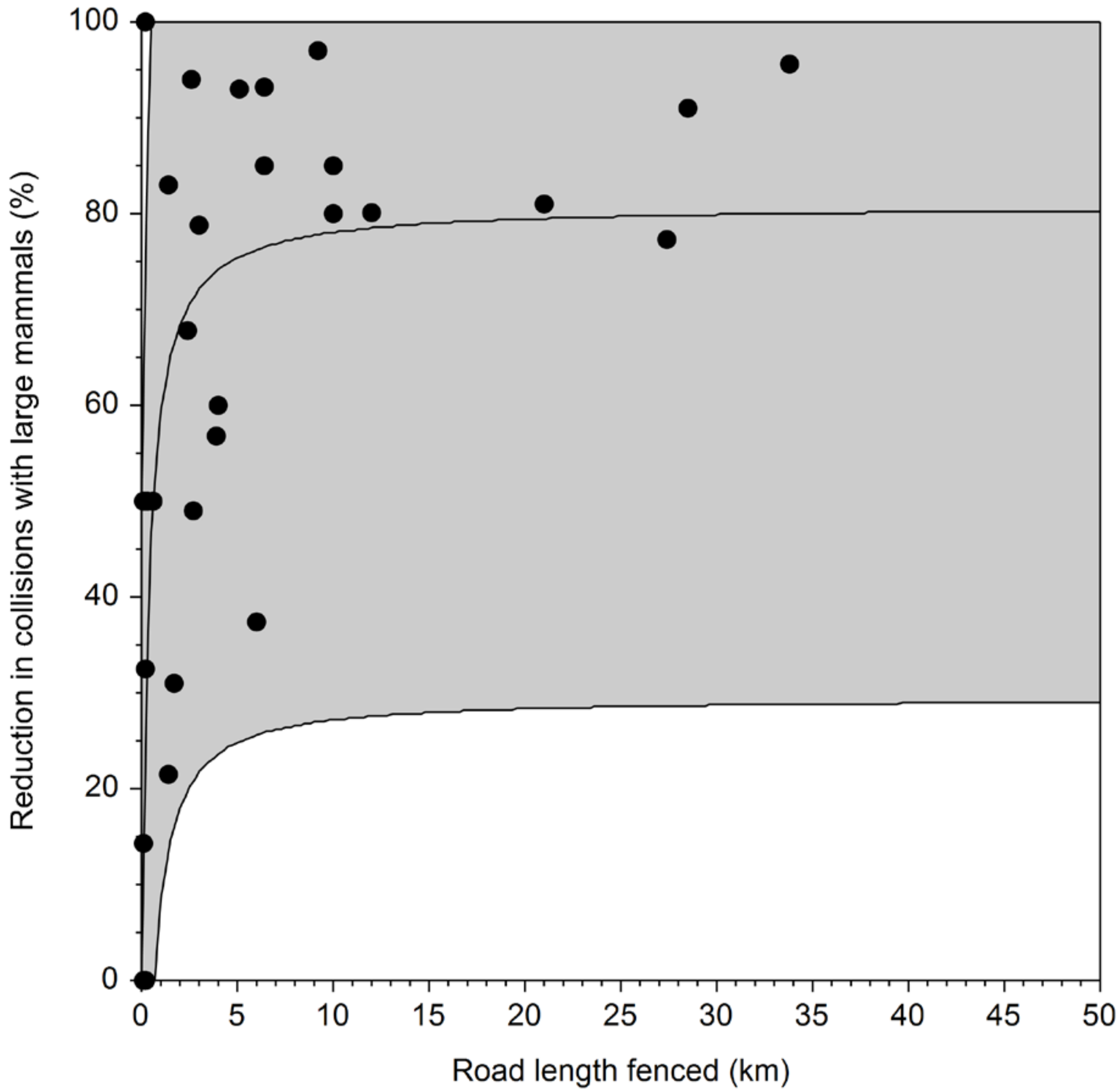

Figure 16: The effectiveness of the 30 fenced road sections (13 of these road sections were situated along US 93 North) with varying fence lengths in reducing collisions with large mammals.
A Michaelis-Menten function (black line) was fitted to the data (Y=80.87*X/(0.36+X)) with associated 95% confidence interval (grey area).

Table 3: The reduction in wildlife-vehicle collisions for fenced road sections ≤3.1 mi (≤5 km) and >3.1 mi (> 5 km).
The reduction is based on large wild mammal carcasses or wildlife crashes or the average of these two parameters. See Appendix E and Huijser *et al.* 2016 for the raw data.

	Mean	SD	Median	Range (min-max)	N
All road sections ≤3.1 mi (≤5 km)	46.59	31.50	50.00	0.0-100.0	18
All road sections >3.1 mi (>5 km)	82.97	15.85	85.00	37.4-97.0	12

3.4. Discussion and Conclusion

3.4.1. Effectiveness Fenced Road Sections US 93 North in Reducing Collisions

After highway reconstruction, large wild mammal carcasses were on average 17.79 percent lower in the fenced road sections. Wildlife crashes were 50.62 percent lower on average. Wildlife-vehicle collisions (average of the carcass and crash data) were reduced by 33.52 percent. While the fences did result in a reduction of wildlife-vehicle collisions, their effectiveness was relatively low compared to other studies (79-97 percent reduction) ((Reed *et al.* 1982, Ward 1982, Woods 1990, Clevenger *et al.* 2001, Dodd *et al.* 2007b).

3.4.2. Short Fences are Less Effective and more Variable in Reducing Collisions

Based on a review of the literature, wildlife fences and associated measures implemented along short road sections (≤3.1 mi (≤5 km) were, on average, less effective in reducing collisions with large mammals than fences implemented along long road sections (>3.1 mi (>5 km)). Mitigated road sections that were at least 3.1 mi (5 km) long, reduced collisions with large mammals by 82.97 percent on average whereas mitigated road sections that were shorter than 3.1 mi (5 km) only reduced these collisions by 46.59 percent on average. In addition, the effectiveness of mitigated road sections shorter than 3.1 mi (5 km) was extremely variable. This meant that the effectiveness of wildlife fences was highly unpredictable for any specific mitigated road section shorter than 3.1 mi (5 km) in length. On the other hand, mitigated road sections that were at least about 3.1 mi (5 km) long were almost always at least 80 percent effective in reducing collisions with large mammals. When large mammals, specifically large ungulates, are the target species, reducing the length of wildlife fences to less than about 3.1 mi (5 km) can substantially limit effectiveness.

Based on the literature, road sections at and near fence ends tend to have a concentration of wildlife-vehicle collisions which reduces the effectiveness of the mitigated road section near a fence end. When a fenced road section is very short (≤3.1 mi (≤5 km), it appears to be either under partial or full influence of fence-end effects, which can suppress the effectiveness of the fence for the entire mitigated road section. However, the results of the literature review conducted in this chapter suggest that when a fenced road section is longer than about 3.1 mi (5 km), the fence-end effects are sufficiently diluted to almost always achieve at least 80 percent reduction in collisions with large mammals.

Fence-end effects can include a concentration of wildlife crossings at fence ends, wildlife entering the fenced right-of-way at fence ends, and spatial inaccuracies of the collision data. These issues are explained here based on the literature. When animals approach a fenced section of highway they may follow the fence (LeBlond *et al.* 2007) until they encounter a suitable crossing structure or an at-grade crossing opportunity at a fence end. The latter can result in a higher concentration of at-grade wildlife crossings and associated collisions at fence ends compared to other unfenced road sections that are further away from a fence end (e.g. Clevenger *et al.* 2001, Parker *et al.* 2008, Gulsby *et al.* 2011, Chapter 4). This phenomenon is sometimes referred to as a “fence-end run”. Fence-end runs may not always be present (e.g. Craighead *et al.* 2011, Bissonette and Rosa 2012). Fence-end runs do not necessarily impact the effectiveness of fenced road sections, but since the spatial precision of crash and carcass data is typically only 0.1 mile or 0.1 km at best (Huijser *et al.* 2007), some of the animals that are hit just outside the fenced road section are likely to be mistakenly assigned to the fenced road section. In addition, some of the animals at the fence ends may end up wandering into the fenced road corridor. Ungulates that are attracted to the vegetation in the right-of-way may be particularly interested in accessing the fenced road section (e.g. Carbaugh *et al.* 1975, Huijser *et al.* 2016). Such intrusions into the fenced road corridor can result in collisions in the mitigated road section, especially near fence ends (Siemers *et al.* 2015, Chapter 4). Fence end effects can be minimized through proper placement of fence ends (e.g. at a bridge or steep slopes), fences that angle away from the road, and barriers in the right-of-way and road surface that discourage wildlife from entering the fenced road corridor.

Short fenced road sections were, on average, not only less effective in reducing large mammal-vehicle collisions than longer fenced road sections, but their effectiveness in reducing wildlife-vehicle collisions was more variable. This can be related to variations in spatial accuracy of the collision data and thus varying levels of errors when assigning the collisions to either the mitigated or unmitigated highway section. In addition, differences in local topography and habitat, nearby wildlife crossing structures, as well as the presence or absence of fence-end treatments (see Chapter 4) are likely to have a substantial impact on wildlife movements and collisions near fence ends. This variation also exists for longer fenced road sections. However, fence-end effects, including variations in fence-end effects, are substantially diluted and less apparent if the fenced road sections are at least 3.1 mi (5 km) long.

3.4.3. Implications

Wildlife fences for large ungulates are most effective at reducing collisions (almost always at least about 80 percent reduction) if the fences and associated measures are installed over road lengths of at least 3.1 mi (5 km). If fences are implemented over relatively short road lengths (<3.1 mi (<5 km)), the average effectiveness in reducing collisions with large mammals may drop to about 45 percent. The effectiveness of wildlife fences was highly unpredictable for any specific mitigated road section shorter than 3.1 mi (5 km) in length. Note that the associated economic benefits (i.e. fewer collisions and lower costs) will decrease disproportionally compared to the costs associated with the mitigation measures. Proper placement of fences in relation to hotspots, buffer zones, and local topography and habitat; as well as fence-end treatments (see Chapter 4) can help improve the effectiveness of short sections of wildlife fences in reducing collisions. These factors can also help reduce the variation in the effectiveness of short fences. Finally, improving the spatial precision of collision data and noting whether a collision took place inside or outside a fenced road section can reduce or eliminate mistakes that can affect the calculations for the effectiveness of a fenced road section.

4. FENCE END EFFECTS

4.1. Introduction

A concentration of wildlife-vehicle collisions inside a mitigated road section at and near fence ends can reduces the effectiveness of the mitigated road section. When a fenced road section is short (≤3.1 mi (≤5 km)), it is either under partial or full influence of fence-end effects, which can suppress the effectiveness of the fence for the entire mitigated road section. Fence-end effects can include a concentration of animal crossings at fence ends and animals entering the fenced right-of-way at fence ends (Figure 17). Finally, spatial inaccuracies of the collision data can cause an artificial fence end effect (Figure 17).

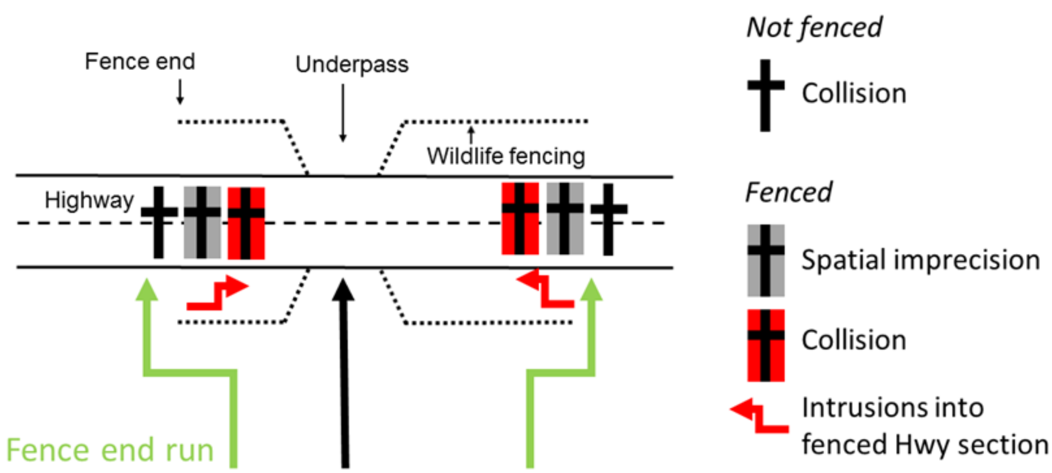

Figure 17: Schematic representation of fence end effects.

When animals approach a fenced section of highway they may follow the fence (LeBlond *et al.* 2007) until they encounter a suitable crossing structure or an at-grade crossing opportunity at a fence end. The latter can result in a higher concentration of at-grade crossings and collisions at fence ends compared to other unfenced road sections that are further away from a fence end (e.g. Clevenger *et al.* 2001, Parker *et al.* 2008, Gulsby *et al.* 2011). This phenomenon is sometimes referred to as a “fence-end run”. However, fence-end runs may not always be present (e.g. Craighead *et al.* 2011, Bissonette and Rosa 2012). Fence-end runs do not necessarily impact the effectiveness of fenced road sections, but since the spatial precision of crash and carcass data is typically only 0.1 mile or 0.1 km at best (Huijser *et al.* 2007), some of the animals that are hit just outside the fenced road section are likely to be mistakenly assigned to the fenced road section. In addition, some of the animals at the fence ends may end up wandering into the fenced road corridor. Ungulates that are attracted to the vegetation in the right-of-way may be particularly interested in accessing the fenced road section (e.g. Carbaugh e*t al.* 1975, Huijser *et al.* 2016). Such intrusions into the fenced road corridor can result in collisions in the mitigated road section, especially near fence ends (Siemers *et al.* 2015). This chapter reports on the potential presence of a fence end effect for the fenced road sections along US 93 North.

4.2. Methods

The researchers assigned each fence end along US 93 North between Evaro and Polson to a 0.1 mi (160.9 m) reference post, similar to the observations of large wild mammal carcasses (see Chapter 2). The researchers included all fence ends (14 fenced road sections, 28 fence ends) in the analyses. This also included one road section that only had a wildlife fence one side of the highway (Schley Creek). All fenced road sections had at least one crossing structure considered suitable for large mammals. The distance to the nearest fence end was calculated for each 0.1 mi road length unit (in 0.1 mi units). For fence ends, the distance to the fence end was set at zero (0.0 mi). The researchers then calculated the relative abundance (proportion) of these 0.1 mi units for the units inside and outside the fenced sections.

The researchers selected all large wild mammal carcass data from 2011 through 2015 (post highway reconstruction) and each large wild mammal carcass was assigned a 0.1 mi reference post, and the distance to the nearest fence end was calculated (similar to the procedure described above). The researchers then calculated the proportion of the large wild mammal carcasses for each 0.1 mi distance unit inside and outside the fenced sections. In some cases the fences on opposite ends of the highway did not end at the same 0.1 mi unit but in adjacent 0.1 mi units. In those cases the fence end was set at the 0.1 mi unit that still had fences on both sides of the highway. This meant that some of the adjacent unfenced 0.1 mi units had some fencing on one side of the road.

The “concentration” or “dilution” of large wild mammal carcasses at and near fence ends was calculated separately for the fenced and unfenced road sections. For the unfenced road sections (excluding the 0.1 units where the fence ends were located) the researchers selected the 0.1 mi distance units up to 0.5 mi from the nearest fence end and divided the proportion of large wild mammal carcasses in each of these 0.1 mi units by the proportion of the abundance of the individual 0.1 mi distance units. When this value is equal to 1, the number of large wild mammal carcasses in a 0.1 mi distance unit is exactly what could be expected if the distribution of the carcasses would be homogeneous and independent of the distance to the fence end. A value greater than 1 represented a concentration of large wild mammal carcasses and a value smaller than 1 represented fewer carcasses than expected (“dilution”). For each 0.1 mi unit (up to 0.5 mi from a fence end) the observed and expected number of large wild mammal carcasses was calculated. The researchers applied the same procedure to fenced road sections. However, for the fenced road sections there were six 0.1 mi units: one for the fence ends (set at 0.0 mi distance from a fence end) and five adjacent distance units up to 0.5 mi from the nearest fence end.

Wilcoxon Matched-Pairs Signed-Ranks Tests were conducted to test for potential significant concentration or dilution of the large wild mammal carcasses in each of the 0.1 mi units measured from the fence ends. Two-sided tests were conducted first as it was unknown how far a potential fence end effect would extend from a fence end and when a potential change from a concentration to a potential dilution of carcasses would occur. In addition, one-sided tests were conducted as a concentration of carcasses was expected at and immediately adjacent to the fence ends and a dilution of carcasses was expected further away from the fence ends.

4.3. Results

There was a higher than expected concentration of large wild mammal carcasses at and near fence ends (Figure 18). The fence end effect extended 0.2 mi (322 m) into unfenced road sections, and 0.2 mi (322 m) into the fenced sections (including the fence end itself); totaling 0.4 mi (644 m). The number of large wild mammal carcasses was significantly higher than expected in the first 0.1 mi outside the fenced road sections (Table 4). The number of large wild mammal carcasses was significantly lower than expected further away from the fence ends (0.4 and 0.2 mi inside the fenced sections and 0.3 mi outside the fenced road sections) (Table 4).

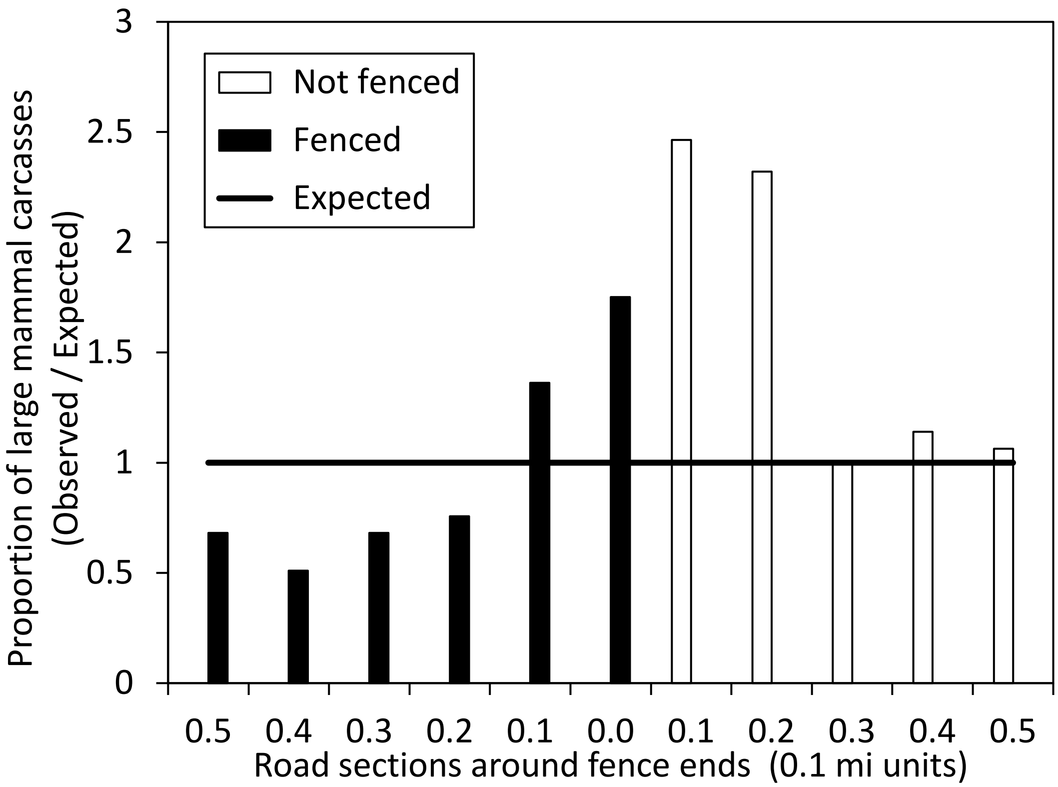

Figure 18: The concentration of large wild mammal carcasses at and near the fence ends (N=28) along US 93 North (Fenced N=66 carcasses; Not fenced N=114 carcasses).
The bars represent the proportion of observed large mammal carcasses divided by the proportion of expected large mammal carcasses. The horizontal line (with value 1) represents a situation where the observed proportion of carcasses is equal to the expected proportion of large wild mammal carcasses. The fence ends are in the middle of the graph at 0.0 mi distance from a fence end.

Table 4: Two-sided and one-sided tests for significant concentration of dilution of large wild mammal carcasses at and near fence ends.
Wilcoxon Matched-Pairs Signed-Ranks Tests, grey cell = P < 0.05.

Fenced or unfenced	Distance to fence end (mi)	P-value			N	Direction effect
		2-sided	1-sided			
		Observed ≠ expected	Observed > expected	Observed < expected		
Fenced	0.5	0.251	0.875	0.125	8	N/A
Fenced	0.4	0.083	0.958	0.041	8	Dilution
Fenced	0.3	1.000	0.500	0.500	8	N/A
Fenced	0.2	0.043	0.979	0.021	9	Dilution
Fenced	0.1	0.823	0.412	0.588	14	N/A
Fence	0.0	0.499	0.751	0.249	28	N/A
Unfenced	0.1	0.041	0.021	0.979	27	Concentration
Unfenced	0.2	0.679	0.339	0.661	22	N/A
Unfenced	0.3	0.049	0.976	0.024	20	Dilution
Unfenced	0.4	0.143	0.928	0.072	19	N/A
Unfenced	0.5	1.000	0.500	0.500	16	N/A

4.4. Discussion and Conclusion

4.4.1. Evidence for Fence End Effects along US 93 North

There was a fence end effect for the fenced road sections along US 93 North. The concentration of large mammal carcasses was significantly higher than expected for the first 0.1 mi (160.9 m) in the unfenced road sections. However, the fence end effect appears to extend up to 0.2 mi (322 m) from a fence end in the unfenced road sections. This means that control road sections (see Chapter 2) require a gap of 0.2 mi (322 m) between a fence end and a control area. This results in control road sections that are unaffected by fence end effects. There was also a concentration of large wild mammal carcasses at fence ends and at the first 0.1 mi (160.9 m) inside the fenced road sections. However, this concentration was not significant. Nonetheless, the data indicated that fenced road sections up to 0.4 mi (644 m) in length (0.2 mi from each of the two fence ends of a fenced road section) are likely to have a concentration of large wild mammal carcasses and are under complete influence of fence end effects. Therefore, fenced road sections ≤0.4 mi (≤644 m) are, on average, unlikely to reduce wildlife-vehicle collisions. The presence of a fence end effect inside the fenced road sections also explains why short road sections are less effective in reducing wildlife-vehicle collisions than longer road sections. This supports the findings described in Chapter 3. Fenced road sections of ≥0.5 mi (≥800 m) start diluting the fence end effects, but it appears that a mitigated road length of at least 3.1 mi (5 km) is required to obtain a reduction in wildlife-vehicle collisions of at least 80 percent (Chapter 3).

4.4.2. Fence-End Treatments and Other Design Considerations can Improve the Effectiveness of Fences

Fence-end treatments are designed to discourage wildlife from crossing the highway at fence ends and to discourage wildlife from entering the fenced road corridor at a fence end. Fewer animals crossing the highway at fence ends and fewer intrusions into the fenced road section should result in fewer collisions, both within and outside the mitigated section. Fence-end treatments designed to discourage wildlife from crossing the highway at-grade at fence ends include angling fences away from the road or ending fences at a bridge or steep slope (Huijser *et al.* 2015). Fence-end treatments designed to discourage wildlife from entering the fenced road corridor at a fence end include fences angled towards the road, boulder fields that block access into the fenced vegetated right-of-way, or wildlife guards or electric mats embedded in the travel lanes designed to deter wildlife (Huijser *et al.* 2015)).

When designing mitigation measures and deciding on where fences should start and end, it is important to consider the location of potential collision hotspots, the surrounding landscape and the size of the home range of the target species. Tailoring the design of the mitigation measures to local conditions can greatly improve the effectiveness of fences in reducing wildlife-vehicle collisions. Obviously the mitigated road section should cover the entire length of a wildlife-vehicle collision hotspot that may have been identified based on wildlife-vehicle collision data. However, in real world settings this does not always happen (Cramer *et al.* 2014). In addition, the fences should also include “buffer zones” on either side of a hotspot (Ward *et al.* 1982, Huijser *et al.* 2015). If a fence ends exactly where the hotspot ends, the animals that approach the road at the edge of the hotspot can simply step to the side and cross the highway at grade at a fence end. Such fence-end runs are less likely if the fences extend further than the actual hotspots. In this context it is useful to consider the home range size of the target species. Note that the diameter of the home range for most large wild ungulates is a few hundred yards (meters) up to about 5 mi (8 km) (USDA 1999, Foresman 2012). If an animal has the center of its home range at the edge of a hotspot it can be expected to be able to travel a distance equivalent to the radius of its home range. This provides an indication of the appropriate length of the buffer zones. Local topography and habitat can also help guide decisions on where wildlife fences should start and end. It is also important to consider the spatial accuracy of the wildlife-vehicle collision data (typically only 0.1 mi or 0.1 km at best) (Huijser *et al.* 2007). If mitigation measures are proposed for very short road sections, e,g. only a few hundred meters, it would be relatively easy to partially or fully miss a hotspot (Ford *et al.* 2011). Wildlife fences are likely most effective if the supporting wildlife-vehicle collision data are spatially accurate, if the mitigation measures cover the actual hotspots as well as adjacent buffer zones, and if the designs are tailored to the local conditions, including topography and habitat. Consulting experts and people with local knowledge and expertise, including road maintenance personnel, is likely to improve the effectiveness of the mitigation measures. However, very short fences (up to 0.4 mi (644 m)) are unlikely to reduce wildlife-vehicle collisions, and mitigated road lengths of at least 3.1 mi (5 km) are required to almost always obtain a reduction in wildlife-vehicle collisions of at least 80 percent (Chapter 3).

5. BEAR-VEHICLE COLLISIONS ALONG US 93 NORTH

5.1. Introduction

This chapter reports on the number of reported bear-vehicle carcasses along US 93 North between Evaro and Polson. The researchers included observations of black bear (*Ursus americanus*) as well as grizzly bear (*Ursus arctos*). The researchers investigated the effectiveness of the wildlife mitigation measures in reducing black bear-vehicle collisions along the entire road corridor between Evaro and Polson and in the Evaro, Ravalli Curves and Ravalli Hill areas. The researchers also investigated the location of the grizzly bear carcasses along the already reconstructed highway sections and the highway section through the Ninepipe area that will likely be reconstructed in the future.

5.2. Methods

The researchers combined bear carcass and collision data along US 93 North from three sources:

- Montana Department of Transportation carcass removal data from 1998-2015.
- Hardy *et al.* (2007) with bear carcass data from 1995-2005. This source combined the following data related to black bear and grizzly bear carcasses: Montana Department of Transportation carcass removal data from US 93 North and carcass observations by Montana Fish Wildlife & Parks. Data from Montana Fish Wildlife & Parks related to the southern end of the road section of interest; around the southern boundary of the Flathead Indian Reservation (Evaro area). Bear observations that did not explicitly indicate the species were assumed to relate to black bear rather than grizzly bear.
- Tribal Game Wardens bear carcass data from 2008-2015. These data included observations by law enforcement officers, including tribal game wardens.

The bear carcass data mostly related to incidental observations as standard monitoring methods (e.g. carcass removal data by the Montana Department of Transportation) are not very suitable for recording rare species. Bear carcasses are often removed by others (legally or illegally) before a road maintenance crew comes by. Data from 2006 and 2007 may have been missing in their entirety as it was after the period covered by Hardy *et al.* (2007) and before the period for which tribal game warden data were available. The researchers combined the data from the three sources described above and removed duplicate records (Appendix F). In addition, the researchers only included bear carcasses observed between Evaro and Polson (mile reference post 7.1-59.0). If no reference post was indicated (e.g. “Evaro area”), the researchers excluded the observations. The latter related to three observations by Montana Fish Wildlife & Parks which were likely outside the Flathead Indian Reservation and just south of the highway section of interest.

The researchers calculated the number of grizzly bear and black bear carcasses per calendar year for the entire corridor between Evaro and Polson (mi reference post 7.1-59.0) between 1995 and 2015.

The researchers calculated the number of black bear carcasses before (2002 through 2005) and after (2011 through 2015) highway reconstruction along the entire road corridor between Evaro and Polson. The black bear carcass removal data were transformed (ln(x+0.1)) to make the count variable resemble a normal distribution. This allowed for the investigation of a potential difference in black bear carcasses before and after highway reconstruction and the associated mitigation through a T-test (two-sided).

The researchers calculated the number of black bear carcasses before (2002 through 2005) and after (2011 through 2015) highway reconstruction in the three highway sections with relatively long sections of wildlife fences and unmitigated road sections (controls); Evaro, Ravalli Curves, and Ravalli Hill (see Figure 3 and Table 1 in Chapter 2). For the three areas combined, the years before and after construction included in the analyses were 2002 through 2005 (before) and 2011 through 2015 (after). The bear carcass data for the three areas combined were transformed (ln(x+0.1)) to make the count variable resemble a normal distribution. This allowed for the investigation of a potential interaction of the before-after and fenced-control parameters through an ANOVA. If there was an effect of the treatment (i.e. the wildlife fences and associated crossing structures) on the number of bear carcasses, the researchers expected the mitigation measures to result in fewer collisions rather than more. Hence our ANOVA was one-sided.

5.3. Results

The number of reported black bear and grizzly bear carcasses varied substantially between the years (Figure 19). There were 59 observations of black bear carcasses and 6 of grizzly bear carcasses between 1995 and 2015 and 49 black bear and 6 grizzly bear carcasses between 2002 and 2015 (Figure 19). After all highway reconstruction was completed there were 23 black bear and 5 grizzly bear carcasses reported (2011-2015) (Appendix F).

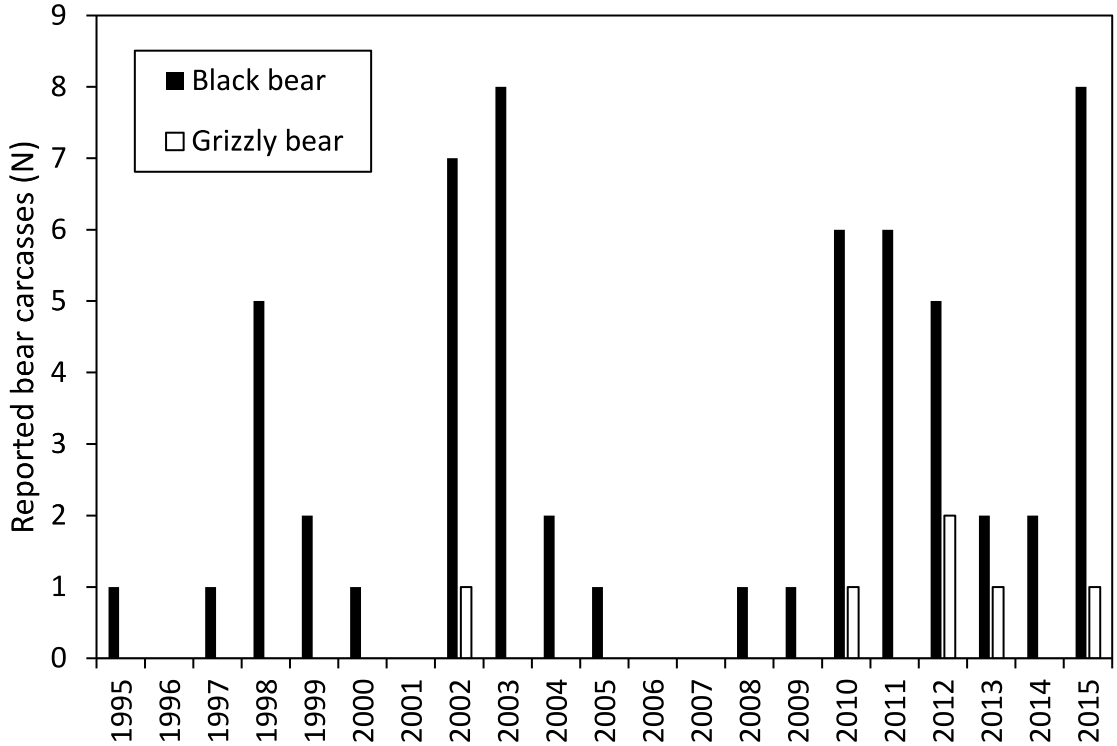

Figure 19: Total number of reported black bear and grizzly bear carcasses along US 93 North between Evaro and Polson (mi reference post 7.1–59.0) from 1995 through 2015.
See Appendix F for more details.

The locations of the black bear and grizzly bear carcasses between 2002 and 2015 was plotted (Figures 20-21).

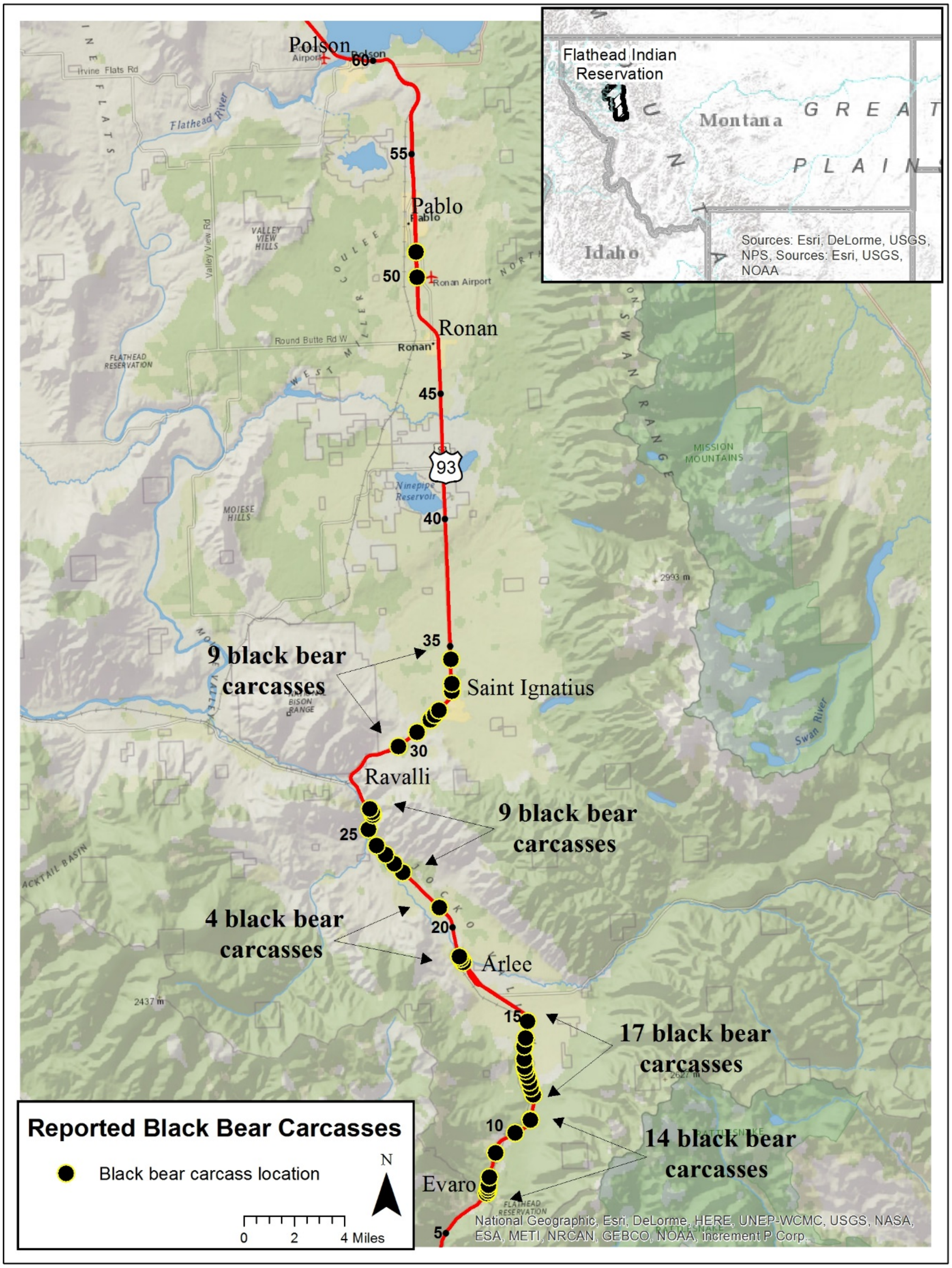

Figure 20: The location of the reported black bear carcasses (2002-2015) along US 93 North (mi reference post 7.1–59.0).
See Appendix F for more details.

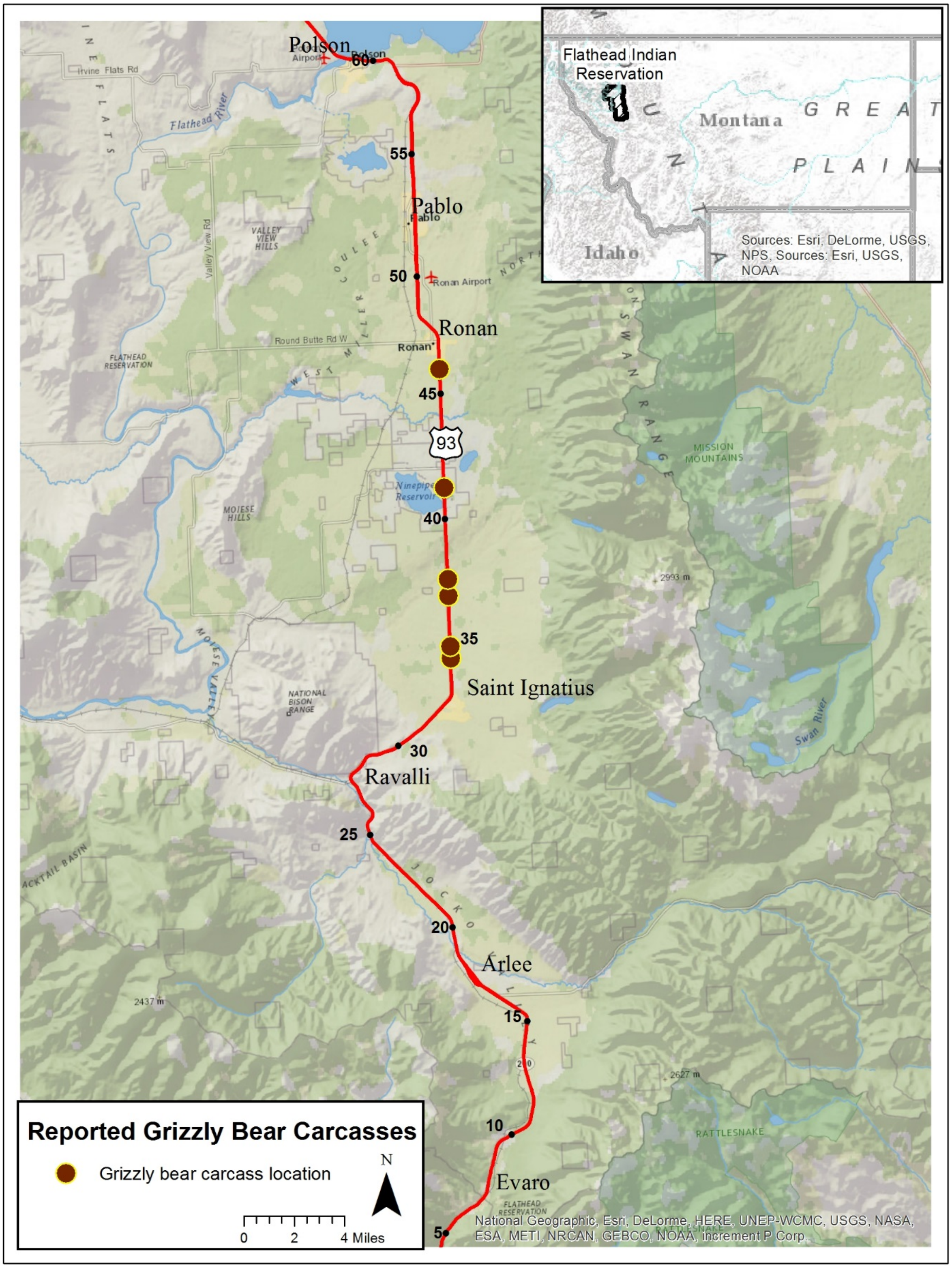

Figure 21: The location of the reported grizzly bear carcasses (2002-2015) along US 93 North (mi reference post 7.1–59.0).
See Appendix F for more details.

There number of reported black bear carcasses was similar before and after highway reconstruction between Evaro and Polson (Two-sided T-test, T-value=0.3405, P=0.744) (Figure 22).

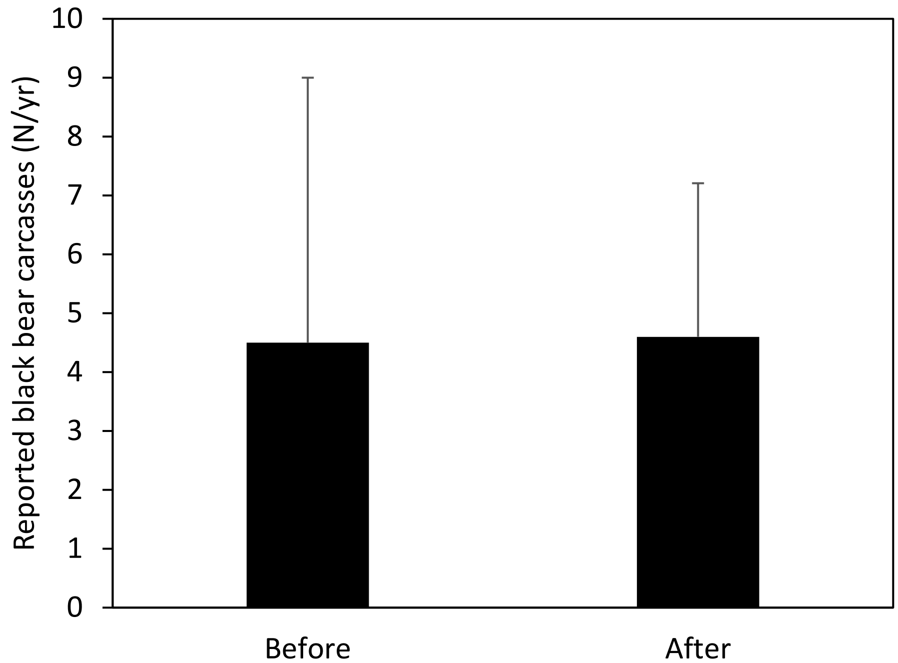

Figure 22: The number of reported black bear carcasses per year (and associated standard deviations) before (2002-2005) and after (2011-2015) highway reconstruction and associated mitigation along the entire road corridor between Evaro and Polson.

Based on a simple "before-after" comparison for the mitigated road sections there was a 20.0 percent increase in reported black bear carcasses in the mitigated road sections of Evaro, Ravalli Curves, and Ravalli Hill combined (Figure 23). Furthermore, the number of reported black bear carcasses in the control road sections decreased by 80% (Figure 23). However, the absolute numbers were small and the interaction of the before-after and mitigated-control parameters was not significant (one-sided ANOVA $F_{1,14}$=0.229, P=0.320). This means that the effect of the highway reconstruction (before-after) on the number of black bear carcasses did not depend on the treatment (wildlife fences and wildlife crossing structures vs. no wildlife mitigation measures).

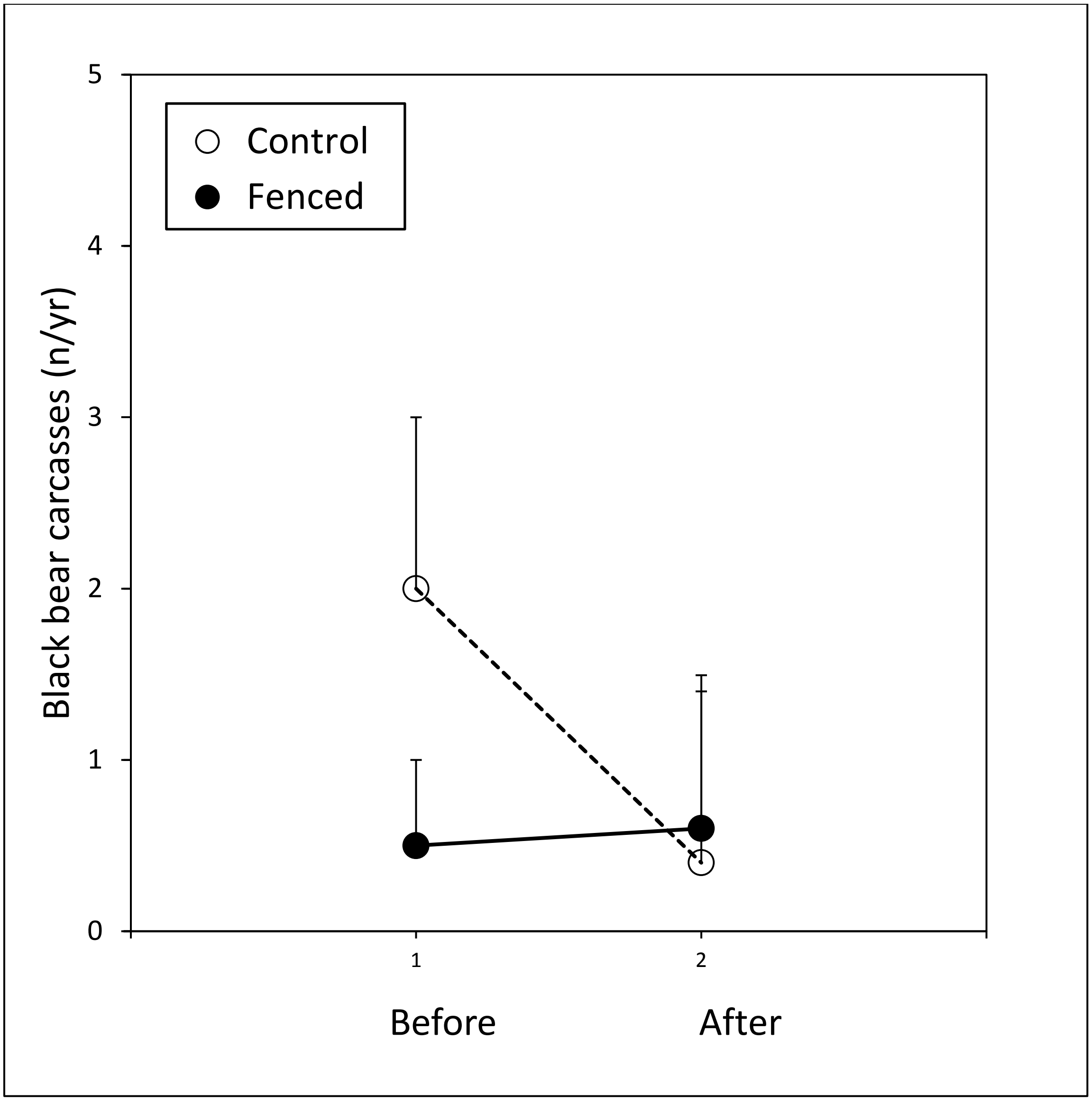

Figure 23: The average number of reported black bear carcasses (and associated standard deviations) before (2002-2005) and after (2011-2015) highway reconstruction and mitigation in the three mitigated and control (unmitigated) road sections in Evaro, Ravalli Curves, and Ravalli Hill areas combined.

5.4. Discussion and Conclusion

Black bear carcasses continued to be recorded in similar numbers after highway reconstruction and associated mitigation measures along the entire US 93 North corridor between Evaro and Polson (16.8% of the road length was mitigated, see Chapter 2). There was also no evidence that the mitigation measures in Evaro, Ravalli Curves, and Ravalli Hill reduced the number of reported black bear carcasses. This is likely related to the relatively short road lengths equipped with mitigation measures, the design of the wildlife fence, and the gaps in the wildlife fence at access roads and steep slopes (see Figures 4-6 in Chapter 2). Mitigated road sections longer than 3.1 mi (5 km) are more effective in reducing collisions with large wild mammals than shorter sections (Chapter 3). However, the large wild mammals included in the analyses in Chapter 3 are mostly large ungulates and minimum recommended mitigated road length does not necessarily apply to black bear. While the minimum recommended fence length is likely to depend on the species, the principle that longer mitigated road sections are more effective than short mitigated road sections is likely to hold for all species, including black bear. Furthermore, the wildlife fence along US93N is primarily designed for large ungulates. Black bear can place their feet in the relatively large meshes of the fence (7 inches (17.8 cm) high, 12 inches (30.5 cm) wide) and climb the fence. In addition, the wooden poles resemble trees which can also be climbed by black bears. Evidence of black bear climbing the wildlife fence has been found occasionally along US 93 North. If a fence is specifically designed for black bear, smaller mesh sizes (e.g. chain-link fence), metal posts, and an overhang facing away from the road are advisable (Huijser *et al.* 2015). Gaps in the wildlife fence are potential weak spots that allow wildlife, including black bears, to access the fenced road corridor. Therefore, it is advisable to reduce the number of gaps in the wildlife fence. This can include minimizing the number of access roads and having continuous fencing, even when steep slopes are present. A barrier for wildlife, including black bears, should be in place at the remaining access roads. While the current wildlife guards are a substantial barrier for ungulates, they are not a meaningful barrier to black bears (Chapter 10). Electric mats at access roads are likely the most effective barrier for bears (Huijser *et al.* 2015).

All grizzly bear carcasses along US 93 North (N=6) were reported between St. Ignatius and Ronan. Interestingly, this is an area with no or very few black-bear vehicle collisions. All but one of the six grizzly bears was hit after highway reconstruction and the associated implementation of the mitigation measures. The road section between St. Ignatius and Ronan was partially reconstructed and mitigated with short sections of wildlife fences and wildlife underpasses (up to mi reference post 37.4, about 4.4 mi north of St. Ignatius). However, the road section further north (mi reference post 37.4 and higher) goes through the Ninepipe area and has not been reconstructed or mitigated yet. Nonetheless, 3 of the 5 post-construction grizzly bear carcasses were reported from road sections that were upgraded, and all three observations were from the period after this highway section was reconstructed with short sections of wildlife fences and wildlife underpasses in selected locations. The data showed that grizzly bear continue to be hit by traffic after highway reconstruction, though some wildlife underpasses (especially Post Creek 3) are used by grizzly bear (Chapter 6). The researchers suggest tying the existing short sections of wildlife fence at Post Creek 1, 2 and 3 together to make one longer fenced road section. As grizzly bear would be among the target species in this area, access roads should probably be mitigated with electric mats rather than wildlife guards (Chapter 10). Electric mats embedded in the pavement may also be required at the fence ends to reduce intrusions into the fenced road corridor (Chapter 4) and improve the effectiveness of short fenced road sections in reducing collisions with large wild mammals (Chapter 3). While no grizzly bear carcasses have been reported between Ravalli and St. Ignatius, grizzly bear have been observed using wildlife underpasses in this area (Ravalli Hill 2 and Pistol Creek 1). Therefore, the researchers also advise additional mitigation measures for grizzly bear between Ravalli Hill and St. Ignatius as it seems only a matter of time before grizzly bears are hit by vehicles in this area too. The researchers also advise extending the wildlife fence north of Post Creek 3. However, the fence should not be extended without also providing for wildlife crossing structures that are suitable for grizzly bear. The current crossing structures Post Creek 4, 5, 6, and 7 (see Chapter 1, Appendix A1) are not considered suitable for grizzly bear because of their small dimensions (Clevenger and Huijser 2011). Finally, the researchers suggest continuous wildlife fences with wildlife crossing structures suitable for grizzly bear through the Ninepipe area (mi reference post 37.4 up to Ronan). The researchers advise using electric mats at access roads and fence ends. The implementation of these wildlife mitigation measures is most cost efficient if it is combined with the expected highway reconstruction through this area.

6. WILDLIFE USE OF THE CROSSING STRUCTURES

6.1. Introduction

This chapter reports on the wildlife use of the crossing structures along US 93 North. The analyses were focused on white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*) and black bear (*Ursus americanus*). In addition, the use of the crossing structures was evaluated for species of special concern: grizzly bear (*Ursus arctos*), elk (*Cervus canadensis*) and moose (*Alces americanus*). Finally, the researchers investigated the deer and black bear use of the crossing structures for potential evidence of a learning curve. A learning curve occurs if wildlife use the structures more frequently as the structures have been in place for longer. Animals may learn about the location of the structures and that it is safe to use them to access the other side of the highway.

6.2. Methods

6.2.1. Structures Monitored

Different sections of US 93 North were under reconstruction at different times between the end of 2004 and the summer of 2011 (Appendix A1, B). The reconstruction included wildlife fences and wildlife crossing structures. The researchers investigated wildlife use of 29 crossing structures from 2008 through 2015 (Appendix G). However, as different road sections were completed at different times, not all structures were monitored during the same time period. The researchers distinguished 4 crossing structure groups, with different monitoring methods and periods:

Evaro area: This 1.7 mile (2.74 km) long fenced road section (mi reference post 9.3-11.0) included 6 wildlife crossing structures: 4 large corrugated metal culverts, 1 very large bridge (across the railroad), and 1 vegetated overpass (Appendix G). Construction took place in 2009 and 2010. These structures were monitored from 1 January 2011 through 31 December 2015 (5 years) with wildlife cameras.

Ravalli Curves area: This 3.8 mile (6.11 km) long fenced road section (mi reference post 22.9-26.7) included 9 wildlife crossing structures: 3 small box culverts, 1 small round culvert, 3 large corrugated metal culverts, and 2 short bridges (Appendix G). Construction took place in 2006 and 2007. These structures were monitored from 23 May 2008 through 31 December 2012 (5 years). The monitoring methods included both tracking on tracking beds (23 May 2008 through 26 February 2010; Allen 2011) and wildlife cameras (26 February 2010 through 31 December 2012).

Ravalli Hill area. This 1.8 mile (2.90 km) long fenced road section (mi reference post 27.5-28.7) included 2 wildlife crossing structures: 2 large corrugated metal culverts (Appendix G). Major construction took place in 2006 and 2007. These structures were monitored from 23 May 2008 through 31 December 2012 (5 years). Both tracking on tracking beds (23 May 2008 through 26 February 2010; Allen 2011) and wildlife cameras were used to record wildlife at the crossing structures (26 February 2010 through 31 December 2014; 5 years).

Isolated crossing structures: These structures were not located along a separate road section. The structures were spread out between Evaro and Polson. The structures had either no fences or they had only relatively short fences. The researchers monitored 12 of these isolated structures (Appendix G). The 12 structures were all considered suitable for large mammals and were built out of either concrete or metal. Construction took place between 2004 and 2010. These structures were monitored from 1 January 2011 through 30 June 2015 (4.5 years) with wildlife cameras.

6.2.2. Monitoring Methods

Wildlife use of the crossing structures in the Ravalli Curves and Ravalli Hill areas was measured through tracking on sand tracking beds from 23 May 2008 through 26 February 2010 (Allen 2011). The tracking beds covered the entire width of the underpasses, excluding areas with standing or moving water. The tracking beds were about 6.6 ft (2 m) wide and they were located in the middle of the underpasses. The sand consisted of 7 parts sand, 1 part 1/8 inch (0.32 cm) crushed aggregate material (consistent with the pre-construction sand tracking beds (Hardy *et al.* 2007)). However, one structure (RC 377) was permanently inundated (about 1 ft (0.3 m) deep standing water) and this structures was monitored with a wildlife camera (Reconyx, PM35) starting in August 2008. The sand tracking beds were checked for wildlife tracks twice per week (i.e. once every 3-4 days) in the summer (23 May 2008 - 10 October 2008 and 8 May 2009 – 21 Aug 2009), and once per week in the fall, winter and spring. The researchers only selected records for which the species was identified as “certain” and for which the researchers classified the tracks as a “crossing” of the tracking bed, and presumably also the structure. The tracking was specifically targeted at deer (*Odocoileus* spp.) and black bear (*Ursus americanus*). It was not possible to distinguish between white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*) (Halfpenny 2001). The tracking was not very suitable for medium and small sized animals (e.g. coyote (*Canis latrans*) and smaller); the tracks in the dry sand often lacked sufficient detail.

From 26 February 2010 through 31 December 2012, wildlife cameras (Reconyx, PM35 and PC900 HyperFire) were installed at all the structures in the Ravalli Curves and Ravalli Hill areas. For structures wider than 10 m (32.8 ft) multiple cameras were installed. The memory cards were replaced once per month and the batteries (Energizer® Ultimate Lithium) were replaced once every three months. Additional cameras were installed at the structures in the Evaro area (1 January 2011 through 31 December 2015) and at the isolated structures (1 January 2011 through 30 June 2015). Note that additional isolated structures were monitored before 2011 but the start dates were different and there were changes in the selection of the isolated structures before 2011. Cameras were placed at an approximate height of 3.3 ft (1 m). The cameras were programmed to take 10 photos in rapid succession (in less than 10 s) each time they were triggered, with zero lag time before the next series of images could be taken. For the data obtained through the cameras the researchers only selected records for which the species of the animals involved was identified as “certain” and for which the animals did not turn back through the structure within five minutes.

6.2.3. Wildlife Use of the Crossing Structures

The researchers summarized all successful wildlife crossings per structure (Appendices H1 through H6). Note that the Appendix only includes data from 2010 onwards for the Ravalli Curves and Ravalli Hill areas as tracking data from 2008 and 2009 were not suited to identify medium sized mammals and smaller (e.g. coyote and smaller). There was a short period (1 January 2010 – 26 February 2010) for which only tracking data were available for the Ravalli Curves and Ravalli Hill areas. The researchers added these tracking data to the data obtained from the cameras in 2010. However, for crossings based on deer tracks, a correction factor (1.623) was applied to make the number of crossings based on track data comparable to that what the cameras would have observed (see Chapter 9 for the calculation of the correction factor). There were no bear crossings observed in January and February 2010 in the Ravalli Curves and Ravalli Hill areas, thus there was no need to apply a correction factor to black bear tracks for these months.

The researchers plotted the crossing structure use for white-tailed deer, mule deer, and black bear for each individual structure within each of the 4 crossing structure groups (Evaro, Ravalli Curves, Ravalli Hill, Isolated). For each of the four crossing structure groups the researchers calculated the expected use of a structure should the animals have used each structure equally within the crossing structure group. This “expected” number allowed for a rapid assessment of the use of a structure, given the use of the other structures in the crossing structure group. Since the isolated structures were far apart, the comparison of wildlife use between these structures is heavily influenced by the presence or absence of a species near the individual structures rather than the wildlife use of the other isolated structures.

6.2.4. Species of Special Concern

The researchers specifically evaluated use of the structures for three species that were of special concern based on their conservation status (grizzly bear (*Ursus arctos*)) or because the species are known to be somewhat hesitant in using wildlife crossing structures (elk (*Cervus canadensis*) and moose (*Alces americanus*)).

6.2.5. Learning Curve

The researchers investigated the use of the crossing structures by deer (white-tailed deer and mule deer combined) and black bear for potential evidence of a learning curve. A learning curve is presumed to occur when wildlife use of the structures increases with the age of the structures. Presumably, more animals learn about the location of the structures and that it is safe to use them to access the other side of the highway when the structures have been in place for longer. For this analysis the researchers used both the tracking data from Ravalli Curves and Ravalli Hill, as well as the camera data from the Evaro, Ravalli Curves and Ravalli Hill areas. The tracking data were "translated" to camera data by applying a correction factor (1.623 for deer and 1.088 for black bear (see Chapter 9 for the calculation of the correction factors)). In addition, the researchers added a proportional number of deer crossings for the period 1 January 2008 – 23 May 2008. A similar correction was applied to the 2008 data for black bears, but only for the period when bears were active (1 April – 23 May 2008). The number of successful crossings was summarized per year. The data related to one year after construction was completed (2010 in the Evaro area, 2008 in the Ravalli Curves and Ravalli Hill areas) up to five years after completion of the construction (2015 for Evaro, 2012 for Ravalli Curves and Ravalli Hill).

6.3. Results

6.3.1. Wildlife Use of the Crossing Structures

Within the time periods indicated in the methods, the researchers recorded 95,274 successful crossings through the 29 crossing structures (Table 5). The average number of successful crossings per year was 22,648 for the 29 crossing structures (Evaro: 5,772, Ravalli Curves: 4,941, Ravalli Hill 1,411, Isolated: 10,524). The vast majority of these crossings were by white-tailed deer (69 percent). Mule deer and domestic dogs and cats each represented about 5 percent of the successful crossings. In addition, there were 1,531 successful black bear crossings. The crossing structures were successfully used by 20 different species of medium sized or large sized terrestrial wild mammals (Table 6). To ease interpretation of table 5, the successful crossings were also summarized by species group (Table 6).

Figures 24 through 26 show the use of the individual structures by white-tailed deer, mule deer, and black bear. Comparison of the "observed use" of a structure with the "expected use" allowed for a rapid assessment of the use of a structure, given the use of the other structures in the crossing structure group. Within the Evaro area the railroad bridge and the overpass were used more than expected by white-tailed deer whereas the large culverts were used less than expected. The Ravalli Curves area did not have a bridge as large as the railroad bridge in the Evaro area. Instead it had two smaller bridges and culverts with different dimensions. One of the bridges (RC 381) and one of the large culverts (RC 396) were used more than expected whereas the small culverts (RC 377, RC 426, RC 427, RC 431) were barely used at all by white-tailed deer. The two large culverts in the Ravalli Hill area were similar in size and white-tailed deer use was about as expected for both structures. Even though the isolated structures were all similar in size, some structures (i.e. Post Creek 2 and 3) were used far more frequently than the others

Mule deer were first observed at the structures in the Evaro area in 2011. They mostly used one large culvert (Finley Creek 3) and used the other structures less than expected. In the Ravalli Curves area the mule deer used one bridge (RC 422) and two large culverts (RC 396 and RC 406) more frequently than expected. Similar to white-tailed deer the smaller culverts were not or barely used by mule deer. The two large culverts in the Ravalli Hill area were used about as expected. Of the isolated structures only the large culvert at Polson Hill received substantial use.

In contrast to white-tailed deer, black bear used 3 of the 4 large culverts in the Evaro area more frequently than expected. Black bear used the railroad bridge and the overpass less frequently than expected. In the Ravalli Curves area black bear used one large culvert (RC 432) more frequently than expected while a bridge and a small culvert were used about as expected. Though the structures in the Ravalli Hill area were very similar, black bear used one of them (RH 1) far more frequently than the other. Of the isolated structures Mission Creek was used far more frequently than expected.

Table 5: The number of successful crossings through the 29 wildlife crossing structures.

	Successful crossings (N)					
	All structures		Evaro	Ravalli Curves	Ravalli Hill	Isolated
	29 structures		6 structures	9 structures	2 structures	12 structures
			5 yrs	3 yrs	3 yrs	4.5 yrs
Species	N	%	2011-2015	2010-2012	2010-2012	2011-2015
White-tailed deer (*Odocoileus virginianus*)	65909	69.18	23870	8677	207	33155
Mule deer (*Odocoileus hemionus*)	5365	5.63	382	1732	2592	659
Domesticated dog (*Canis lupus familiaris*)	5258	5.52	262	107	0	4889
Domesticated cat (*Felis catus*)	4523	4.75	1272	278	6	2967
Human data collector	2351	2.47	803	729	236	583
Raccoon (*Procyon lotor*)	1897	1.99	124	374	14	1385
Human	1769	1.86	293	414	129	933
Black bear (*Ursus americanus*)	1535	1.61	605	458	202	270
Birds (Aves)	1428	1.50	652	39	172	565
Coyote (*Canis latrans*)	958	1.01	134	485	127	212
Deer spp. (*Odocoileus* spp.)	854	0.90	70	678	50	56
Red fox (*Vulpes vulpes*)	695	0.73	6	2	1	686
Western striped skunk (*Mephitis mephitis*)	572	0.60	17	110	26	419
Bobcat (*Lynx rufus*)	568	0.60	149	236	157	26
Human and dog	428	0.45	13	296	0	119
Rabbits and hares (Lagomorpha)	261	0.27	31	84	35	111
Mountain lion (*Felis concolor*)	227	0.24	58	69	87	13
Other	188	0.20	2	0	156	30
Cattle (*Bos taurus*)	119	0.12	66	0	0	53
Human and ATV	70	0.07	3	0	0	67
Unknown	56	0.06	5	7	2	42
Human and bicycle	43	0.05	8	0	0	35
American badger (*Taxidea taxus*)	38	0.04	0	4	23	11
Grizzly bear (*Ursus arctos*)	29	0.03	0	0	1	28
Elk (*Cervus canadensis*)	32	0.03	30	0	2	0
Bear spp (*Ursus* spp.)	16	0.02	1	10	3	2
North American beaver (*Castor canadensis*)	14	0.01	0	14	0	0
Northern river otter (*Lontra canadensis*)	13	0.01	1	8	0	4
Human and horse	10	0.01	0	0	0	10
American mink (*Mustela vison*)	9	0.01	0	0	0	9
Dom. dog or coyote	9	0.01	1	3	3	2
Yellow-bellied marmot (*Marmota flaviventris*)	7	0.01	0	3	0	4
Human and car	4	0.00	0	1	0	3
Porcupine (*Erethizon dorsatum*)	4	0.00	0	0	0	4
Moose (*Alces americanus*)	3	0.00	3	0	0	0
Long-tailed weasel (*Mustela frenata*)	3	0.00	0	2	0	1
Horse (*Equus ferus caballus*)	2	0.00	0	2	0	0
Weasel spp. (*Mustela* spp.)	2	0.00	0	0	1	1
Bat (Chiroptera)	2	0.00	0	0	0	2
Domesticated goat (*Capra aegagrus hircus*)	2	0.00	0	0	0	2
Human on skis	1	0.00	0	0	0	1
	95274	100.00	28861	14822	4232	47359

Table 6: The number of successful crossings through the 29 wildlife crossing structures by species group.

Species group	N	%
Wild ungulates (white-tailed deer, mule deer, elk, moose)	72162	75.74
Domesticated species (dog, cat, cattle, horse, goat)	9904	10.40
Humans	4676	4.91
Raccoons	1897	1.99
Wild canids (coyote, red fox)	1653	1.73
Bears (black bear, grizzly bear)	1580	1.66
Birds (mostly wild turkey and ring-necked pheasant	1428	1.50
Wild felids (bobcat, mountain lion)	795	0.83
Mustelids (skunk, weasel spp., badger, river otter, mink)	638	0.67
Rabbits and hares	261	0.27
Other (unknown, other, bat)	255	0.27
Rodents (beaver, porcupine, yellow-bellied marmot)	25	0.03
Total	95274	100.00

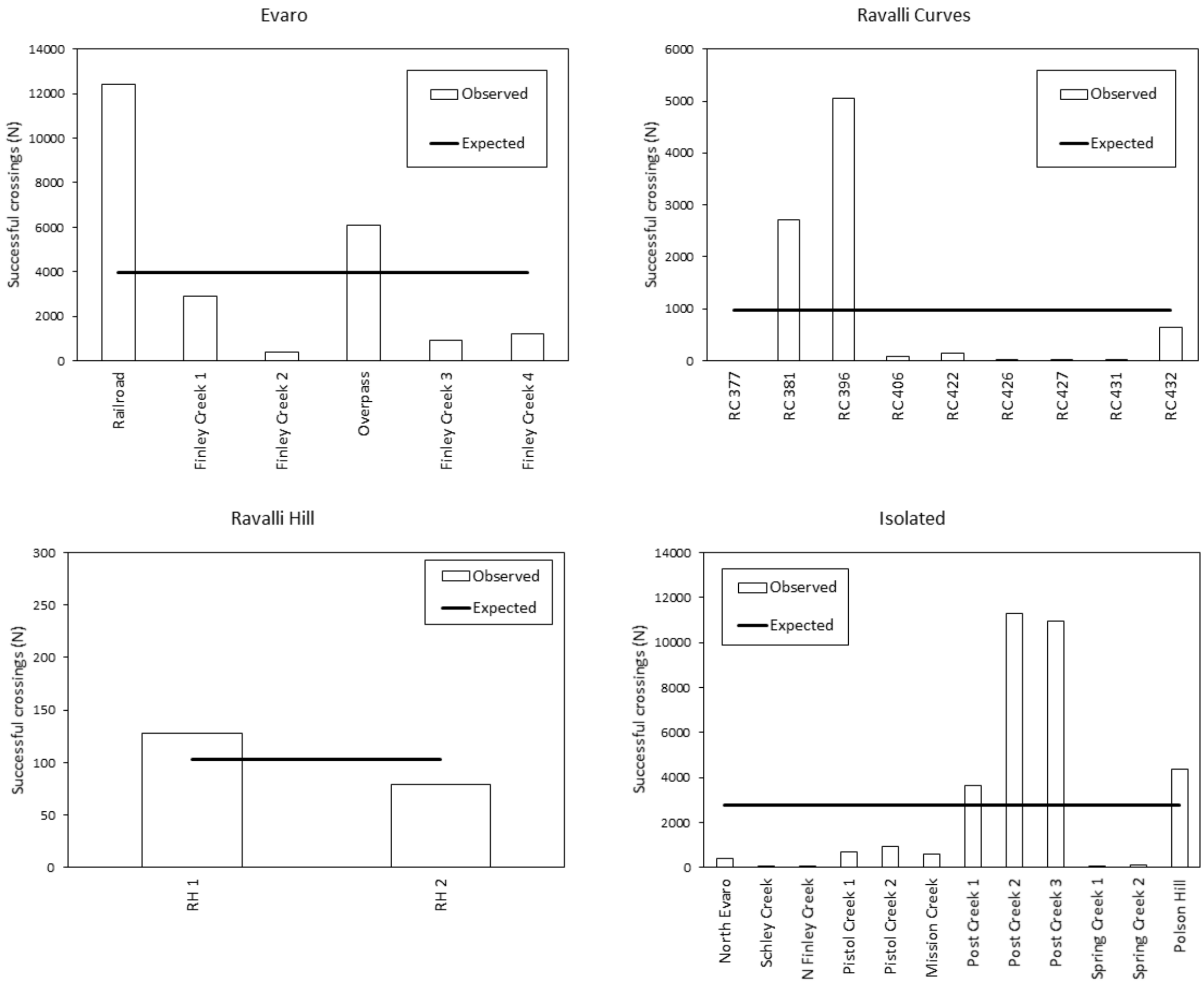

Figure 24: Successful crossings (observed) by white-tailed deer through the crossing structures. The horizontal bars indicate what the expected number of crossings was, should the animals have used each structure equally within each of the four crossing structure groups.

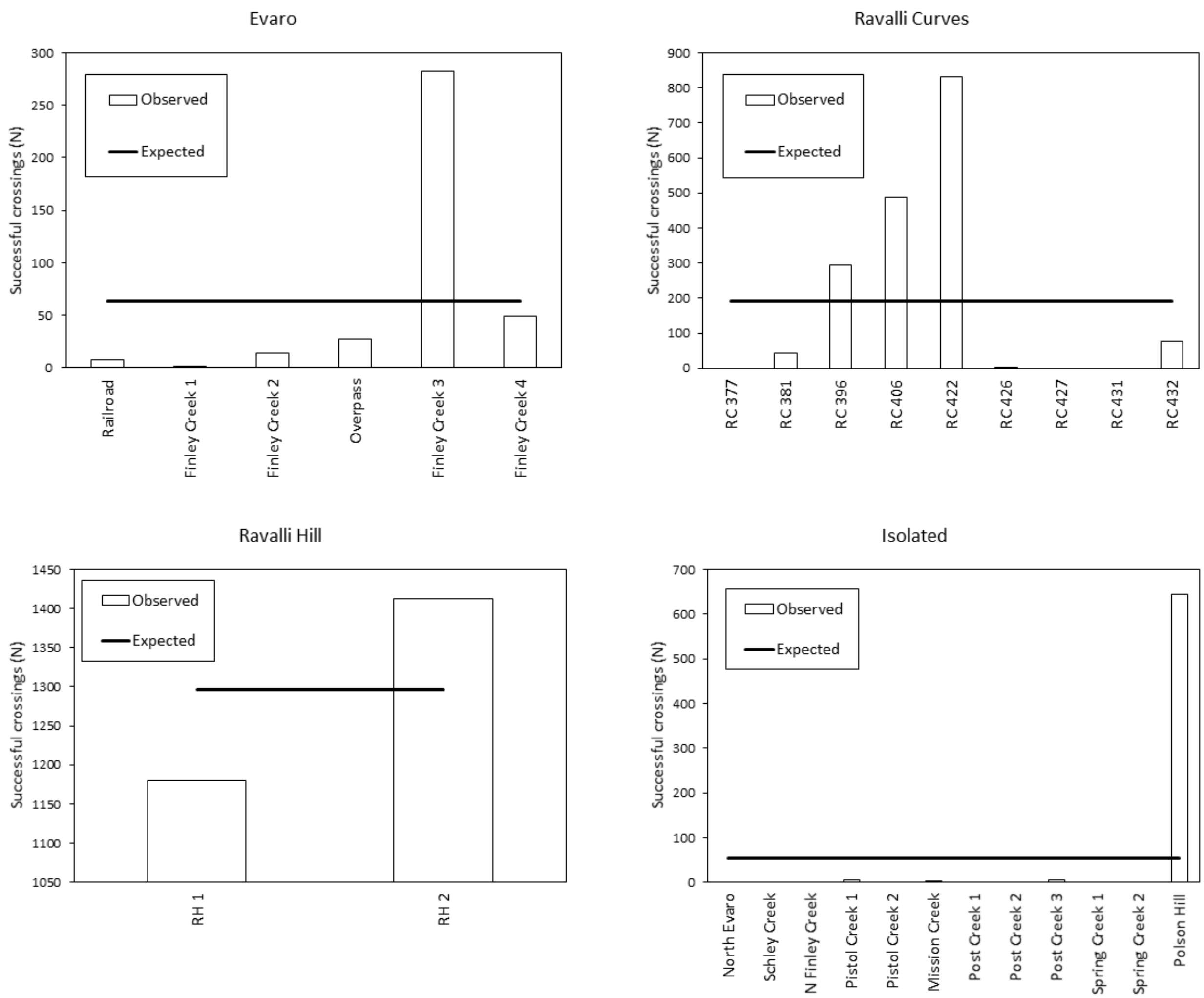

Figure 25: Successful crossings (observed) by mule deer through the crossing structures.
The horizontal bars indicate what the expected number of crossings was, should the animals have used each structure equally within each of the four crossing structure groups.

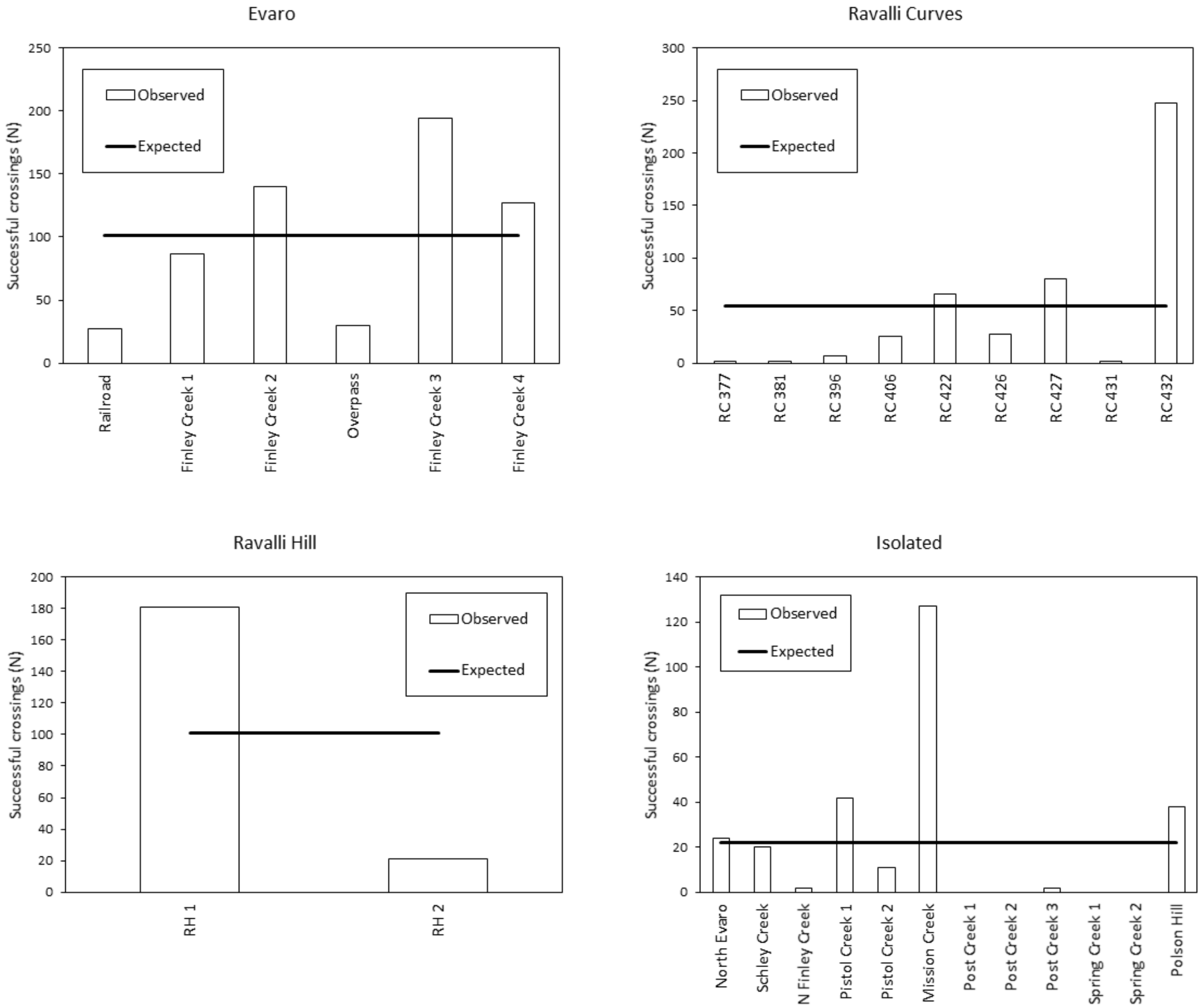

Figure 26: Successful crossings (observed) by black bear through the crossing structures.
The horizontal bars indicate what the expected number of crossings was, should the animals have used each structure equally within each of the four crossing structure groups.

6.3.2. Species of Special Concern

Within the monitoring period there were 29 successful crossings through the structures by grizzly bears (Table 5, Appendix H5 and H6). The large culverts of Post Creek 3 (19 crossings) and Pistol Creek 1 (9 crossings) were used most frequently. Ravalli Hill 2 (large culvert) was used once by grizzly bears.

There were 32 successful crossings by elk (Table 5, Appendices H3 and H5). All but two of the elk crossings were in the Evaro area; mostly on the wildlife overpass (N=24, 75 percent of 32 crossings) and to a lesser degree through two large culverts (Finley Creek 4 (N=5) and Finley Creek 3 (N=1)). There were two additional elk crossings through Ravalli Hill 2. Interestingly, 20 of the 32 crossings occurred in 2015. While there were only three successful moose crossings in the monitoring period, all three moose crossings occurred on the wildlife overpass.

6.3.3. Learning Curve

Deer successfully used the crossing structures in the Evaro, Ravalli Curves and Ravalli Hill areas 4,442 times one year after the structures were completed (Figure 27, Table 7). However, deer use of the crossing structures continued to increase in later years up to 8,048 successful crossings five years after construction (an increase of 81 percent). The number of successful crossings for black bear followed a similar trend: an increase from 200 to 493 (an increase of 147 percent). The learning curve for deer may be close to flattening out whereas the learning curve for black bear showed no indication of flattening out yet after five years. The mean number of deer and black bear crossings per year was 6,293 and 305 respectively.

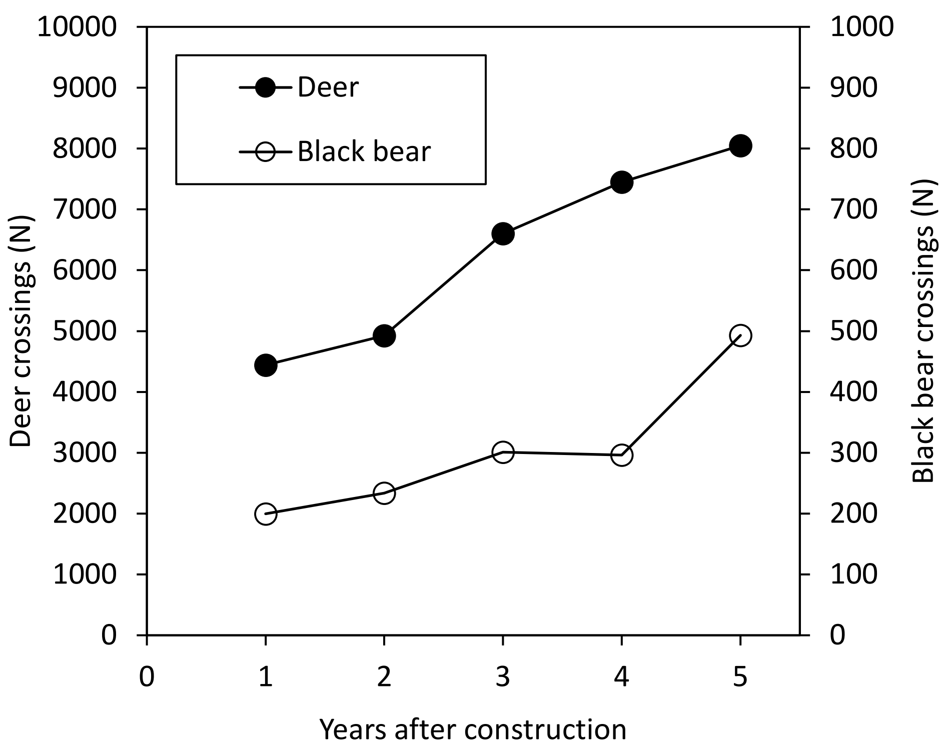

Figure 27: The number of successful crossings by deer (white-tailed deer and mule deer combined) and black bear through the crossing structures in the Evaro, Ravalli Curves and Ravalli Hill areas in relation to the number of years after the crossing structures were constructed.

Table 7: The number of successful crossings by deer and black bear crossing structures in the Evaro, Ravalli Curves and Ravalli Hill areas in relation to the number of years after the crossing structures were constructed.

Years after construction	Deer	Black bear
1	4442	200
2	4925	233
3	6602	301
4	7449	296
5	8048	493
Mean	6293	305
SD	1565.9	113.6

6.4. Discussion and Conclusion

Total wildlife use of the 29 crossing structures that were monitored can be described as substantial with 95,274 successful crossings in total, and 22,648 successful crossings per year. The vast majority of these crossings were by white-tailed deer (69 percent). Mule deer and domestic dogs and cats each represented about 5 percent of the successful crossings. In addition, there were 1,531 successful crossings by black bear.

Depending on the type and dimensions of alternative crossing structures in an area, white-tailed deer can use bridges, overpasses and large culverts more than expected. Small culverts are not or barely used by this species. Mule deer can also use bridges and large culverts more than expected. Similar to white-tailed deer, mule deer do not or barely use small culverts. Black bear can use a wider variety of structures more than expected: bridges, large culverts and small culverts. Grizzly bears exclusively used large culverts. However, within the area known to be used regularly by grizzly bears this is the most common type of structure. Elk and moose mostly or exclusively used the wildlife overpass.

The data showed that there is a learning curve for deer (white-tailed deer and mule deer combined) and black bear for using the wildlife crossing structures. While deer and black bear use can already be considered high one year after construction of the structures, both species showed an increase in successful crossings for at least five years after construction. The learning curve for deer may be close to flattening out whereas the learning curve for black bear showed no indication of flattening out yet after five years. This suggests that wildlife use, specifically by deer and black bear, is likely to continue to grow, even after five years past construction. The presence of a learning curve also indicates that studies that evaluate the number of deer and black bear movements through wildlife crossing structures may reach very different conclusions depending on how long a crossing structure has been in place at the time of monitoring.

7. EFFECTIVENESS OF THE CROSSING STRUCTURES FOR DEER AND BLACK BEAR

7.1. Introduction

This chapter reports on the effectiveness of the crossing structures in passing wildlife along US 93 North. The effectiveness is measured through comparing the number of animals that crossed the highway at grade before the road was reconstructed to the number of animals that crossed the highway through the wildlife crossing structures after construction and the implementation of the wildlife mitigation measures. The analyses were focused on white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*) and black bear (*Ursus americanus*). Furthermore, the analyses related to the three areas with relatively long sections of wildlife fences: Evaro, Ravalli Curves and Ravalli Hill.

7.2. Methods

7.2.1. Sand Tracking Beds and Cameras

Before the highway was reconstructed the researchers estimated the number of deer (white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*) combined) and black bear (*Ursus americanus*) that crossed the highway at grade. The research was conducted in three road sections that would later be mitigated with wildlife fences and wildlife crossing structures (Evaro, Ravalli Curves and Ravalli Hill). After the highway was reconstructed, the researchers measured the number of deer and black bear that crossed the highway using the 17 crossing structures in the same three road sections (see Chapter 1 and 2 for a description of the three fenced highway sections and Appendix A1 and A2 for the crossing structure and wildlife fence characteristics in these three road sections).

The “before” highway crossings were measured through sand tracking beds parallel to the highway (Hardy *et al.* 2007). In the spring of 2003 the researchers installed 38 sand tracking beds (Evaro N=12, Ravalli Curves N=20, Ravalli Hill N= 6). Each sand tracking bed was 328 ft (100 m) long and 6.6 ft (2 m) wide, and they were located about 1.6 ft (0.50 m) from the edge of the pavement. These 38 tracking beds covered about 33 percent of the road length that would later be mitigated with wildlife fences and wildlife crossing structures. The location of the tracking beds within the Evaro, Ravalli Curves and Ravalli Hill areas was randomized based on the 328 ft (100 m) road length units that were specified on the design plans (MDT 2002). The side of the highway (east or west) was also randomized. The sand tracking beds were checked for deer (white-tailed deer and mule deer combined) and black bear tracks once per week (2003) or twice per week (2004 and 2005) (3 years in total). For the purpose of this analysis the researchers only selected the records for which the species or species group identification was "certain". Furthermore, the researchers only selected records that related to a "highway crossing" based on interpretation of the tracks by the researchers. Not all tracking beds were exactly 100 m long. Therefore the researchers corrected the number of deer and black bear crossings observed on the tracking beds and standardized the crossing numbers to 328 ft (100 m) long tracking bed lengths (Hardy *et al.* 2007). The tracking beds were only monitored in the summer months (June through October). Since the start and end dates for the monitoring varied between the three years, the monitoring period was standardized (15 June through 15 October, 122 days). The tracking data were extrapolated to estimate the total number of deer and black bear highway crossings in the Evaro, Ravalli Hill and Ravalli Curves areas combined (Hardy *et al.* 2007). The "before" situation included a railroad bridge in the Evaro area. This bridge was much more narrow (from the animal's perspective) than the new bridge that was constructed in 2009-2010. Cameras were installed on both sides of the railroad tracks in 2002 (24 August 2002 - 9 December 2002) and 2003 (20 May - 4 June 2003) (Hardy *et al.* 2007).

The "after" highway crossings were measured through sand tracking beds and cameras inside underpasses (Allen 2011). The structures in the Ravalli Curves and Ravalli Hill areas were constructed in 2006-2007 whereas the structures in Evaro were constructed in 2009-2010. The crossing structures in the Ravalli Curves (9 structures) and Ravalli Hill (2 structures) areas were monitored through sand tracking beds from 23 May 2008 through 26 February 2010 and wildlife cameras were used from 26 February 2010 through 31 December 2012 (5 years in total). However, one of the 9 structures in the Ravalli Curves area (RC 377) was permanently inundated (about 0.3 m deep standing water). Therefore this structure was monitored with a wildlife camera (Reconyx, PM35), starting in August 2008. The crossing structures in the Evaro area (6 structures) were monitored with cameras from 1 January 2011 through 31 December 2015 (5 years in total). The sand tracking beds were checked for wildlife tracks twice per week (i.e. once every 3-4 days) in the summer (23 May 2008 - 10 October 2008 and 8 May 2009 – 21 Aug 2009), and once per week in the fall, winter and spring. The researchers only selected tracks for which the species was identified as "certain" and tracks that indicated the animals had crossed the tracking bed, and presumably also the structure. The tracking was specifically targeted at deer (*Odocoileus* spp.) and black bear (*Ursus americanus*). For the camera data the researchers only selected records for which the species of the animals involved was identified as "certain" and for which the animals did not turn back through the structure within five minutes.

The monitoring of the pre-and post construction highway crossings by deer and black bear took place in different seasons and used different methods. In order to be able to compare the pre-and post construction wildlife highway crossing data, the researchers only used tracking data and camera data from the period 15 June through 15 October (Appendix I). In addition, correction factors were applied to the tracking data to make them comparable to the camera data (Appendix I). The correction factor was 1.623 for deer and 1.088 for black bear (see Chapter 9 for calculation of the correction factors). The "before data for the railroad bridge in the Evaro area were also standardized to estimate the number of deer and black bear crossings in a 122 day period (15 June – 15 October). These numbers were added to the tracking data for the Evaro area in 2002, 2003 and 2005 (Appendix I).

7.2.2. Analyses

The researchers conducted separate analyses for deer and black bear to investigate potential differences in highway crossings before and after highway reconstruction. The “before” data related to 2003 through 2005 for all three areas (Evaro, Ravalli Curves and Ravalli Hill). The “after” data were based on the first five years after the highway was reconstructed. This meant that the “after” data for the Ravalli Curves and Hill areas related to 2008-2012 and 2011-2015 for the Evaro area. The researchers also conducted analyses without the first two years after highway reconstruction as there was a learning curve for deer and black bear using the crossing structures (see Chapter 6). With these analyses the “after” data for the Ravalli Curves and Hill areas related to 2010-2012 and 2013-2015 for the Evaro area. These most recent 3 years were likely more representative of a “stable” situation after construction of the crossing structures. However, reducing the number of years with “after” data from 5 to 3 did reduce the sample size and thus the power of the analyses. The data were summarized in box plots. The researchers used a two-sided ANOVA to investigate the potential differences in deer and black bear highway crossings before and after highway reconstruction and the associated wildlife fences and crossing structures.

7.3. Results

Based on five years with “after” data, deer highway crossings were not significantly different before and after highway reconstruction and the associated mitigation measures ((ANOVA $F_{1,6}$=5.07, P=0.065) (Figure 28). However, there was a trend towards significance ($P \leq 0.10$) with more deer crossing after highway reconstruction. When the first two years after construction were dropped from the analyses, there were significantly more deer crossing the highway after reconstruction ((ANOVA $F_{1,4}$=35.16, P=0.049) (Figure 28).

Black bear highway crossings were similar before and after highway reconstruction (ANOVA $F_{1,6}$=2.10, P=0.197) (Figure 29). When the first two years after construction were dropped from the analyses, the number of black bear crossings were still similar ((ANOVA $F_{1,4}$=3.41, P=0.139) (Figure 29).

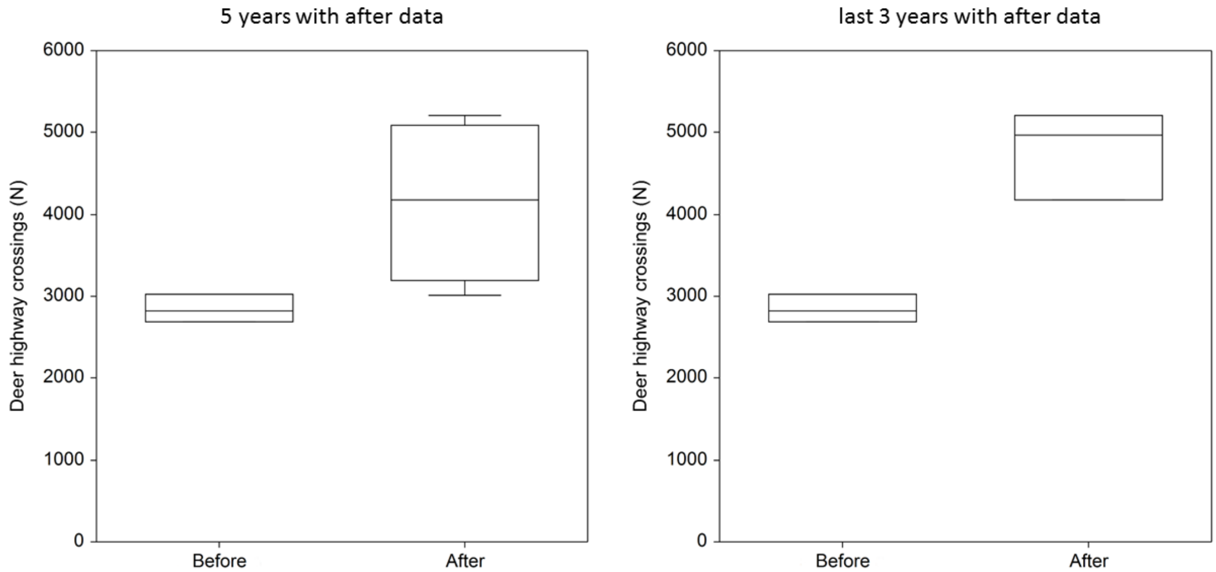

Figure 28: The number of successful highway crossings by deer (white-tailed deer and mule deer combined) before (3 years) and after (3-5 years) highway reconstruction and the implementation of the mitigation measures in the Evaro, Ravalli Curves and Ravalli Hill areas combined.
Left figure: 5 years of "after" data, right figure: 3 years of after data (the most recent 3 years). Box: middle 50% of the data (25–75 quartile); horizontal line: median; whisker boundaries: 1.5 times inter-quartile range; severe outliers: 3.0 times inter-quartile range.

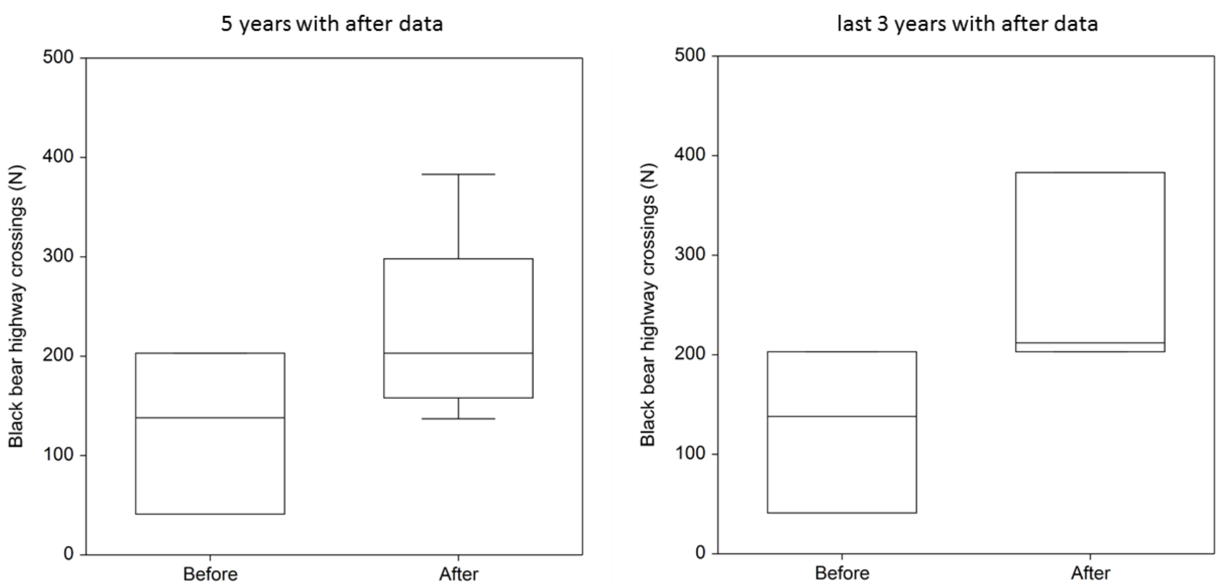

Figure 29: The number of successful highway crossings by black bear before (3 years) and after (3-5 years) highway reconstruction and the implementation of the mitigation measures in the Evaro, Ravalli Curves and Ravalli Hill areas combined.
Left figure: 5 years of "after" data, right figure: 3 years of after data (the most recent 3 years). Box: middle 50% of the data (25–75 quartile); horizontal line: median; whisker boundaries: 1.5 times inter-quartile range; severe outliers: 3.0 times inter-quartile range.

7.4. Discussion and Conclusion

Deer highway crossings either remained similar or increased after highway reconstruction. Black bear highway crossings remained similar after highway reconstruction. Since there was no indication of an increase in deer population size after reconstruction compared to preconstruction (see Chapter 2), the researchers conclude that the highway reconstruction and the associated mitigation measures did not reduce habitat connectivity for deer. Instead, when the learning curve is considered (see Chapter 6), habitat connectivity for deer across the highway increased in the mitigated road sections. The researchers did not have data on potential changes in black bear population size before and after highway reconstruction. Assuming there were no substantial changes in the black bear population size, habitat connectivity for black bear across the highway was at least similar before and after reconstruction in the mitigated road sections.

After highway reconstruction and the implementation of the fences in the Evaro, Ravalli Curves and Ravalli Hill areas, the deer and black bear could no longer cross the highway anywhere. The wildlife fences kept them from accessing the highway and helped guide them towards the wildlife crossing structures. The number of deer and black bear that used the wildlife crossing structures was high enough to compensate for no longer being able to cross the highway anywhere. In addition, the number of deer crossings through the structures was higher than the number of at-grade crossings before highway reconstruction, presumably because the animals learn about the location of the structures, that it is safe to use them, and that they do not expose them to vehicles.

8. WILDLIFE USE OF CROSSING STRUCTURE WITH NO OR VERY SHORT FENCES

8.1. Introduction

Wildlife fences in combination with wildlife crossing structures is commonly regarded as the most effective and robust strategy to reduce wildlife-vehicle collisions while also maintaining connectivity across highways for wildlife (review in Huijser *et al.* 2009b). If wildlife fences and crossing structures are designed based on the requirements of the target species, if the road length fenced is at least 3.1 mi (5km) long, and if the fences and structures are implemented and maintained correctly, the measures can reduce large mammal-vehicle collisions by more than 80 percent (see Chapter 3, Huijser *et al.* 2016). In addition, the number of animal movements across overpasses or through underpasses, as well as the percentage of animals out of a local population that use the structures, can be substantial (Clevenger and Waltho 2000, Sawaya *et al.* 2013, Sawyer *et al.* 2012).

Despite the benefits described above, implementing wildlife fences, wildlife crossing structures and associated measures can be a contentious issue. Wildlife fences for large ungulates are typically 8 ft (2.4 m) high and can affect landscape aesthetics (Evans and Wood 1980). In addition, some landowners may also object to associated measures such as gates, wildlife guards, or similar measures at access roads as they may be time consuming or unpleasant to drive across. Furthermore, despite the wildlife crossing structures that may be present, fences are sometimes a problem for wide ranging large mammal species such as mule deer (*Odocoileus hemionus*) and pronghorn (*Antilocapra americana*) (Coe *et al.* 2015, Poor *et al.* 2012, Seidler *et al.* 2015). They can even be a source of injury and direct mortality for the animals (Jones 2014). Finally, transportation agencies as well as the public may perceive wildlife fences and associated measures as relatively expensive to construct and maintain.

Because of the issues described above, highway managers tend to minimize the length of wildlife fences associated with wildlife crossing structures (Ascensão *et al.* 2013, Ford *et al.* 2011, van Manen *et al.* 2012). Sometimes crossing structures are not accompanied by wildlife fences at all. This occurs especially in multifunctional landscapes where fences, mitigation at access roads, and wildlife crossing structures are more likely to conflict with other land uses. However, even with short fenced road sections, planners and designers need to know how long the mitigated zone should be in order to obtain a substantial reduction in wildlife-vehicle collisions and, as a consequence, a substantial improvement in human safety (Rytwinski *et al.* 2015). They also need to know if wildlife fences are required or how long the fences should be in order to help guide wildlife to designated crossing structures rather than have them cross at grade on the road surface (Rytwinski *et al.* 2015). Partly based on data from the US 93 North study, the researchers found that large mammal-vehicle collisions can be reduced by 80 percent or more if the road length fenced is at least 3.1 mi (5 km) (see Chapter 3). This chapter investigates whether longer sections of wildlife fence are associated with higher use of wildlife crossing structures by large mammals. The researchers were specifically interested if the use of isolated underpasses with no or very short fences (up to a few hundred meters) was similar to that of underpasses with longer sections of fences (up to several kilometers).

8.2. Methods

The researchers measured large mammal use of underpasses with no or very short fences and compared the use to that of underpasses that were associated with longer sections of wildlife fences (up to a few kilometers). The researchers selected 22 underpasses along US 93 North on the Flathead Indian Reservation (Table 8). All underpasses had dimensions considered suitable for large mammals including ungulates; they included small bridges and large culverts (Appendix A1). The underpasses were constructed between 2005 and 2010 (age during the time this research was conducted was 1-10 years). The fenced road length associated with the underpasses varied between 0.0-3.8 mi (0.0-6.1 km) (Appendix A1 and A2), and fence height was 8 ft (2.4 m). The researchers placed wildlife cameras (Reconyx Hyperfire PC900) at the entrances of the 22 underpasses and kept them, depending on the site, in operation for 3-5 years between 1 January 2010 and 31 December 2015). For underpasses wider than 39.4 ft (12 m) the researchers used multiple cameras as the maximum range of the cameras at night (with infrared flash IR flash) was about 39.4 ft (12 m). The researchers analyzed the images and counted the number of large mammals (deer size and larger) that used the underpasses to access the other side of the highway. The crossing data only related to successful crossings. Events where animals entered the underpass but turned around within 5 minutes were not included in the analyses.

The researchers categorized the 22 underpasses in three groups: no or very short fences (0.00-0.25 mi (0.0-0.4 km) mitigated road length, 10 isolated underpasses with fence not connected to other structures), several kilometers of fences (0.87-1.68 mi (1.4-2.7 km), 7 underpasses with fence typically connected to other structures), and about 6 kilometers of fences (3.79-3.85 mi (6.1-6.2 km), 5 underpasses with fence always connected to other structures) (Appendix A1 and A2). For each underpass the researchers calculated the number of successful large mammal crossings per year. The number of large mammal crossings per year was summarized in a box plot for each of the three fence length categories.

Table 8: The 22 wildlife crossing structures and the road length fenced at the structures.

Structure	Road length fenced (mi)	Road length fenced (km)
Finley Creek 1	1.67	2.69
Finley Creek 2	1.67	2.69
Finley Creek 3	1.67	2.69
Finley Creek 4	1.67	2.69
RC 381	3.74	6.02
RC 396	3.74	6.02
RC 406	3.74	6.02
RC 422	3.74	6.02
RC 432	3.74	6.02
RH 1	1.09	1.75
RH 2	1.09	1.75
North Evaro	0.00	0.00
N Finley Creek	0.00	0.00
Pistol Creek 1	0.00	0.00
Pistol Creek 2	0.00	0.00
Mission creek	0.22	0.35
Post Creek 1	0.07	0.11
Post Creek 2	0.07	0.11
Post Creek 3	0.11	0.18
Spring Creek 1	0.15	0.24
Spring Creek 2	0.09	0.14
Polson Hill	0.87	1.40

8.3. Results

The number of large mammal crossings through the underpasses varied greatly between the individual structures, regardless of the length of the fenced road section (Figure 30). There was no indication that the number of large mammals that used the isolated underpasses with no or very short fences (0.00-0.25 mi (0.0-0.4 km)) was consistently different from underpasses associated with longer fenced road sections (0.87-1.68 mi (1.4-2.7 km) or (3.79-3.85 mi (6.1-6.2 km)) (Figure 30).

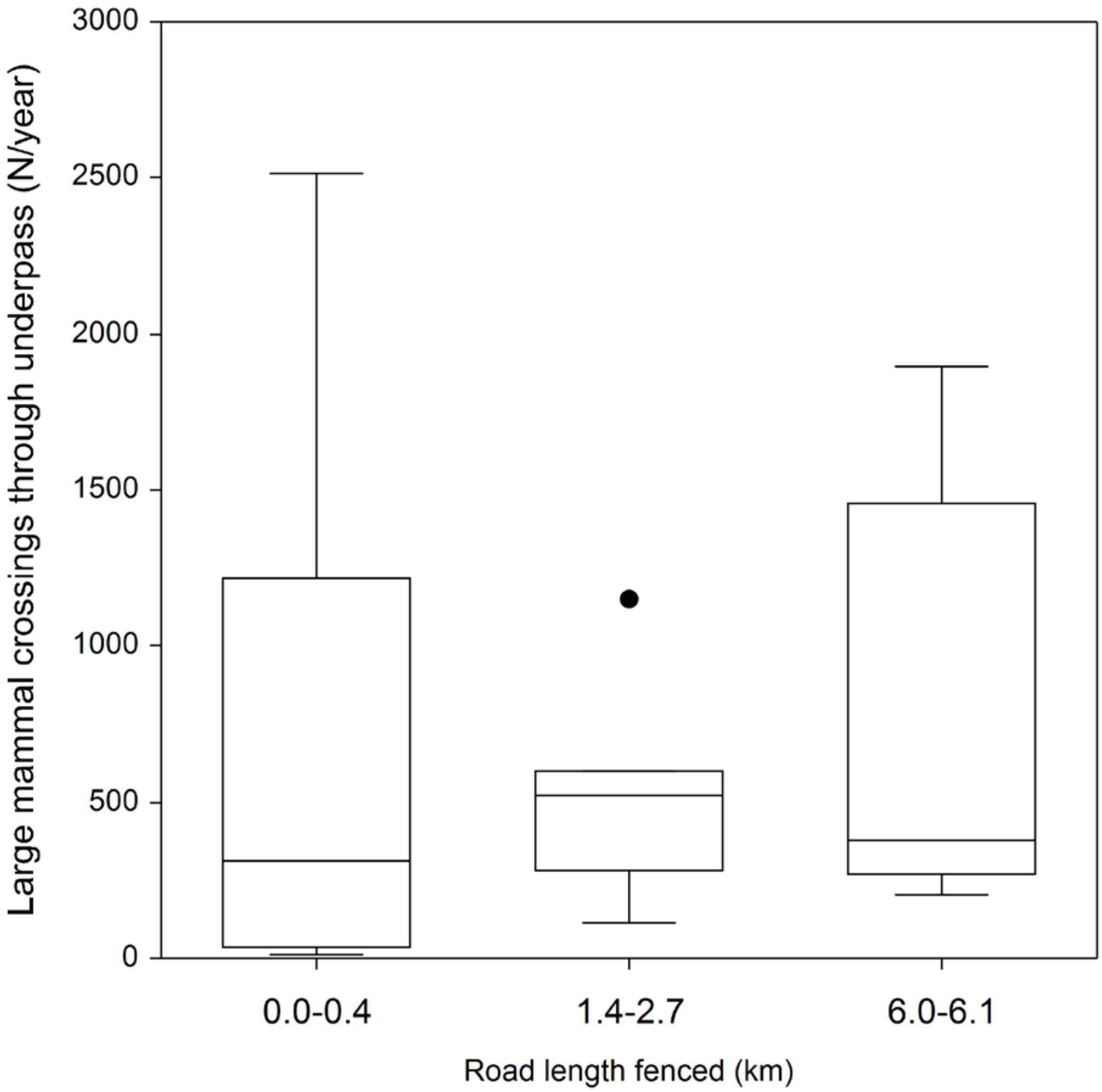

Figure 30: Box plot of the number of large mammal crossings through the 22 underpasses per year. The underpasses were divided into three categories based on the fenced road length associated with the underpasses. Box: middle 50% of the data (25–75 quartile); horizontal line: median; whisker boundaries: 1.5 times inter-quartile range; severe outliers: 3.0 times inter-quartile range.

8.4. Discussion and Conclusion

The data showed that large mammal use of underpasses designed for large mammals varied greatly between the structures. The use was similar for isolated structures with no or limited fences, structures connected to a few kilometers of fences, and structures connected to more than 3.8 mi (6 km) of fences. The data showed that the presence of wildlife fences and longer fence lengths did not necessarily guarantee higher wildlife use. Similarly, the absence of fences or the presence of very short sections of fences did not always result in low use of an underpass by large mammals. This suggests that large mammal use of underpasses is heavily influenced by other factors. These factors likely include the location of the structure in relation to the surrounding habitat, wildlife population density, and wildlife movements.

The findings may seem to contradict other studies that clearly showed that connecting crossing structures to wildlife fences can result in a very substantial increase in wildlife use (Dodd *et al.* 2007a, Gagnon *et al.* 2010). However, while the data in this chapter showed great variability in wildlife use of underpasses regardless of the presence and length of wildlife fences, the data do not necessarily contradict studies that showed the importance of fences. Along US 93 North the presence or length of wildlife fences at the structures was not manipulated. The US 93 North data relate to a comparison of large mammal use of different structures that happened to have or not have wildlife fences. In contrast, Dodd *et al.* (2007a) and Gagnon *et al.* (2010) were able to record wildlife use of crossing structures both before and after wildlife fences were installed and connected to particular structures. Thus, while wildlife use of underpasses is highly variable, probably mainly because of differences between locations, an individual underpass may still have higher wildlife use if that underpass is connected to wildlife fences and if the fence length is long rather than short.

9. DETECTION PROBABILITY OF DEER AND BLACK BEAR THROUGH TRACKING AND WILDLIFE CAMERAS ALONG HIGHWAYS AND AT UNDERPASSES

9.1. Introduction

Different sections of US 93 North on the Flathead Indian Reservation were reconstructed between 2005 and 2010. Wildlife fences and wildlife crossing structures were installed along some of the road sections. A research project was initiated to answer several questions. One of the questions was whether the reconstruction and associated wildlife mitigation measures resulted in a change in the number of deer (white-tailed deer (*Odocoileus virginianus*) and mule deer (*O. hemionus*) combined) and black bear (*Ursus americanus*) that crossed the highway successfully (Chapter 7). The research methods used were different before and after highway reconstruction. Before highway reconstruction, wildlife crossings were measured through sand tracking beds in the right-of-way, immediately adjacent to the pavement (2003 through 2005) (Hardy *et al.* 2007). After highway reconstruction and the implementation of the mitigation measures, wildlife crossings were measured though sand tracking beds inside underpasses (2008 and 2009) (Allen 2011) and also through wildlife cameras (2010 and beyond). An important advantage of wildlife cameras is that wildlife can be detected throughout the year whereas sand tracking beds that are exposed to the elements can only be used during the summer months when the substrate is not frozen (Ford *et al.* 2009). Furthermore, cameras allow for more reliable species identification, they provide insight into the behavior of animals at and in the immediate vicinity of the crossing structures, and they are better able to detect relatively small species, especially if tracking occurs in coarse substrate (Mateus *et al.* 2011, Gužvica *et al.* 2014). If the entire substrate consists of marble dust, or if fine substrate is mixed with silt or loam, mammal tracking can be very effective (Mata *et al.* 2008, Gužvica *et al.* 2014). However, implementing fine substrate in large volume and applying it outside of underpasses where it is exposed to the elements is less practical and quite costly. Finally, cameras can be more economical for multiple year studies and when a high number of wildlife events is expected (Ford *et al.* 2009, Gužvica *et al.* 2014).

The researchers used three different methods to detect deer and black bear crossings for the US 93 North study: 1. Sand tracking beds that are exposed to the elements (in the right-of-way adjacent to the pavement); 2. Sand tracking beds that are sheltered from some of the elements (inside underpasses); and 3. Wildlife cameras (inside underpasses and outside at the entrance of the crossing structures). It is very likely that a correction factor is required to make the highway crossings recorded through the different methods comparable to one another (see e.g. Ford *et al.* 2009, Mateus *et al.* 2011, Gužvica *et al.* 2014). This chapter reports on the correction factors required to make data obtained from sand tracking beds comparable to data obtained from wildlife cameras.

9.2. Methods

9.2.1. Study Locations

The researchers selected four wildlife underpasses that had a relatively high number of deer and black bear crossings (based on Huijser *et al.* 2011) (Table 9). One of the underpasses (RH459) had a wildlife camera and a sand tracking bed inside (protected from most of the elements), two (RC396 and RC427) had wildlife cameras and sand tracking bed outside the structure (exposed to the elements), and one (RC432) had – at different times - wildlife cameras and sand tracking beds both inside and an outside the underpass (Table 9). All but one of the cameras were pointed directly over the corresponding tracking bed. However, the camera inside the RH459 underpass was turned at a 45° angle which excluded the tracking bed from view. Table 9 summarizes which underpasses and which tracking beds and cameras (inside underpass or outside underpass) were in operation during which time periods.

Table 9: The underpasses, their locations and dimensions, and the time periods they were sampled for deer and black bear crossings.

Underpass name and location (latitude, longitude)	Crossing structure type and dimensions from animal's perspective (Height-Width-Length)	Tracking bed and camera inside structure	Tracking bed and camera outside structure
RC396 47°14'17.80"N 114° 9'39.88"W	Corrugated elliptical culvert with dirt on floor (3.7-6.7-18.4 m)		31 Aug 2010 - 29 Oct 2010 24 May 2011 - 25 Oct 2011
RC427 47°15'44.52"N 114°10'9.69"W	Corrugated elliptical culvert with dirt on floor (1.5-1.9-1.8 m)		31 Aug 2010 - 29 Oct 2010 24 May 2011 - 25 Oct 2011
RC432 (Copper Creek) 47°15'54.96"N 114°10'22.65"W	Corrugated elliptical culvert with dirt on floor (3.5-7.7-18.4 m)	31 Aug 2010 - 22 Sep 2010	22 Sep 2010 - 29 Oct 2010 24 May 2011 - 25 Oct 2011
RH459 (Ravalli Hill 1) 47°17'7.80"N 114°10'42.70"W	Corrugated elliptical culvert with dirt on floor (5.2-7.4-33.6 m)	14 Sep 2010 - 29 Oct 2010* 24 May 2011 - 25 Oct 2011*	

*Camera angled away from tracking bed rather than in line with tracking bed

9.2.2. Tracking

The tracking beds consisted of sandy material: 7 parts sand, 1 part 1/8 inch (0.32 cm) crushed aggregate material (consistent with the pre-construction sand tracking beds (Hardy *et al.* 2007)). The beds were about 6.6 ft (2 m) wide and spanned the width of an underpass (for inside tracking beds) or the area between the fences that funneled wildlife to an underpasses (for outside tracking beds). The tracking beds were checked, inside and outside the underpasses twice per week (3-4 day interval in the summer season between May and October), similar to the frequency for the pre-construction tracking beds along the highway (Hardy *et al.* 2007) and the post-construction tracking beds inside the underpasses in 2008 and 2009 (Allen 2011). The crossing structures were visited 52 times during the late summer season in 2010 and during the summer season of 2011. Tracks of deer (white-tailed deer and mule deer combined) and black bear were recorded and categorized as “crossing the tracking bed” (and presumably the structure and thus the highway) versus “not crossing the tracking bed” (and presumably not crossing the underpass and the highway). For data obtained from the sand tracking beds there was no distinction between a “crossing of the sand tracking bed” and a “highway crossing through the associated underpass”.

9.2.3. Wildlife Cameras

The wildlife cameras (RECONYX™, Inc., models PM35 and PC900) were checked once a month. Each month the memory cards were changed and once every three months the batteries (AA Energizer® Ultimate Lithium) were replaced. The images were interpreted and the following parameters were recorded: day, time, species, whether the individual(s) crossed the sand tracking bed, and whether the individual(s) crossed the highway through the underpass. Crossings of the sand tracking bed were slightly different from highway crossings through the underpasses. To be classified as a highway crossing through an underpass the individual(s) concerned needed to display movements that indicated the animals were indeed using the underpass to cross the highway, and the individual(s) concerned were not allowed to return within 5 minutes. If the animals did return within 5 minutes it was not considered a highway crossing. In contrast, the same animal movements with the animals returning within 5 minutes would have resulted in two crossings of the tracking bed as observed by the same camera. Thus highway crossings through an underpass are by definition more conservative than crossings of the tracking bed, all observed by the same wildlife camera.

9.2.4. Correction Factor for Sand Tracking Beds

Reconyx cameras are known to have a relatively fast response time (TrailCamPro, 2015). Cameras with a fast response time appear to be far more accurate in detecting deer (*Odocoileus* spp.) than sand tracking beds (Ford *et al.* 2009). Black bear appear to be equally likely to be detected by these types of wildlife cameras versus through sand tracking beds, though the checking of the tracking beds may have to occur every other day (Ford *et al.* 2009). However, given the 3-4 day interval between checks of the sand tracking beds, wildlife cameras may be more accurate, even for black bear, as tracks deteriorate and are more likely to be covered by new tracks if the interval for checking the tacking beds exceeds two days (Mateus *et al.* 2011). For these reasons, the correction factors were investigated for the tracking bed data rather than the correction factors for the wildlife cameras. In this case there were both tracking beds outside of the underpasses along the roadway (similar to the “before” data from 2003 through 2005) and tracking beds inside the underpasses (similar to the “after” data from 2008 and 2009). Thus separate correction factors were calculated for the “inside” and “outside” tracking beds as well as for the two species (“deer” and black bear). Since sand tracking beds outside the structures were more exposed to the elements (e.g. rain, wind) than the sand tracking beds inside the underpasses, the sand tracking beds inside underpasses were expected to retain tracks better than the outside sand tracking beds.

All highway crossings of deer and black bear were tallied for the inside tracking beds and for the outside tracking beds that were detected during 52 visits by the researches to the underpasses. In addition all highway crossings observed by the wildlife cameras were tallied for the same time period. The correction factor for the data obtained from the tracking beds was calculated as:

$$\text{Correction factor} = \frac{\text{Highway crossings observed by cameras}}{\text{Highway crossings observed on tracking beds}}$$

The researchers then proceeded to investigate how stable the correction factors were through calculating and then plotting the correction factors after each of the 52 visits to the underpasses by the researchers. As more and more data were already present (previous visits) each additional visit was less likely to result in a substantial change of a correction factor; the correction factor can be expected to become more stable over time.

9.2.5. Detection Probability of Deer and Black Bear Based on Tracking and Cameras

The researchers summarized the number of outside tracking bed crossings by deer and by black bear based on tracking data for each visit. Similarly the researchers summarized the number of outside tracking bed crossings by deer and by black bear based on the camera data for each visit. This allowed for a pairwise comparison (Wilcoxon matched pairs - signs ranks test) of crossings of the outside tracking beds based on tracking and based on the cameras. The researchers only included data pairs for which at least one of the data collection methods detected at least one deer or at least one black bear. If no deer or black bear were detected at all, the data pair was excluded from the analysis. Based on Ford *et al.* (2009) the researchers hypothesized that if there was a difference in the number of tracking bed crossings based on tracking versus data obtained from the cameras, cameras would likely detect more animals and thus more crossings (one-sided test). The researchers were not able to conduct this test for deer for the inside tracking beds as the camera in underpass RH459 was not in line with the sand tracking bed, and the inside tracking bed and camera at underpass RC432 was only installed for a short period during which only 3 data pairs were generated for black bear.

9.3. Results

9.3.1. Correction Factor for Sand Tracking Beds

The cameras detected substantially more highway crossings by deer than both the inside tracking beds and outside tracking beds (Figure 31). However, the number of highway crossings detected for black bear were quite similar between the tracking beds and the cameras (Figure 31). Since different structures generated different data, the number of highway crossings detected by the inside and outside tracking beds should not be compared.

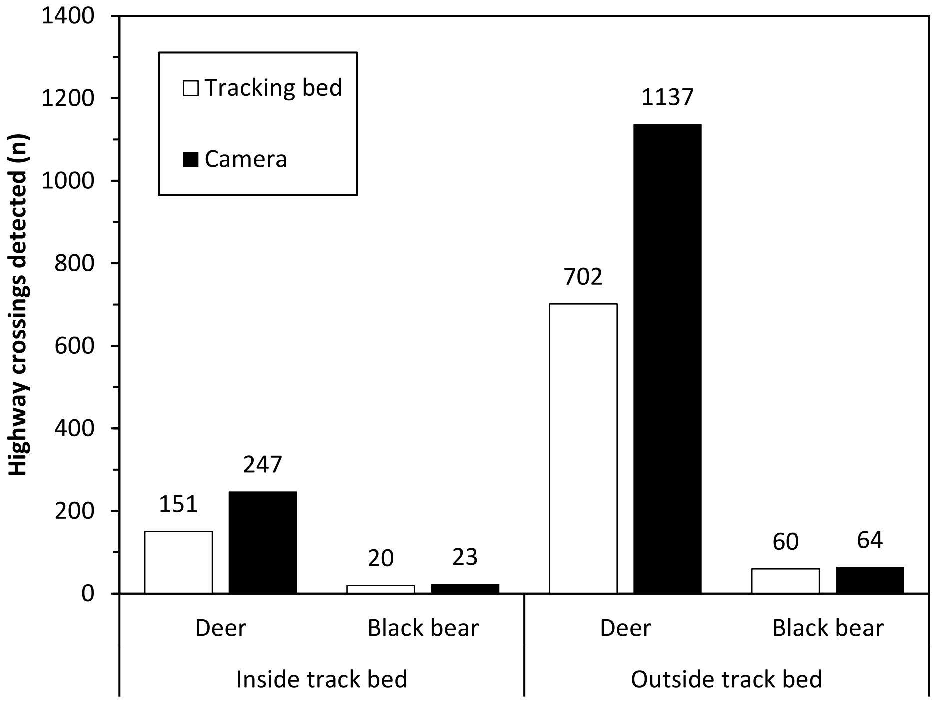

Figure 31: The number of deer and black bear highway crossings based on tracking data from the tracking beds (inside and outside the underpasses) versus highway crossings based on data obtained from the cameras.

The data were used to calculate correction factors required to make the number of highway crossings based on tracks from the sand tracking beds comparable to the number of highway crossings obtained from the cameras (Table 10). The correction factors for the sand tracking beds were very different for deer (1.623) and black bear (1.088) but quite similar for tracking beds inside and outside the structures (Table 10).

Table 10: The correction factors for the sand tracking beds required to make the number of highway crossings based on tracks from the sand tracking beds comparable to the number of highway crossings obtained from the cameras.

Location tracking bed and camera	Deer (*Odocoileus* spp.)	Black bear (*Ursus americanus*)
Inside structure	1.636	1.150
Outside structure	1.620	1.067
Inside and outside combined	1.623	1.088

The correction factor for deer appears to have reached stability after about 20 visits by the researchers to the underpasses and associated recording of tracks and camera data (Figure 32). The correction factor for the inside and outside tracking beds was very similar with almost complete overlap of the confidence intervals, suggesting that there was no reason to use different correction factors for the inside and outside tracking beds.

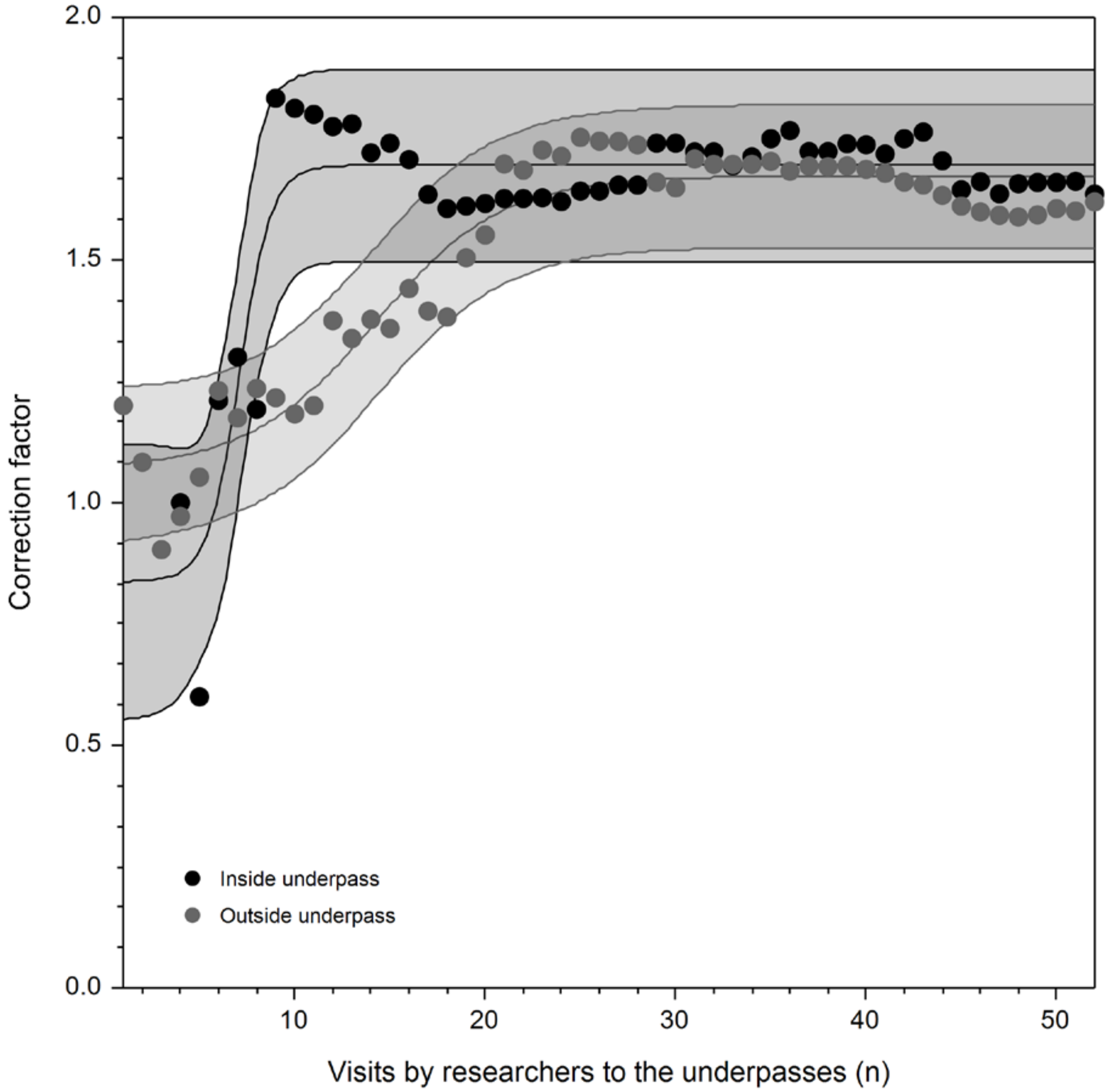

Figure 32: The stability of the correction factor for deer for the sand tracking beds inside and outside underpasses required to make the number of highway crossings based on tracks from the sand tracking beds comparable to the number of highway crossings obtained from the cameras.
The curves (lines) were fitted based on a logistic regression with associated 95% confidence interval (grey areas).

The correction factor for black bear appears to have reached stability at different levels at different times (Figure 33). However, the "early" stability levels are mostly because black bears primarily used the underpasses in September and October and only occasionally earlier in the season. During spring and summer very few - if any - new data were added which resulted in a seemingly stable correction factor. Nonetheless, after about 43-48 visits by the researchers to the underpasses associated data recording stability was obtained once again (Figure 33). This time the correction factors for the inside and outside tracking beds were very similar with substantial overlap of the 95 percent confidence intervals, suggesting that there was no reason to use different correction factors for the inside and outside tracking beds.

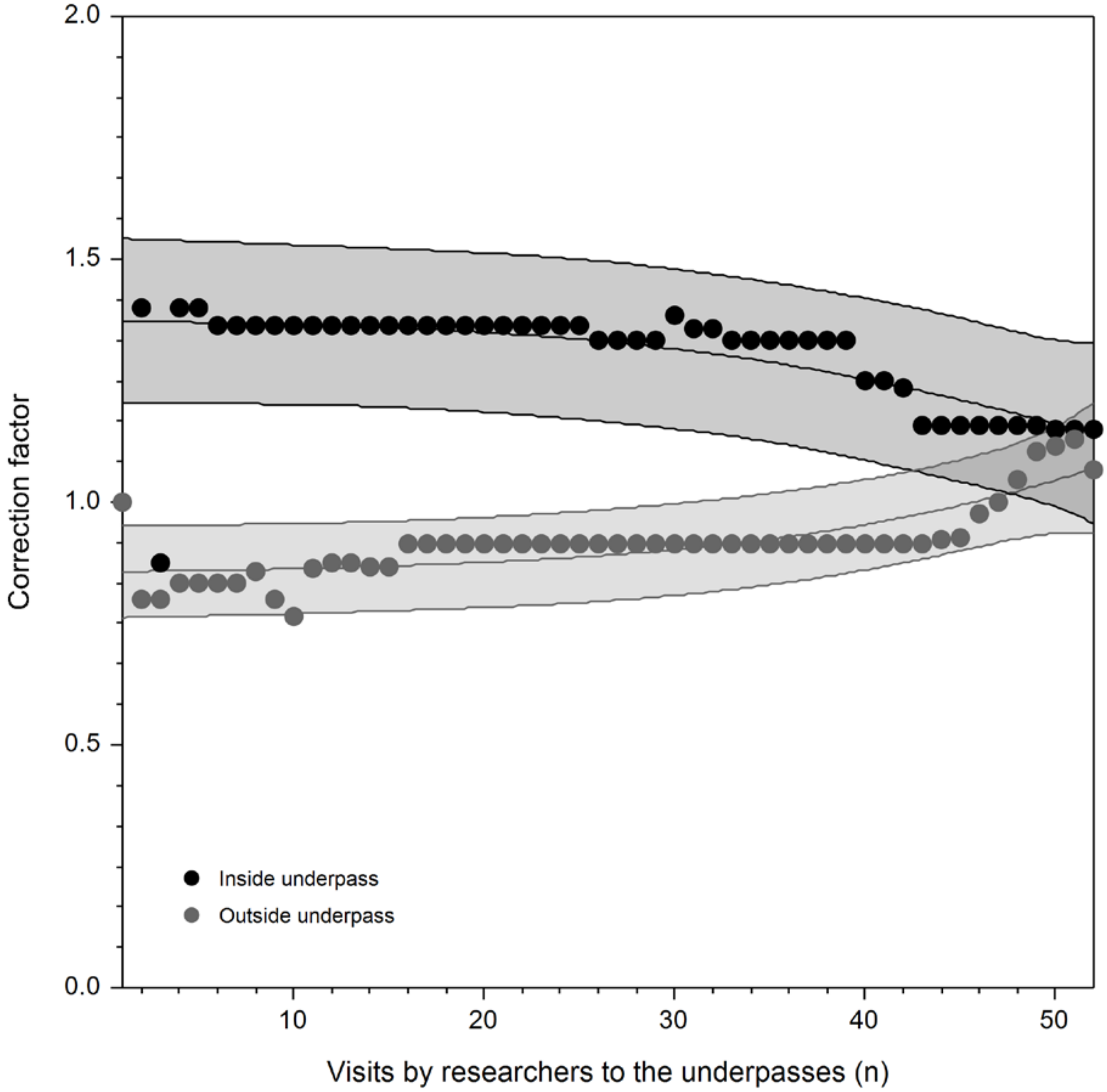

Figure 33: The stability of the correction factor for black bear for the sand tracking beds inside and outside underpasses required to make the number of highway crossings based on tracks from the sand tracking beds comparable to the number of highway crossings obtained from the cameras.
The curves (lines) were fitted based on a logistic regression with associated 95% confidence interval (grey areas).

9.3.2. Detection Probability of Deer and Black Bear Based on Tracking and Cameras

The average number of deer that was observed crossing the outside tracking beds between visits by the researchers was much higher based on data from the cameras (mean = 21.61, SD=14.30) than based on the tracking data (mean = 12.74, SD=7.19) (Wilcoxon matched pairs - signs ranks test, one-sided, $Z = -5.632$, $P<0.001$, $N=54$). However, the average number of black bear that were observed crossing the outside tracking beds between visits by the researchers was similar for the camera data (2.13, SD = 1.57) and the tracking data (1.94, SD = 1.48) (Wilcoxon matched pairs - signs ranks test, one-sided, $Z = -1.202$, $P=0.115$, $N=31$). Interestingly, the correction factor that would have to be applied to the number of track bed crossings based on tracking data (deer $N_{total} = 688$; black bear $N_{total} = 60$) to make them match the number of crossings of the tracking bed based on cameras (deer $N_{total} = 1167$; black bear $N_{total} = 66$) was very similar to that for highway crossings (correction factor deer = 1.696; correction factor black bear = 1.110). In other words, the number of highway crossings based on the cameras was very similar to the number of tracking bed crossings based on the cameras. Furthermore, if the researchers assume the cameras did not miss any deer crossing the tracking beds, the tracking data only detected 58.96 percent of the deer that crossed the outside tracking beds, but the tracking data detected 90.09 percent of the black bear that crossed the outside tracking beds.

9.4. Discussion and Conclusion

Wildlife cameras detected about 62 percent more deer highway crossings through underpasses than tracking on sand tracking beds. This was far less pronounced for black bears (about 9 percent). The correction factor for deer was very stable suggesting that the likelihood for a substantial error in translating highway crossings based on tracking bed data to highway crossings based on camera data is very low. The correction factor for black bear also appears to have reached stability, though it took much longer than for deer. This is likely related to the fact that black bear highway crossings were much rarer than deer highway crossings and it is much harder to reach stability with small sample sizes. The "early" stability levels are related to the fact that the vast majority of the black bear crossings occurred in the fall. Since there were no or very few black bear crossings between May and August there were no or only very small changes in the correction factor resulting in "false stability levels". However, as soon as additional black bear data were obtained in September and October the correction factors changed substantially.

Interestingly there was no reason to assume that the correction factors for inside tracking beds were different from those for outside tracking beds; not for deer and not for black bear. This suggests that the primary concern is that the number of crossings on tracking beds are underestimated by the researchers and that the protection of the sand tracking beds from the elements inside underpasses does not noticeably improve the retention of the tracks on the tracking beds compared to tracks on tracking beds outside of the underpasses that were exposed to the elements. It appears that the loose texture of the sand and tracks falling in on themselves was more important than exposure to wind or rain.

The correction factor for deer (1.62 for highway crossings, 1.70 for crossings of the sand tracking bed) was much higher than for black bear (1.09 for highway crossings, 1.11 for crossings of the sand tracking bed). This is consistent with the findings in another study where the correction factor for deer was 1.37 and for black bear 1.05 (Ford *et al.* 2009). It appears that common large ungulates that travel through crossing structures (and across tracking beds) in relatively high numbers (in this study on average 21.64 deer in 3-4 days (excluding observations with no deer tracks)) and potentially also in relatively large groups, are more likely to step on and obscure previous tracks than less common species with distinctly different tracks that are less likely to “fall in on themselves”, and that use the underpasses and cross the associated tracking beds less frequently in smaller groups (in this study on average 2.13 black bear in 3-4 days (excluding observations with no black bear tracks)). Apparently researchers are especially likely to underestimate the number of tracks from common large ungulates and this difference was shown to be significant based on the tests as well as the one conducted by Ford *et al.* (2009). This bias appears to increase with longer intervals between visits to the tracking beds by the researchers; deer in this study had a substantially higher correction factor (1.62 or 1.70) with 3-4 days between visits than in a study with only 2 days between visits (correction factor 1.37) (Ford *et al.* 2009). For black bear the increase in bias was much less pronounced and perhaps not really different at all (correction factor 1.09 or 1.11 versus 1.05) according to the tests conducted along US 93 North and Ford *et al.* (2009).

10. WILDLIFE GUARDS

10.1. Introduction

Wildlife fences can be very effective in keeping large wild mammals from accessing the road corridor and can therefore reduce wildlife-vehicle collisions substantially (See Chapter 1 and 2). However, in multi-functional landscapes access roads are required resulting in gaps in the wildlife fences. In order to reduce the probability of wildlife accessing the fenced road corridor through these gaps, road managers have provided gates, wildlife guards (similar to cattle guards) or electric mats (Peterson *et al.* 2003, Huijser *et al.* 2015). In this chapter the researchers report on the effectiveness of wildlife guards in keeping large wild mammals from accessing the fenced road corridor.

10.2. Methods

The researchers installed wildlife cameras at four wildlife guards (Table 11). The design of the guards is described by Allen (2011) and Allen *et al.* (2013). Camera images showing wildlife were reviewed and classified as a full crossing of the wildlife guard (either entering or leaving the fenced road corridor) or as presence without crossing the wildlife guard (either on the safe side of the wildlife fence or on the highway side). Because the cameras were situated to the side of the wildlife guards and slightly facing the safe side of the wildlife guard, animals that were present on the highway side were rarely recorded. In addition, the researchers recorded whether an animal that crossed, walked on a concrete ledge around the guard (the walls for the pit under the metal grate) rather than on the metal grate itself. The N and S guards were equipped with a feature designed to reduce the probability that animals bypassed the metal bridge grate (i.e. the wildlife guard) by walking on a concrete ledge between the grate and the sections of wildlife fence installed perpendicular to the highway. The feature consisted of wildlife fence that "bulbed-out" on the right-of-way side of the wildlife guards. The feature is referred to as a "bulb-out".

Table 11: The four wildlife guards that were monitored for their permeability to wildlife.

Wildlife guard	Coordinates	Start monitoring	End monitoring
N Guard	47°15'57.15"N, 114°10'23.97"W	15 May 2012	31 Dec 2015
S Guard	47°15'48.11"N, 114°10'12.45"W	17 May 2012	31 Dec 2015
RC 396 Guard	47°14'20.33"N, 114° 9'40.92"W	6 June 2012	31 Dec 2015
RC Guard	47°13'57.14"N, 114° 9'10.49"W	16 Apr 2012	31 Dec 2015

10.3. Results

Domesticated cats, mule deer, black bear, coyote, white-tailed deer, mountain lion, bobcat and raccoon crossed the wildlife guards most frequently (Table 12). When they crossed the wildlife guards, regardless of whether they accessed or left the fenced road corridor, some species used the concrete ledge relatively frequently: raccoon (60 percent), domesticated cat (58 percent), coyote (29 percent), white-tailed deer (16 percent), and mule deer (12 percent). While two of the four wildlife guards (N guard and S guard) had a fence bulb-out across the ledge at the safe side of the wildlife fence, mule deer (11 percent) and white-tailed deer (20 percent) still used the concrete ledge frequently when crossing those wildlife guard.

Very few of the mule deer (0.45 percent) and white-tailed deer (1.26 percent) that were present on the safe side of the wildlife guards used the wildlife guards to gain access into the fenced road corridor. However, the wildlife guards were quite permeable for mountain lion (94 percent), bobcat (73 percent), black bear (53 percent), domesticated cats (46 percent), and raccoon (34 percent). Note that the fact that wildlife guards appeared completely permeable for deer and other species that wanted to leave the fenced road corridor is mostly an artefact. The cameras were slightly oriented towards the safe side of the wildlife guards and were therefore rarely able to record animals that were present on the highway side of the wildlife guard.

Table 12: The permeability of the four wildlife guards monitored with cameras.

Species	Passage (N)			No passage (N)		Permeability accessing highway (%)	Permeability leaving highway (%)	Use ledge (% of all crossings)
	Leaving highway	Accessing highway	Used ledge	Highway side fence	Safe side fence			
Domesticated cat (*Felis catus*)	62	77	81	8	91	45.83	88.57	58.27
Mule deer (*Odocoileus hemionus*)	56	3	7	0	665	0.45	100.00	11.86
Black bear (*Ursus americanus*)	12	21	0	0	19	52.50	100.00	0.00
Coyote (*Canis latrans*)	9	12	6	0	259	4.43	100.00	28.57
White-tailed deer (*Odocoileus virginianus*)	8	17	4	0	1337	1.26	100.00	16.00
Mountain lion (*Felis concolor*)	8	16	0	0	1	94.12	100.00	0.00
Bobcat (*Lynx rufus*)	6	11	1	0	4	73.33	100.00	5.88
Raccoon (*Procyon lotor*)	5	10	9	0	19	34.48	100.00	60.00
Domesticated dog (*Canis lupus familiaris*)	3	1	0	0	17	5.56	100.00	0.00
Western striped skunk (*Mephitis mephitis*)	2	3	3	0	2	60.00	100.00	60.00
Yellow-bellied marmot (*Marmota flaviventris*)	2	1	2	0	1	50.00	100.00	66.67
American badger (*Taxidea taxus*)	1	0	0	0	2	0.00	100.00	0.00
Elk (*Cervus canadensis*)	1	0	0	0	3	0.00	100.00	0.00
Other	1	0	0	0	128	0.00	100.00	0.00
Rabbits and hares (Lagomorpha)	0	2	1	0	2	50.00	n/a	50.00
Red fox (*Vulpes vulpes*)	0	1	0	0	4	20.00	n/a	0.00
Deer spp. (*Odocoileus* spp.)	0	0	0	0	76	0.00	n/a	n/a
Cattle (*Bos taurus*)	0	0	0	0	1398	0.00	n/a	n/a
Unknown	0	0	0	0	1	0.00	n/a	n/a

10.4. Discussion and Conclusion

The wildlife guards had very low permeability to large ungulates, specifically white-tailed deer (1.26 percent) and mule deer (0.45 percent). The permeability was lower than reported by Allen (2013) because Allen (2013) excluded animals that were simply walking by and that were not necessarily interested in crossing the wildlife guards. Allen (2013) focused on animals that got very close to the wildlife guards and showed behavior indicating that they were interested in potentially crossing the guards. On the other hand, the wildlife guards were quite permeable for mountain lion (94 percent), bobcat (73 percent), black bear (53 percent), domesticated cats (46 percent), and raccoon (34 percent).

In conclusion, the wildlife guards are a substantial barrier to white-tailed deer and mule deer but not to mountain lion, bobcat or black bear. However, there may be a danger associated with wildlife guards that is underestimated at this time; animals, specifically deer that walk on the metal grate, sometimes fall through the openings with their legs, potentially resulting in broken legs and ultimately death. The researchers observed deer falling through the openings of the metal grate with their legs several times at the wildlife guards that were monitored. The researchers could not evaluate whether the animals broke their legs, nor whether this may eventually have resulted in their death. The researchers suggest investigating this potential problem before implementing wildlife guards at a wider scale. The researchers also recommend making the concrete ledges on the sides of the wildlife guards completely inaccessible to wildlife. Many species, including large ungulates, used the concrete ledges to gain access into the fenced road corridor. The current fix (fence bulb-outs) at the N and S guards are not keeping wildlife from accessing these concrete ledges. When bears, mountain lions or bobcats are the target species (e.g. Chapter 5) the researchers strongly recommend other measures than wildlife guards. Electric mats appear to be a good alternative (e.g. Huijser *et al.* 2015).

11. WILDLIFE JUMP-OUTS

11.1. Introduction

Wildlife jump-outs are earthen ramps within the fenced right-of-way. They allow wildlife caught in between the fences to walk up a slope at a fence line and then jump down to the safe side of the fence. Jump-outs should be low enough so that wildlife will readily jump down to the safe side of the fence. However, jump-outs should also be high enough so that wildlife will not or rarely jump into the fenced road corridor. This implies that the height of the wildlife jump-outs depends on the target species and their ability and willingness to jump. The height of the jump-outs along US 93 North varies, but is about 6-7 ft (1.82-2.13 m). So far most of the data on the appropriate height for wildlife jump-outs is based on mule deer (*Odocoileus hemionus*) and elk (*Cervus canadensis*). However, the most abundant ungulate along US 93 North was white-tailed deer (*Odocoileus virginianus*).

11.2. Methods

The researchers monitored the use of 52 wildlife jump-outs along the US 93 North corridor through tracking (Evaro N=23, Ravalli Curves N=25, Ravalli Hill N=4) (Figures 34-36). Sand tracking beds were installed on the top and bottom of each of the jump-outs (about 16.4 ft (5 m) long, 6.6 ft (2 m) wide). The researchers checked the tracking beds once a week in the summer months for about five years. The monitoring of the sand tracking beds at the jump-outs in the Evaro area took place 4 August 2010 -29 October 2010, 3 June 2011 - 21 October 2011, 6 June 2012 – 5 October 2012, 21 May 2013 - 9 October 2013, 15 May 2014 - 16 October 2014, and 8 May 2015 – 12 October 2015. The monitoring of the sand tracking beds at the jump-outs in the Ravalli Curves and Ravalli Hill areas took place 8 June 2008 – 24 July 2008, 10 June 2009 – 17 August 2009, 24 August 2010 – 28 October 2010, 31 May 2011 – 25 October 2011, and 29 May 2012 – 17 Oct 2012. The researchers recorded the date, the species, and whether the animals concerned jumped down, jumped up or whether they were only present on the top or bottom of the jump-out. The researchers could not distinguish between white-tailed deer and mule deer tracks. For the analyses the researchers only selected the records for which the species or species group identification was certain.

In addition, the researchers installed cameras at selected jump-outs (N=10, 6 in the Evaro area, 4 in the Ravalli Hill area) that were most frequently visited by deer (based on the tracking data). Though the cameras were active in the period 29 Sep 2014 – 7 May 2016, the installation date of the cameras varied.

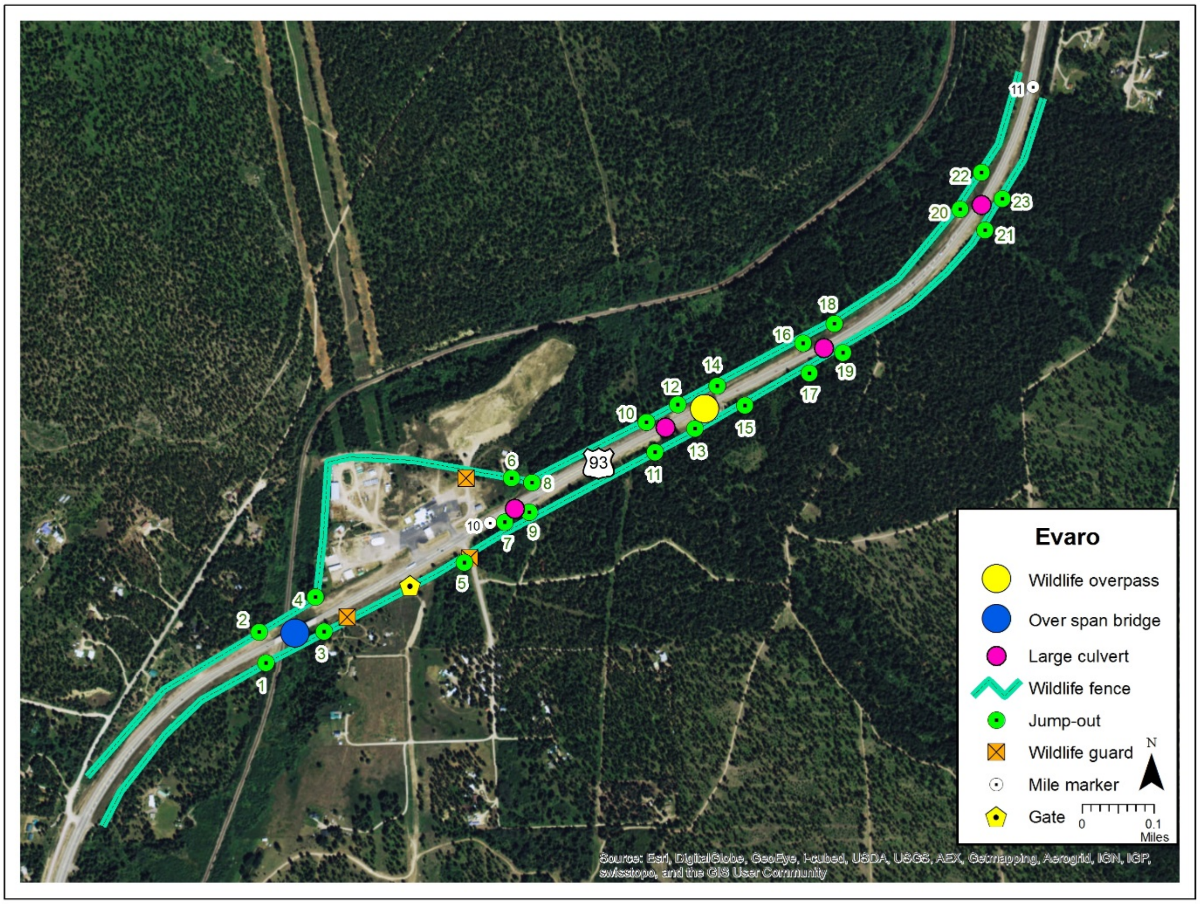

Figure 34: The jump-outs and other mitigation measures in the Evaro area.

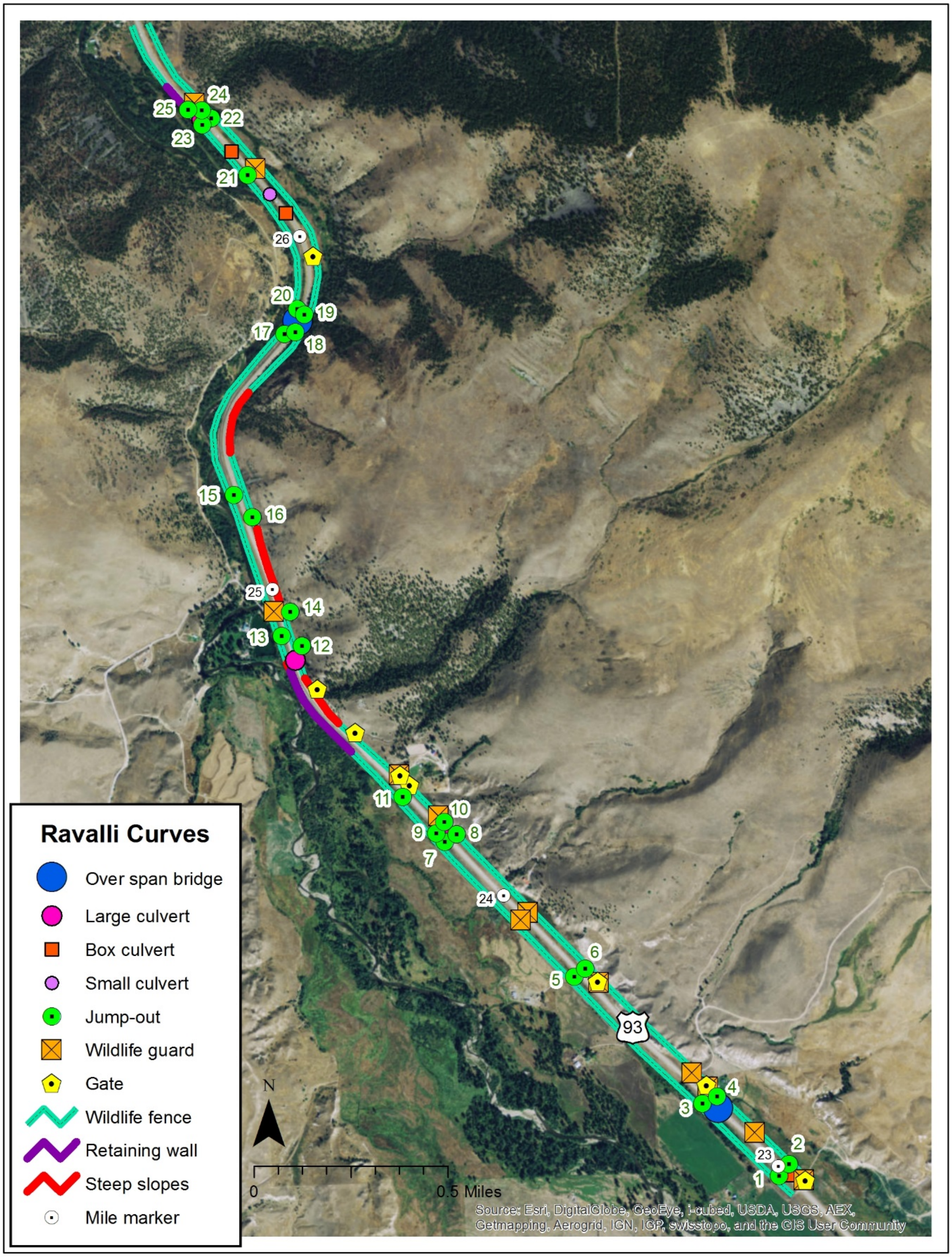

Figure 35: The jump-outs and other mitigation measures in the Ravalli Curves area.

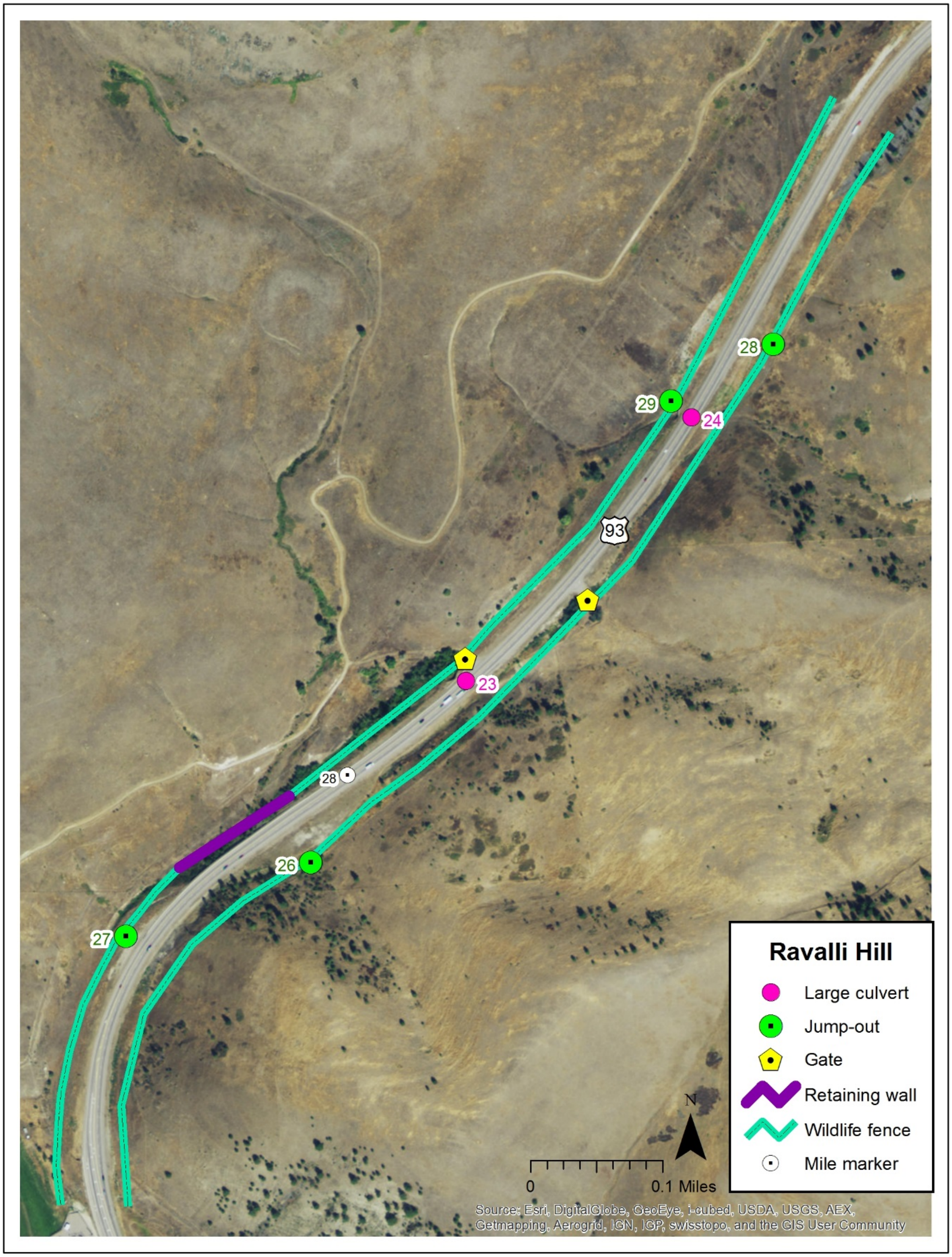

Figure 36: The jump-outs and other mitigation measures in the Ravalli Hill area.

11.3. Results

Deer were the most frequently observed species group at the bottom and on top of the jump-outs (Table 13). Only about 14 percent of the deer that were on top of a jump-out used the jump-out to leave the fenced road corridor. Black bear had a similar use rate of about 15 percent. Deer were never recorded having jumped up into the fenced road corridor, but there was one observation of an elk, one of a black bear, and one of a mountain lion that did use a wildlife jump-out to access the fenced road corridor.

Table 13: The use of the 52 jump-outs in the Evaro, Ravalli Curves and Ravalli Hill areas based on tracks on sand tracking beds.

Species	Jump down (N)	Jump up (N)	Top only (N)	Bottom only (N)	Jump down (%)	Jump up (%)
Deer spp. (*Odocoileus* spp.)	142	0	884	4655	13.84	0.00
Coyote (*Canis latrans*)	12	0	27	37	30.77	0.00
Mountain lion (*Felis concolor*)	8	1	0	11	100.00	8.33
Canid spp.	6	0	25	17	19.35	0.00
Black bear (*Ursus americanus*)	4	1	22	108	15.38	0.92
Bobcat (*Lynx rufus*)	2	0	11	21	15.38	0.00
Domesticated cat (*Felis catus*)	2	0	169	353	1.17	0.00
Elk (*Cervus canadensis*)	1	1	1	2	50.00	33.33
Dom. dog (*Canis lupus familiaris*)	1	0	7	8	12.50	0.00
Raccoon (*Procyon lotor*)	1	0	21	25	4.55	0.00
Cattle (*Bos taurus*)	0	0	1	1085	0.00	0.00
Horse (*Equus ferus caballus*)	0	0	0	6	n/a	0.00
Rabbits and hares (Lagomorpha)	0	0	22	32	0.00	0.00
Wild turkey (*Meleagris gallopavo*)	0	0	6	37	0.00	0.00

The cameras showed that white-tailed deer (7 percent) that were on top of the wildlife jump-outs were far less likely to use it to access the safe side of the fence than mule deer (32 percent) (Table 14). Black bear had a use rate similar to that for mule deer (32 percent). Bobcat and wild turkeys that were recorded at the bottom of the jump-outs always jumped up or flew up into the fenced road corridor.

Table 14: The use of 10 jump-outs visited most frequently by deer in the Evaro and Ravalli Hill areas based on cameras.

Species	Jump down (N)	Jump up (N)	Top only (N)	Bottom only (N)	Jump down (%)	Jump up (%)
White-tailed deer (*Odocoileus virginianus*)	15	0	203	154	6.88	0.00
Mule deer (*Odocoileus hemionus*)	11	0	23	77	32.35	0.00
Domesticated cat (*Felis catus*)	5	0	25	0	16.67	n/a
Bobcat (*Lynx rufus*)	4	8	7	0	36.36	100.00
Black bear (*Ursus americanus*)	3	0	6	0	33.33	n/a
Elk (*Cervus canadensis*)	1	0	5	10	16.67	0.00
Coyote (*Canis latrans*)	1	0	2	0	33.33	n/a
Red fox (*Vulpes vulpes*)	1	0	1	0	50.00	n/a
Bighorn sheep (*Ovis canadensis*)	1	0	0	0	100.00	n/a
Wild turkey (*Meleagris gallopavo*)	0	5	0	0	n/a	100.00
Deer spp. (*Odocoileus* spp.)	0	0	1	10	0.00	0.00
Cattle (*Bos taurus*)	0	0	1	280	0.00	0.00
Dom. dog (*Canis lupus familiaris*)	0	0	1	4	0.00	0.00
Rabbits and hares (Lagomorpha)	0	0	4	0	0.00	n/a
American badger (*Taxidea taxus*)	0	0	9	0	0.00	n/a
Porcupine (*Erethizon dorsatum*)	0	0	1	0	0.00	n/a
Western striped skunk (*Mephitis mephitis*)	0	0	2	0	0.00	n/a

11.4. Discussion and Conclusion

While there are no established standards for the performance of wildlife jump-outs, the use by the most common large ungulate along the US 93 North corridor (white-tailed deer) appears very low (about 7 percent use to access the safe side of the wildlife fence). Mule deer appear more able or willing to use the jump-outs to access the safe side of the wildlife fence (about 32 percent use). As no deer were observed jumping up into the fenced road corridor, the researchers suggest experimenting with gradually lowering the wildlife jump-outs. However, the researchers strongly suggest accompanying this with further research and monitoring as lower jump-outs may also result in more animals jumping up to access the fenced road corridor with the associated risk of wildlife-vehicle collisions. For future studies the researchers recommend using wildlife cameras rather than tracking beds. Camera data not only record the behavior of the animals better, but they also allow for better identification of the species (e.g. white-tailed deer vs. mule deer). However, should tracking beds be used, the researchers recommend using tracking beds on the bottom of jump-outs that are wider than 6.6 ft (2 m) (perhaps at least 9.8 ft (3 m) wide).

12. HUMAN ACCESS POINT

12.1. Introduction

The reconstruction of US 93 North included relatively long distances of wildlife fences. The 8 ft (2.4 m) tall wildlife fence is not only a barrier to large mammals, but also to people. At one location, a human access point was provided that allowed humans to pass through the wildlife fence (in the Ravalli Curves area, just north of Spring Creek or RC 381, west side of the highway). The access point consists of a gap in the fence, large enough for people to walk through, with fences extending at approximately 45 degrees on both sides from the existing fence line (i.e. on one side the wildlife fence ends in a “Y-shape” while opposite fence end on the other side of the gap ends in between the “arms” of the Y. This design was based on the hypothesis that it would allow for easy access for humans, but that it would exclude large ungulates (e.g. white-tailed deer), because of the sharp turn required to pass through the gap. The researchers investigated whether the design of the human access point was successful in keeping large ungulates from accessing the fenced road corridor where they could be hit by traffic.

12.2. Methods

From May 2012 through December 2015 the human access point was monitored with a motion-activated camera. Human and wildlife movements at and near the human access point were recorded. The researchers recorded human and wildlife species “walking by” (i.e. simply walking by the access point without approaching or attempting to cross the fence-line at the human access point) and human and wildlife species that crossed through the human access point. The researchers also distinguished between “walking by” on the safe side of the wildlife fence and on the highway side of the wildlife fence. In addition, the researchers recorded the direction of the crossings through the gap; either leaving the fenced road corridor or entering the fenced road corridor. The permeability of the human access point for large ungulates (in this case only white-tailed deer) was calculated in order to investigate how effective the design of the human access point was in keeping animals from entering into the fenced road corridor.

12.3. Results

A total of 414 movements were recorded, 94 percent of which related to white-tailed deer. A total of 237 movements related to animals that were simply “walking by” the site, making no attempt to cross the fence-line (Table 15). Of the animals just “walking by” 229 (97 percent) occurred outside of the fenced-right-of-way, while 8 occurred within the fenced road corridor (Table 15). Records where an animal aborted a crossing attempt through the human access point or where the animal returned within 5 minutes were excluded from table 15 (these records all related to white-tailed deer, N=25).

White-tailed deer were the most abundant species observed at and near the human access point (Table 15). White-tailed deer crossed through the human access point a total of 140 times. About 22 percent of all white-tailed deer that were recorded on the safe side of the fence crossed into the fenced road corridor through the human access point. For the other direction the permeability was about 93 percent. Humans crossed through the access point 9 times.

Table 15: The permeability of the human access point to humans and wildlife species.

Species	Enters fenced r-o-w (N)	Exits fenced r-o-w (N)	Only outside fenced r-o-w (N)	Only inside fenced r-o-w (N)	Permeability entering fenced r-o-w (%)	Permeability exiting fenced r-o-w (%)
White-tailed deer (*Odocoileus virginianus*)	61	79	219	6	21.79	92.94
Human (excluding data collectors)	5	4	0	0	100.00	100.00
Cattle (*Bos taurus*)	1	0	1	0	50.00	n/a
Raccoon (*Procyon lotor*)	1	0	1	0	50.00	n/a
Red fox (*Vulpes vulpes*)	1	0	0	1	100.00	0.00
Domesticated cat (*Felis catus*)	0	0	3	0	0.00	n/a
Dom. dog or coyote	0	0	3	0	0.00	n/a
Coyote (*Canis latrans*)	0	0	2	1	0.00	0.00

12.4. Discussion and Conclusion

The human access point received relatively little use by humans (only 9 crossings in 3.5 years). However, white-tailed deer crossed frequently through the human access point over the same time period (140 times). The data suggest that while the human access point does allow people to access the other side of the fence, it also allows deer to move in and out of the fenced road corridor. Deer that are inside the fenced road corridor may then be hit by traffic. Interestingly, while only 22 percent of the white-tailed deer that were on the safe side of the wildlife fence crossed through the human access point, the permeability for deer that left the fenced road corridor was much higher (93 percent). This is presumably because the animals may have had a much greater motivation exit the fenced road corridor to access cover or safety away from traffic, than animals that were already on the safe side of the wildlife fence. In conclusion, the human access point is not a substantial barrier to white-tailed deer, and human use was very low. The researchers suggest closing the human access point as it mostly allows wildlife, specifically white-tailed deer, to access the fenced road corridor while the need for human access was almost absent.

13. COST-BENEFIT ANALYSES

13.1. Introduction

It is evident that there are costs associated with including wildlife mitigation measures in road construction or reconstruction projects. However, it is also evident that collisions with large wild mammals are costly and dangerous to humans. Huijser *et al.* (2009b) developed a cost-benefit model and showed that it can be more costly to allow wildlife-vehicle collisions to continue to occur than to invest in effective wildlife mitigation measures. However, the number of large mammal-vehicle collisions per mile (or km), the spatial configuration of the mitigation measures, and the actual costs associated with the mitigation measures always vary between different road construction or reconstruction projects. Therefore the researchers investigated the costs and benefits for the mitigation measures implemented along US 93 North.

While the cost-benefit analyses in this chapter are almost exclusively based on human safety parameters (see Huijser *et al.* 2009b), the decision to implement mitigation measures along US 93 North was not primarily because of human safety concerns. The wildlife mitigation measures were an integral part of the reconstruction of US 93 North because of additional values related to culture, landscape, and natural resources, including wildlife. The Confederated Salish and Kootenai Tribes required the reconstructed highway to be respectful of the land, the people and their culture, and wildlife (Becker and Basting 2010). Without approval and collaboration of all three governments (i.e. federal, state and the tribal government), the highway reconstruction project could not have been initiated (Becker and Basting 2010). Values related to culture, landscape, and natural resources are not uniquely Native American. These values are present in almost any society. However, in the specific context of the reconstruction of a highway on a Native American reservation, these values were actually made an integral component of a context sensitive approach to redesigning the highway.

Along US 93 North, wildlife mitigation measures were implemented in selected areas only. The road sections with wildlife mitigation were partially based on a history of wildlife-vehicle collisions. Other parameters included local knowledge and experience with regard to where wildlife was frequently seen on or near the road alive, low probability for changes in land use that could potentially negatively affect wildlife approaching the highway (i.e. protected tribal, federal or state lands, or private land with easements), topography (e.g. road cuts (overpasses) or road fills (underpasses)) and stream and river crossings (i.e. make a culvert or bridge across a stream or river also suitable for large terrestrial mammals).

The cost-benefit analyses are well suited for human safety parameters, but they currently do not include parameters associated with achieving the cultural, and ecological goals for which the mitigation measures were built (e.g. viable wildlife populations, cultural importance of wildlife, respecting the landscape and wildlife, maintaining or restoring wildlife connectivity). Thus the limitations of the current cost-benefit model, as applied to the US 93 North mitigation measures, must be recognized when interpreting the results. An economic assessment that also measures the economic costs and benefits of the mitigation measures outside of the safety context could be developed separately in the future.

13.2. Methods

The researchers based the costs associated with large mammal-vehicle collisions on Huijser *et al.* (2009b). Note that these costs were almost entirely based on human safety parameters and not on passive use values. Passive use values can include viable wildlife populations and reduced probability of vehicles killing threatened or endangered species (e.g. grizzly bear) (Huijser *et al.* (2009b)). Since white-tailed deer and mule deer dominated the reported carcasses (98 percent, Chapter 2), the researchers only included the costs associated with an average deer-vehicle collision in the analyses ($6,617, see Huijser *et al.* 2009b). There were only two elk carcasses and zero moose carcasses reported between 2002 and 2015 (Chapter 2).

The costs for the mitigation measures were based on the actual costs for US 93 North (obtained through Pat Basting, Montana Department of Transportation). Structures that were not at least partially designed as a crossing structure for large mammals were excluded from the analyses. If a structure passed a stream, river or railroad, the costs were calculated for a structure that would have been needed for that other purpose. These costs were subtracted from the total construction cost to estimate the costs associated with providing safe crossing opportunities for wildlife (Appendix J1). Similarly, the costs for a right-of-way fence were subtracted from the costs for the wildlife fence (Appendix J2). In this case the researchers used the costs associated with wildlife friendly livestock fences as a surrogate for standard right-of-way fences. Some highway sections in the Ravalli Curves and Ravalli Hill areas had a retaining wall or a steep slope without wildlife fences. The researchers ignored these gaps in the fences and the calculations were based on Ravalli Curves and Ravalli Hill areas being fenced in their entirety. The wildlife fence in the Evaro and Ravalli Hill areas had a dig barrier ("apron") attached. A dig barrier is a section of fence that is attached to the main fence and buried into the soil to reduce the likelihood that animals would dig under the wildlife fence to access the fenced road corridor. The Ravalli Curves area had the dig barrier installed only along the northernmost mile. The costs for these dig barriers were included in the costs for the wildlife fences. In addition, the researchers counted the number of single and double gates and wildlife guards at access points, as well as the number of wildlife jump-outs. The costs associated with these measures were all included in the cost-benefit analyses.

The cost savings associated with reducing large mammal-vehicle collisions in the Evaro, Ravalli Curves and Ravalli Hill areas were also based on actual data from US 93 North. The Before-After-Control-Impact effect of the mitigation was a reduction of 1.78 large mammals per mile per year (1.11 per km per year) and 0.93 crashes per mile per year (0.58 crashes per km per year). The percentage reduction in large wild mammal carcasses was 71.44 percent and 80.04 percent for wildlife-vehicle crashes (average 75.74 percent). The effectiveness for the remaining mitigated road sections was set at 50 percent reduction in wildlife-vehicle collisions based on the reduced effectiveness for mitigated road sections shorter than 3.1 mi (5 km) in length (see Chapter 3). This equated to a reduction of 0.90 wildlife-vehicle collisions per mile per year (0.56

per km per year) (a collision reduction of 1.37 collisions per mile per year (0.85 per km per year) represented 75.74 percent).

Design costs for the mitigation measures along US 93 North were an integral part of the design costs for the reconstruction of the highway. Therefore the researchers could not include design costs in the cost-benefit analyses. However, the researchers did include maintenance costs and, at the end of the life span of a mitigation measure, costs associated with its removal (for values see Huijser *et al.* 2009b). The life span of a mitigation measure was defined as the number of years a mitigation measure can be functional before it needs to be replaced in its entirety (see Huijser *et al.* 2009b).

The cost-benefit analyses were identical to those described in Huijser *et al.* (2009b). The life span for the crossing structures, wildlife guards and jump-outs was set at 75 years. The life span for wildlife fences and gates was set at 25 years. The cost-benefit analyses were conducted with a discount rate of 3 percent, appropriate for intergenerational investments (Huijser *et al.* 2009b). The cost benefit analyses were conducted separately for the three areas with relatively long wildlife fences (Evaro, Ravalli Curves and Ravalli Hill). Ignoring differences in crossing structure type and associated costs, the density of wildlife crossing structures in these three areas was 3.5, 2.4 and 1.6 structures per mile respectively (2.2, 1.5, and 1.0 per kilometer). A fourth analyses was conducted for the combination of all remaining mitigation measures spread out along the US 93 North corridor between Evaro and Polson.

13.3. Results

The costs associated with the mitigation measures over a 75 year long time period, including costs associated with maintenance and removal at the end of the life of the mitigation measures, were about 21 million US$ for the entire road section between Evaro and Polson (Table 16). The benefits based on reducing collisions with large mammals were only about 2 million US$; about 10 percent of the costs (Table 16).

The balance (benefits minus costs) for a mitigated kilometer of road was least negative for the Ravalli Curves and Ravalli Hill areas (Table 16). The mitigation measures for these road sections had a negative balance of 1.4 and 1.5 million US$ per kilometer respectively (Table 16). These areas lacked the most expensive type of wildlife crossing structure (i.e. a wildlife overpass) and they had relatively low costs associated with the wildlife crossing structures per road length unit. The balance was more negative in the Evaro road section (-3.9 million US$/km, Table 16) because of the wildlife overpass and the high density of relatively large and expensive wildlife crossing structures. The “other” mitigated road sections had the highest negative balance (-6.9 million US$/km, Table 16) as they were characterized by relatively large and expensive wildlife crossing structures with no or limited sections of wildlife fencing (See appendix A1 and A2). In essence, when a mitigated road section has a relatively low concentration of wildlife crossing structures and relatively long sections of wildlife fence between the crossing structures, the monetary costs decrease. When a road section has a relatively high concentration of wildlife crossing structures and relatively short sections of wildlife fence between the crossing structures, the monetary costs increase.

Table 16: The costs and benefits (in US$, based on human safety parameters, excluding passive use values) for the mitigation measures in the Evaro, Ravalli Curves and Hill areas, and for the other mitigation measures spread out along the US 93 North corridor between Evaro and Polson (based on cost-benefit analyses over a 75 year period, 3% discount rate).

Area	Costs	Benefits	Balance (benefits minus costs)	% Benefits related to costs	Balance (per mitigated km)
Evaro	$4,598,310	$456,949	-$4,141,361	9.94	-$3,919,676
Ravalli Curves	$4,179,416	$1,021,416	-$3,158,000	24.44	-$1,337,163
Ravalli Hill	$1,475,253	$322,553	-$1,152,700	21.86	-$1,545,579
Other	$11,106,895	$437,567	-$10,669,329	3.94	-$6,922,157
Total	$21,359,874	$2,238,485	-$19,121,389	10.48	-$3,351,450

13.4. Discussion and Conclusion

The mitigation measures along US 93 North did not generate monetary benefits in excess of their costs, at least not based on human safety parameters alone. The costs were least for highway sections with long and continuous wildlife fences without the most expensive type of wildlife crossing structure (wildlife overpass). The costs were highest for highway sections that had a high concentration of wildlife crossing structures but only very short sections of wildlife fences or no wildlife fences at all.

When interpreting the results of the cost-benefit analyses it is important to keep the following facts in mind:

1. The cost-benefit analyses in this chapter were almost exclusively based on human safety parameters (see Huijser *et al.* 2009b). Therefore, the balance (costs minus benefits) presented in this chapter were limited by definition and do not include all costs and benefits that one could or should consider. Human safety based analyses can be helpful in the decision process for wildlife mitigation measures but the results of such analyses should be treated as just one of many parameters to consider, not the only one.
2. Parameters based on passive use values were not part of the cost-benefit analyses (see Huijser *et al.* 2009b). Examples of passive use parameters can include having viable wildlife populations or reduced probability of vehicles killing threatened or endangered species (e.g. grizzly bear) (see Huijser *et al.* 2009b). However, such parameters were not included in the current cost-benefit model. This illustrates that the current cost-benefit model is limited in nature.
3. The US 93 North highway reconstruction project would not have been possible without the approval and collaboration of the three governments (federal, state and tribal). The approval and collaboration of the Confederated Salish and Kootenai Tribes depended on the reconstructed highway to be respectful to the landscape, the people and their culture, and wildlife (”the road is a visitor”). The wildlife mitigation measures were part of a

group of measures that were an integral part of the US 93 North highway reconstruction that addressed the requirements of the Confederated Salish and Kootenai Tribes.

4. The “density” of wildlife crossing structures along US 93 North was far higher than the density used in the cost-benefit model developed by Huijser *et al.* (2009b). The “density” of wildlife crossing structures (regardless of type and dimensions) in the Evaro, Ravalli Curves and Ravalli Hill areas was 3.5, 2.4 and 1.6 structures per mile respectively (2.2, 1.5, and 1.0 per kilometer). Huijser *et al.* (2009b) based their calculations on a crossing structure density of 0.8 per mile (0.5 per km) with one overpass every 14.9 mile (24 km). Therefore, the cost-benefit analyses for the mitigation measures along US 93 North do not necessarily indicate that the costs of these types of measures are always higher than the benefits.
5. Huijser *et al.* (2009b) calculated that long sections of wildlife fences were, on average, 87 percent effective in reducing wildlife-vehicle collisions. The researchers have since found that mitigated highway sections shorter than 3.1 mi (5 km) are, on average, only about 50 percent effective in reducing wildlife-vehicle collisions, and that their effectiveness varies greatly from location to location (Huijser *et al.* 2016, Chapter 3). The mitigated highway sections along US 93 North were predominantly shorter than 3.1 mi (5 km) and thus less effective and more variable in their effectiveness than longer mitigated highway sections that the cost-benefit model (Huijser *et al.* 2009b) was based on. Implementing longer sections of wildlife fences (>3 mi (>5 km)) is more cost-effective than mitigating shorter highway sections (<3 mi (< 5 km)) (Huijser *et al.* 2016, Chapter 3).

While wildlife overpasses (e.g. the overpass in the Evaro area) are relatively expensive, wildlife overpasses can be critical in providing habitat connectivity for specific species. The wildlife use of the crossing structures along US 93 North showed that 75 percent of all elk and 100 percent of all moose crossings occurred on the wildlife overpass (Chapter 6). In addition, other researchers have shown that grizzly bears also use wildlife overpasses far more frequently than wildlife underpasses (Sawaya *et al.* 2013).

If wildlife crossing structures (e.g. large culverts suitable for large mammals) are implemented with no or short sections of wildlife fences, the mitigated road length is relative short while the costs are relatively high (mostly for the wildlife crossing structure). Wildlife fences are relatively inexpensive and can not only help reduce wildlife vehicle collisions (and thus contribute to economic benefits based on human safety parameters), but fences can also help guide wildlife to the crossing structure ((Dodd *et al.* 2007a, Gagnon *et al.* 2010). However, structures with no or very short sections of wildlife fences can still have wildlife use that is similar to that of crossing structures associated with longer sections of wildlife fences (Chapter 8). Therefore isolated crossing structures with no or short wildlife fences can still be important in providing habitat connectivity for wildlife.

If the costs and benefits of wildlife mitigation measures are evaluated on human safety based economic analyses, it is best to implement relatively long sections of continuous wildlife fences (3.1 mi (5 km) or longer) (Chapter 3). In the context of the cost benefit model that was applied (Huijser *et al.* 2009b), the wildlife crossing structures mostly cost money as their primary function is not related to human safety but to habitat connectivity for wildlife. However, providing safe crossing opportunities under or over a highway also reduces the likelihood that wildlife will breach the fence and gain access to the fenced road corridor. In addition, one may argue that every large mammal that crosses through a crossing structure instead of at grade on the road surface represents a reduction in the probability of wildlife-vehicle collisions. Nonetheless, the fact that the current model does not include the primary function of wildlife crossing structures illustrates the limited nature of the current cost-benefit analyses and why it should not be used as the only parameter when deciding on the inclusion of wildlife mitigation measures in highway reconstruction projects. The limited nature of the current cost-benefit model is biased against including wildlife crossing structures by definition, especially when the density of crossing structures is high or when relatively expensive crossing structures (e.g. wildlife overpasses) are included. Rather than concluding that wildlife crossing structures should not be included or minimized in number with designs that may not even be suitable for the target species, the researchers suggest expanding the current cost-benefit model to include parameters associated with passive use. As a general rule of thumb, the barrier effect of roads and traffic should not be increased without providing for sufficient safe crossing opportunities for wildlife; wildlife fences as a stand-alone measure can be very damaging ecologically (e.g. Jaeger and Fahrig 2004).

14. MEASURES OF EFFECTIVENESS

14.1. Introduction

The three governments (MDT, CSKT, and FHWA) agreed on measures of effectiveness for the wildlife mitigation measures implemented along US 93 North (Hardy *et al.* 2007, Huijser *et al.* 2009a, Huijser *et al.* 2014). These documents contained specific measures of effectiveness (parameters and thresholds). This chapter lists the measures of effectiveness, summarizes the findings of the research project in the context of these measures of effectiveness, and evaluates whether the thresholds for the different measures of effectiveness were met.

14.2. Human Safety

14.2.1. Reducing Wildlife-Vehicle Collisions in All Fenced Road Sections

Based on Huijser *et al.* (2014): If large wild mammal-vehicle collisions are reduced by at least 30-50 percent in all areas with fences on both sides of the road using 5 years of post-construction monitoring data, the mitigation measures are considered to have sufficiently improved road safety along the mitigated road sections with regard to large wild mammal-vehicle collisions.

After highway reconstruction, large wild mammal carcasses were on average 17.79 percent lower in the fenced road sections along US 93 North (Chapter 3). Wildlife crashes were 50.62 percent lower on average (Chapter 3). Wildlife-vehicle collisions (average of the carcass and crash data) were reduced by 33.52 percent (Chapter 3). In conclusion: Based on a simple before-after comparison for 13 fenced road sections along US 93 North, this measure of effectiveness was not met for large wild mammal carcasses, but it was met for wildlife crashes and for wildlife-vehicle collisions (a combination of large wild mammal carcasses and wildlife crashes). The US 93 North project generated important new data that showed that wildlife fences are most effective in reducing wildlife-vehicle collisions (almost always at least 80 percent reduction) if the fenced road length is at least 3.1 mi (5 km) long (Chapter 3). Furthermore, minimizing the number of gaps in the wildlife fences (e.g. for access roads) and fence end treatments can help improve the effectiveness of wildlife fences, particularly if the fenced road sections are short (≤3.1 mi (≤5 km)). These measures can also reduce the variation in effectiveness between individual road sections.

14.2.2. Reducing Wildlife-Vehicle Collisions in the Evaro, Ravalli Curves and Ravalli Hill Areas

Based on Huijser *et al.* (2014): If large wild mammal-vehicle collisions are reduced by at least 50-70 percent in the three areas with relatively long sections with more or less contiguous fences (Evaro, Ravalli Curves and Ravalli Hill) using 5 years of post-construction monitoring data, the mitigation measures are considered to have sufficiently improved road safety along these three road sections with regard to large wild mammal-vehicle collisions.

Based on a simple before-after comparison for the Evaro, Ravalli Curves and Ravalli Hill areas combined, the data showed that the number of reported wildlife-vehicle collisions decreased by 5.19 percent (carcass removal data) or 61.90 percent (wildlife crash data) (Chapter 2). However, the number of wildlife-vehicle collisions in the control road sections did not remain constant after the road reconstruction; they increased by 232.00 percent (carcass removal data) and 90.77 percent (wildlife crash data). This suggests that if the road sections with wildlife fences would not have been mitigated with wildlife fences they would have seen a similar increase in the number of large wild mammal carcasses and crashes with animals. Yet, presumably because of the mitigation measures, the number of reported large wild mammal carcasses and crashes with animals decreased by 5.19 percent (carcass removal data) and 61.90 percent (wildlife crash data). When the substantial increase in collisions in the control sections was taken into account, the collisions in the three fenced areas were reduced by 71.44 percent (carcass removal data) and 80.04 (crash data). The reductions based on the Before-After-Control-Impact analyses were significant. In conclusion: Based on a simple before-after comparison this measure of effectiveness was met for wildlife crashes, but not for large wild mammal carcasses. Based on Before-After-Control-Impact analyses this measure of effectiveness was met for both large wild animal carcasses and wildlife crashes.

14.2.3. Reducing Potential Collisions with Deer and Black Bear

Based on Hardy *et al.* (2007) and Huijser *et al.* (2009a): If >1,299 deer highway crossings and >82 black bear post-construction crossings through the structures are observed annually in the three areas with continuous fences (Evaro, Ravalli Curves and Ravalli Hill), using 5 years of post-construction monitoring data, the mitigation measures are considered effective in terms potential collisions that were avoided. In order for tracking data to be comparable to camera data, the thresholds for deer highway crossings were corrected by a factor 1.623 (see Chapter 9 for the calculation of the correction factor). For black bear the correction factor was 1.088. The corrected thresholds for deer and black bear highway crossings were >2,108 and >89.

The mean number of deer crossings through the crossing structures per year in the three areas combined was 6,293 (Chapter 6). This was well above the 2,108 threshold for having reduced potential deer-vehicle collisions. In fact, the lowest number of successful deer crossings through the structures per year was 4,442 which was still well above the 2,108 threshold. The mean number of black bear crossings through the crossing structures per year in the three areas combined was 305 (Chapter 6). This was well above the 89 threshold for having reduced potential black bear-vehicle collisions. In fact, the lowest number of successful black bear crossings through the structures per year was 200 which was still well above the 89 threshold. In conclusion: this measure of effectiveness was met.

14.3. Biological Conservation

14.3.1. Reducing Unnatural Mortality for Black Bears

Based on Hardy *et al.* (2007) and Huijser *et al.* (2009a): If black bear-vehicle collisions are reduced by at least 50 percent in the three areas with continuous fences (Evaro, Ravalli Curves and Ravalli Hill), using 5 years of post-construction monitoring data, the mitigation measures are considered to have sufficiently benefitted the black bear population along US 93 North.

Black bear carcasses along US 93 North continued to be recorded after highway reconstruction and there was no evidence that the mitigation measures in Evaro, Ravalli Curves, and Ravalli Hill reduced the number of reported black bear carcasses. In conclusion: this measure of effectiveness was not met.

14.3.2. Maintaining Habitat Connectivity for Deer

Based on Hardy *et al.* (2007) and Huijser *et al.* (2009a): If <1,396 deer (white-tailed deer and mule deer combined) highway crossings are observed in the three areas combined, annually, mitigation is ineffective in maintaining habitat connectivity for deer. If 1,396-2,068 deer-highway crossings are observed in the three areas combined, annually, mitigation is maintaining habitat connectivity for deer. If >2,068 deer highway crossings are observed in the three areas combined, annually, mitigation is improving habitat connectivity for deer. In order for tracking data to be comparable to camera data, the thresholds for deer highway crossings were corrected by a factor 1.623 (see Chapter 9 for the calculation of the correction factor). The corrected thresholds for deer highway crossings were <2,266, 2,266-3,356, and >3,356.

The mean number of deer crossings through the crossing structures per year in the three areas combined was 6,293 (Chapter 7). This was well above the 3,356 threshold for having improved habitat connectivity for deer. In fact, the lowest number of successful deer crossings through the structures per year was 4,442 which was still above the 3,356 threshold. In conclusion: this measure of effectiveness was met.

14.3.3. Maintaining Habitat Connectivity for Black Bear

Based on Hardy *et al.* (2007) and Huijser *et al.* (2009a): If <53 black bear highway crossings are observed in the three areas combined, annually, mitigation is ineffective in maintaining habitat connectivity for black bear. If 53-165 black bear highway crossings are observed in the three areas combined, annually, mitigation is maintaining habitat connectivity for black bear. If >165 black bear highway crossings are observed in the three areas combined, annually, mitigation is improving habitat connectivity for black bear. In order for tracking data to be comparable to camera data, the thresholds for black bear highway crossings were corrected by a factor 1.088 (see Chapter 9 for the calculation of the correction factor). The corrected thresholds for black bear highway crossings were <58, 58-180, and >180.

The mean number of black bear crossings through the crossing structures per year in the three areas combined was 305 (Chapter 7). This was well above the 180 threshold for having improved habitat connectivity for black bear. In fact, the lowest number of successful black bear crossings through the structures per year was 200 which was still above the 180 threshold. In conclusion: this measure of effectiveness was met.

14.4. Conclusion

Almost all of the measures of effectiveness were met, specifically those that related to habitat connectivity for deer and black bear and the functioning of the wildlife crossing structures. Some of the measures of effectiveness that related to human safety were met, but others were not. This is because short road sections with wildlife fences (which characterize US 93 North) are, on average, less effective in reducing collisions with large mammals than long fenced road sections (> 3 mi in road length) (Chapter 3 and Huijser *et al.* 2016). This is new knowledge that was partially based on the results of the US 93 North research project. One could argue that this was yet another possible measure of “success”: investing in research and monitoring of the wildlife mitigation measures resulted in important new knowledge that can applied directly to the policies and practices of highway and wildlife management agencies.

15. RECOMMENDATIONS

15.1. Reducing Collisions with Large Mammals

Wildlife fences are likely most effective in reducing collisions with large wild mammals, specifically ungulates if:

- The design of the wildlife fences is consistent with the physical abilities and behavioral characteristics of the target species (e.g. jumping, climbing, digging, strength). These abilities and characteristics influence fence material (fence as well as posts), mesh size, fence height, the importance of avoiding or reducing the likelihood of gaps under the fence, etc. Note that black bears likely require small mesh size (e.g. chain-link fence), metal posts and a fence overhang facing away from the highway.
- The wildlife fences cover the entire length of a wildlife-vehicle collision hotspot as well as adjacent buffer zones (based on home range size and habitat used by the target species and habitat) (Huijser *et al*. 2015, 2016).
- The fence is constructed on both sides of the highway, and the fences on opposite sides of the highway start and end at the same location (not staggered).
- There are no gaps in the fenced road sections (e.g. actual gaps, gates or wildlife guards at driveways). Be careful with assuming that steep slopes are a barrier to large mammals and that no fence is needed at steep slopes. Minimize the number of access points for both motorized and non-motorized traffic. Mitigate the remaining access points as best as possible and make sure the measures selected are effective for the target species (e.g. gates, wildlife guards, electric mats) (Chapter 10). Wildlife guards are a substantial barrier to ungulates, specifically deer, but not to bears, mountain lions or bobcats. If bears, mountain lions or bobcats are among the target species use electric wildlife deterrent mats at access roads.
- The fenced road sections are at least 3.1 miles (5 km) in length (Chapter 3, Huijser *et al.* 2016). Shorter mitigated road sections are less effective and more variable in reducing collisions with large mammals.
- Measures are put in place to reduce fence end effects (Chapter 4, Huijser *et al.* 2015). Fence end effects include “fence end runs” (a concentration of animals crossing at grade at or near a fence end), animals entering the fenced road corridor at fence ends and mistakenly allocating collisions that happen just outside the fenced road section to the fenced road section due to spatial imprecision during the carcass removal or crash data collection. Fence end runs can be reduced through connecting fence ends to steep slopes, bridges or other features that are a barrier to wildlife movement, or through angling wildlife fence away from the road corridor. Wildlife can be discouraged from entering the fenced road corridor through bringing the wildlife fence close to the road at fence ends and by embedding wildlife guards (for ungulates) or electric wildlife deterrent mats (for bears, mountain lions and bobcats) in the road surface (Chapter 10, Huijser *et al.* 2015). In addition, spatial imprecision of the collision data can make a fenced road section seem less effective in reducing collisions than it really is. Therefore the researchers also recommend collecting data that are spatially precise (i.e. record whether a collision happened inside or outside the fenced road corridor, especially near fence ends). This is

especially an issue for carcass removal data (typically collected to nearest 0.1 mi or 0.1 km) and less of an issue for crash data (typically collected to nearest 0.01 mi (0.01 km)) (Huijser *et al.* 2007).

- Oversee the construction of wildlife fences and modify construction practices if necessary. Make sure they are installed according to the design plans but be open to changes based on specific field situations. This includes, but is not limited to 1. Connecting the fence to the ground level (or better yet, bury the fence (apron)), 2. Avoid areas where (seasonal) erosion may cause gaps under the fence, 3. Leave no gaps between the fence and other structures such as wildlife crossing structures or wildlife guards.
- The wildlife fences are well maintained through a fence inspection and repair program. Gaps in the fence (e.g. because of falling trees, erosion, vehicles running off the road, potential gaps between a fence and a wing wall of a wildlife underpass as a result of construction or design errors) can allow large mammals to access the fenced road corridor and thereby reduce the effectiveness of the mitigation measures in reducing wildlife-vehicle collisions. As part of the routine inspections of the highway by road maintenance personnel, the status of a fence can be inspected from the road. Any observed problems should be addressed preferably the same day. More detailed inspections are recommended on a monthly basis, for example by walking a fence line and inspecting a fence for potential problems.
- Wildlife fences are accompanied by safe crossing opportunities for wildlife (Chapter 6, 7, and 8). Safe crossing opportunities include wildlife underpasses and wildlife overpasses. If a sufficient number of safe wildlife crossing opportunities are provided, if they are constructed in the correct locations, and if they have appropriate dimensions for the target species, the animals are more likely to use a designated safe crossing opportunity to access the other side of the highway than to breach the fence. If fewer animals breach the fence (e.g. through digging, climbing, jumping or breaking the fence), it can be expected to result in fewer wildlife-vehicle collisions in the fenced road corridor.

15.2. Providing Safe Crossing Opportunities for Wildlife

Wildlife crossing structures (i.e. underpasses and overpasses) are likely most effective in providing safe crossing opportunities for wildlife and if the following recommendations are considered:

- The crossing structures are constructed in the locations that meet the objectives. If the locations for safe wildlife crossing opportunities are only or mostly based on carcass removal data or wildlife crash data, then the selected locations are heavily biased towards where the most common large mammals are hit by traffic (i.e. large ungulates). This approach is valid if the main objective is to reduce collisions with large mammals while still allowing wildlife to move under or over a highway. However, these locations are not necessarily the same locations where habitat connectivity across highways is needed most for biological conservation. The species that are of greatest concern to conservation are by definition not common, and their body size is not necessarily large enough to be included in carcass removal data or wildlife crash data. Therefore, if the main objective is to contribute to biological conservation, entirely different road sections may have to be selected that are not, or only partially, based on carcass removal data and wildlife crash data.

- In general, it is considered good practice to make structures across streams and rivers large enough so that they can also be used by large mammals. However, if wildlife crossing structures are only provided in combination with stream or river crossings, then species that are closely associated with high and dry areas are excluded by definition.
- Provide a sufficient number of wildlife crossing structures. The objectives should dictate what a sufficient number or density of the wildlife crossing structures is (van der Grift *et al.* 2013). The objectives can, for example, be based on population viability or maintaining or improving wildlife movements (daily movements within home range, seasonal migration, and dispersal) (Coe *et al.* 2015, Poor *et al.* 2012, Seidler *et al.* 2015, van der Ree *et al.* 2009).
- The crossing structure type and dimensions should be consistent with the requirements of the target species (e.g. Clevenger and Huijser 2011). For example, elk, moose and grizzly bear use appropriately designed and constructed wildlife overpasses far more frequently than wildlife underpasses (Chapter 6). On the other hand, black bear use a wide variety of crossing structures, including box culverts (Chapter 6).
- Wildlife fences can help guide wildlife towards safe crossing opportunities (Dodd *et al.* 2007a, Gagnon *et al.* 2010). However, a crossing structure associated with a long section of wildlife fences does not guarantee high wildlife use of the structure (Chapter 8). Similarly, a structure that is not associated with wildlife fences, or only has a very short section of wildlife fence, can still have relatively high wildlife use.
- Provide cover inside large wildlife underpasses and on top of wildlife overpasses for small animal species (e.g. invertebrates, amphibians, reptiles, small mammals). Small species need cover in order to reduce predation risk. Providing cover can help the crossing structures not only be functional for large mammals but also for smaller species groups (e.g. Connolly-Newman 2013). Depending on the availability of cover (branches, root wads, rocks), placing cover inside underpasses or on top of underpasses may be less expensive than removing, burying or burning the material (Pers. Com. Hans Bekkker, Dutch Ministry of Infrastructure and the Environment).

15.3. Specific Recommendations Mitigation Measures US 93 North

- Implement an effective wildlife fence inspection and maintenance program. Based on the experience of the researchers, the current level of wildlife fence inspection and maintenance is insufficient. Gaps in the fence (e.g. because of falling trees, erosion, vehicles running off the road, potential gaps between a fence and a wing wall of a wildlife underpass as a result of construction or design errors) can allow large mammals to access the fenced road corridor and thereby reduce the effectiveness of the mitigation measures in reducing wildlife-vehicle collisions. As part of routine inspections of the highway by road maintenance personnel, the status of a fence can be inspected from the road. Any observed problems should be addressed immediately (i.e. preferably the same day). More detailed inspections are recommended on a monthly basis, for example by walking a fence line and inspecting a fence for potential problems.

- Increase the length of the fenced highway sections and/or install effective fence end treatments. Most of the fenced sections along US93 North are relatively short and are less effective and more variable in their effectiveness compared to fenced road sections that area at least 3.1 mi (5 km) long (Chapter 3). The short fenced road sections associated with Post Creek 1, 2 and 3 have high priority because of continuing grizzly bear-vehicle collisions in this area (Chapter 5). The access roads and fence ends should be mitigated with electric wildlife deterrent mats. Wildlife guards are not an effective barrier for bears (Chapter 10). Note that increasing fence lengths may require additional wildlife crossing structures as fences alone can be very damaging ecologically (Jaeger and Fahrig 2004).
- Mitigation measures associated with the reconstruction of US 93 North through the Ninepipe wetland area should, in general, have long sections of wildlife fences (preferably continuous) with wildlife crossing structures that are suitable for grizzly bears. Electric mats should be provided at fence ends and access roads as wildlife guards are not an effective barrier for bears (Chapter 10). For low volume access roads automatic gates (electrified or non-electrified) may also be considered (see Huijser *et al.* 2015).
- It is likely that grizzly bears will eventually be hit by vehicles in the area between Ravalli Hill and St. Ignatius (Chapter 5). If the objective is to reduce the likelihood of grizzly-bear vehicle collisions, this road section may require additional mitigation.
- Remove the human access point in Ravalli Curves, just north of Spring Creek (RC 381). The human access point is barely used by humans but it does allow wildlife, including deer, access into the fenced road corridor (Chapter 12). The gap can be closed relatively easily with a section of wildlife fence.
- Retrofit the wildlife guards so that the concrete ledges are no longer accessible to wildlife (Chapter 10). The current bulb-outs with fence material at the N and S guards just south of Ravalli are not effective. The concrete ledges need to be made inaccessible to wildlife across their entire length.
- Retrofit connections between wing walls of certain crossing structures and the retaining walls of certain jump-outs. Wedge shaped openings have led to a deer getting stuck and dying at RC 406. Bringing the fences snug and parallel to the walls can reduce or eliminate this problem.
- Vegetation maintenance at the top and bottom of the jump-outs is required. This is especially true in the Ravalli Curves and Ravalli Hill areas as vegetation maintenance by the researchers ended in 2012. Dense vegetation on the top and bottom of the jump-outs may negatively affect wildlife use of the jump-outs. Lack of vegetation management at the jump-outs may keep wildlife inside the fenced road corridor for a longer period of time.
- Carefully reduce the height of the jump-outs. While there are no established standards for the performance of wildlife jump-outs, the use by white-tailed deer appears very low (about 7 percent use to access the safe side of the wildlife fence). Mule deer appear more able or willing to use the jump-outs to access the safe side of the wildlife fence (about 32 percent use). As no deer were observed jumping up into the fenced road corridor, the researchers suggest experimenting with gradually lowering the wildlife jump-outs. However, the researchers strongly suggest accompanying this with further research and monitoring as lower jump-outs may also result in more animals jumping up to access the fenced road corridor with the associated risk of wildlife-vehicle collisions. It is important

that wildlife jump-outs are low enough to allow wildlife to jump down to the safe side of the wildlife fence but the jump-outs should remain high enough to minimize the probability that wildlife will jump up into the fenced road corridor.

15.4. Research Needs

- Wildlife guards. The wildlife guards are a substantial barrier to white-tailed deer and mule deer but not to mountain lion, bobcat or black bear. However, there is a danger associated with wildlife guards that is underestimated at this time; animals, specifically deer that walk on the metal grate, have been observed falling through the openings with their legs, potentially resulting in broken legs and ultimately death. The researchers suggest investigating this potential problem before implementing wildlife guards at a wider scale.

- Wildlife jump-outs. While there are no established standards for the performance of wildlife jump-outs, the use by white-tailed deer is very low (about 7 percent use to access the safe side of the wildlife fence). Mule deer are more able or willing to use the jump-outs to access the safe side of the wildlife fence (about 32 percent use). As no deer were observed jumping up into the fenced road corridor, the researchers suggest experimenting with gradually lowering the wildlife jump-outs. However, the researchers strongly suggest accompanying this with further research and monitoring as lower jump-outs may also result in more animals jumping up to access the fenced road corridor with the associated risk of wildlife-vehicle collisions. The research may include an experiment with variable height of a jump-out in an enclosure with captive animals as well as an experiment with a limited number of wildlife jump-outs along US 93 North. Based on the results of the research the remainder of the wildlife jump-outs could be modified.

- Electric wildlife deterrent mats. Wildlife guards are ineffective for bear species, mountain lions and bobcats. The researchers have suggested implementing additional mitigation measures in areas with grizzly bear presence and grizzly-bear vehicle collisions (especially between St. Ignatius and Ronan). The suggested measures include longer and preferably continuous wildlife fences and electric mats embedded in the roadway at fence ends and at access roads. The researchers suggest accompanying the implementation of electric mats with research to aid the design of barriers that are effective for both bears and ungulates.

- Automated gates. There is almost no information about the effectiveness and the potential installation and maintenance issues for gates that open automatically when a vehicle approaches (Huijser *et al.* 2015). These gates do not require the driver to leave their vehicle and the gates close automatically after a vehicle has passed.

16. RELATED PUBLICATIONS AND ACTIVITIES

The publications and activities listed below were at least partly based on data generated by the pre- and post-construction research or the implementation of the wildlife mitigation measures along US 93 North.

16.1. Peer-reviewed Publications in Scientific Journals

Huijser, M.P., J.W. Duffield, A.P. Clevenger, R.J. Ament & P.T. McGowen. 2009. Cost-benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada; a decision support tool. Ecology and Society 14(2): 15. [online] URL: http://www.ecologyandsociety.org/viewissue.php?sf=41

Allen, T.D.H, M.P. Huijser & D. Willey. 2013. Evaluation of wildlife guards at access roads. Effectiveness of Wildlife Guards at Access Roads. Wildlife Society Bulletin 37(2):402–408.

Huijser, M.P., E.R. Fairbank, W. Camel-Means, J. Graham, V. Watson, P. Basting & D. Becker. 2016. Effectiveness of short sections of wildlife fencing and crossing structures along highways in reducing wildlife-vehicle collisions and providing safe crossing opportunities for large mammals. Biological Conservation 197: 61-68.

16.2. Conference Proceedings

Hardy, A. A.P. Clevenger, M. Huijser & G. Neale. 2003. An overview of methods and approaches for evaluating the effectiveness of wildlife crossing structures: emphasizing the science in applied science. Pages 319-330 in: C.L. Irwin, P. Garrett, and K.P. McDermott (eds.). 2003 Proceedings of the International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC, USA. Available from the internet. URL: http://www.itre.ncsu.edu/cte/icoet/03proceedings.html

Huijser, M.P., J.W. Duffield, A.P. Clevenger, R.J. Ament & P.T. McGowen. 2010. Cost justification and examples of cost-benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada. Pages: 625-639 in: P. Wagner, D. Nelson and E. Murray (eds.). Proceedings of the 2009 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC, USA. Available from the internet: URL: http://www.icoet.net/ICOET_2009/downloads/proceedings/ICOET2009-Proceedings-Complete.pdf

MacKay, P., R. A. Long, J.S. Begley, A.P. Clevenger, M.P. Huijser, A.R. Hardy & R.J. Ament. 2010. The importance of pre-construction data for planning and evaluating wildlife crossing structures. Pages: 839-840 in: P. Wagner, D. Nelson and E. Murray (eds.). Proceedings of the 2009 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC, USA. Available from the internet: URL: http://www.icoet.net/ICOET_2009/downloads/proceedings/ICOET2009-Proceedings-Complete.pdf

Huijser, M.P., T.D.H. Allen, W. Camel, K. Paul & P. Basting. 2012. Use of wildlife crossing structures on US Highway 93 on the Flathead Indian Reservation in Montana. Pp. 1021-1022. In: Proceedings of the 2011 International Conference on Ecology and Transportation, edited by Paul J. Wagner, Debra Nelson, and Eugene Murray. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University, USA.

Connolly-Newman, H.R., M.P. Huijser, L. Broberg, C.R. Nelson & W. Camel-Means. 2013. Effect of Cover on Small Mammal Movement Through Wildlife Underpasses on U.S. Highway 93 North, Montana, USA. In: Proceedings of the 2013 International Conference on Ecology and Transportation. http://www.icoet.net/ICOET_2013/proceedings-poster-sessions.asp

Purdum, J. & M.P. Huijser2013. Acceptance of Large Mammal Underpasses By White-Tailed Deer and Mule Deer. In: Proceedings of the 2013 International Conference on Ecology and Transportation. http://www.icoet.net/ICOET_2013/proceedings-poster-sessions.asp

van der Grift, E.A., M.P. Huijser, J. Purdum & W. Camel-Means. 2015. Estimating Crossing Rates at Wildlife Crossing Structures: Methods Matter! In: Proceedings of the 2015 International Conference on Ecology and Transportation.

Huijser, M.P., E. Fairbank, W. Camel-Means, D. Becker, J. Graham, V. Watson & P. Basting. 2015. The Effectiveness of Wildlife Underpasses in Combination with Short Sections of Wildlife Fencing in Providing Safe Crossing Opportunities for Wildlife and Reducing Wildlife-Vehicle Collisions for Large Mammals. In: Proceedings of the 2015 International Conference on Ecology and Transportation.

16.3. Theses

McCoy, K.R. 2005. Effects of transportation and development on black bear movement, mortality, and use of the Highway 93 corridor in NW Montana. M.S. Thesis. Wildlife Biology, University of Montana.
http://scholarworks.umt.edu/cgi/viewcontent.cgi?article=3216&context=etd

Camel, W.R. Where does a deer cross a road? Road and land cover characteristics affecting deer crossing and mortality across the US 93 corridor on the Flathead Indian Reservation, Montana. 2007. MSc Thesis in Fish & Wildlife Management, Montana State University, Bozeman, Montana, USA.
http://scholarworks.montana.edu/xmlui/bitstream/handle/1/1030/camelw0507.pdf?sequence=1

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Allen, T.D.H. 2011. The use of wildlife underpasses and the barrier effect of wildlife guards for deer and black bear. Department of Ecology, Montana State University, Bozeman, MT, USA. http://scholarworks.montana.edu/xmlui/bitstream/handle/1/817/AllenT0511.pdf?sequence=1

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Connolly-Newman, H. 2013. Effect of cover on small mammal abundance and movement through wildlife underpasses Environmental Studies, University of Montana, Missoula, MT, USA. http://etd.lib.umt.edu/theses/available/etd-06242013-170719/unrestricted/HCNewman_thesis_FINAL.pdf

Fairbank, E.R. 2014. Use and effectiveness of wildlife crossing structures with short sections of wildlife fencing in western Montana. Environmental Studies, University of Montana, Missoula, MT, USA. http://etd.lib.umt.edu/theses/available/etd-01212014-141624/unrestricted/Fairbank_Elizabeth_Thesis.pdf

Andis, A.Z. 2016. Performance measures of road crossing structures from relative movement rates of large mammals. Environmental Studies, University of Montana, Missoula, Montana, USA. http://scholarworks.umt.edu/cgi/viewcontent.cgi?article=11710&context=etd

16.4. Reports

Excluding annual and quarterly reports for this project.

Hardy, A.R., J.Fuller, M. P. Huijser, A. Kociolek, M. Evans. 2007. Evaluation of Wildlife Crossing Structures and Fencing on US Highway 93 Evaro to Polson. Phase I: Preconstruction Data Collection and Finalization of Evaluation Plan. Final Report. FHWA/MT-06-008/1744-1. Western Transportation Institute, College of Engineering, Montana State University, Bozeman, MT, USA. Available from the internet: http://www.mdt.mt.gov/research/projects/env/wildlife_crossing.shtml

Hardy, A.R., and M. P. Huijser. 2007. US 93 Preconstruction Wildlife Monitoring Field Methods Handbook. FHWA/MT-06-008/1744-2. Western Transportation Institute, Montana State University, Bozeman, MT, USA. Available from the internet: http://www.mdt.mt.gov/research/projects/env/wildlife_crossing.shtml

16.5. People’s Way Partnership

The People’s Way Partnership provides information and conducts educational activities related to the wildlife mitigation measures along US 93 North. More information is available from the website of the People’s Way Partnership: http://www.peopleswaywildlifecrossings.org/
Examples of the outreach activities: providing excursions, public talks, talks in schools, organizing drawing contests for children in schools, and producing posters and brochures with images of wildlife using the structures.

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18. APPENDICES

A1. The 39 wildlife crossing structures along US 93 North considered suitable for medium sized or large mammals.

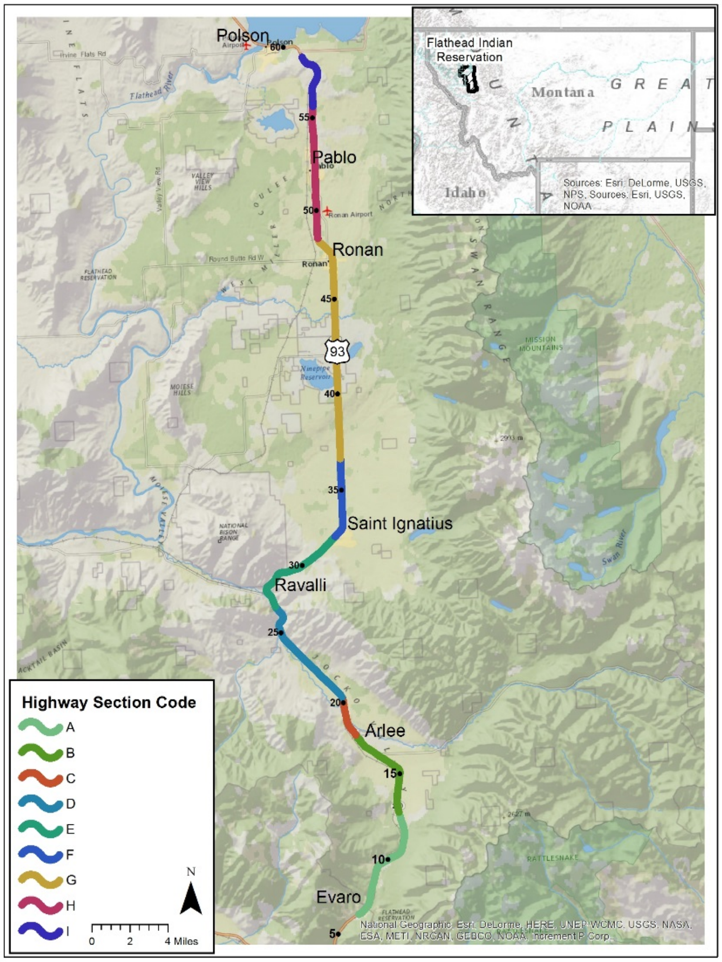
Area	# in Fig. 1	Ref. post	Structure name	Structure type	Dimensions (W x H x L) (ft)*[1]	Dimensions (W x H x L) (m)*[1]	Construction period	Fenced road length (mi)*[2]	Coordinates (latitude, longitude)
	1	8.77	North Evaro	Large culvert	25.4 x 16.7 x 84.6	7.75 x 5.1 x 25.8	2009-2010	No	47° 3'32.62"N, 114° 4'32.19"W
Evaro	2	9.68	Railroad bridge	Over span bridge	339.6 x 31.8 x 39.4	103.5 x 9.7 x 12.0	2009-2010	1.67	47° 4'12.07"N, 114° 3'58.15"W
	3	10.04	Finley Creek 1	Large culvert	26.1 x 18.2 x 105.0	7.95 x 5.55 x 32.0	2009-2010	1.67	47° 4'20.48"N, 114° 3'34.37"W
	4	10.28	Finley Creek 2	Large culvert	26.1 x 18.2 x 71.9	7.95 x 5.55 x 21.9	2009-2010	1.67	47° 4'25.96"N, 114° 3'18.08"W
	5	10.34	Overpass	Overpass	196.9 x n/a x 206.7	60 x n/a x 63.0	2009-2010	1.67	47° 4'27.21"N, 114° 3'13.87"W
	6	10.53	Finley Creek 3	Large culvert	25.4 x 16.7 x 81.0	7.75 x 5.1 x 24.7	2009-2010	1.67	47° 4'31.27"N, 114° 3'0.98"W
	7	10.82	Finley Creek 4	Large culvert	26.1 x 18.2 x 83.0	7.95 x 5.55 x 25.3	2009-2010	1.67	47° 4'41.20"N, 114° 2'43.70"W
	8	11.90	Schley Creek	Large culvert	25.4 x 16.7 x 98.4	7.75 x 5.1 x 30	2009-2010	0.14*[3]	47° 5'35.03"N, 114° 2'26.26"W
	9	12.24	E. Fork Finley Creek	Large culvert	25.4 x 16.7 x 79.7	7.75 x 5.1 x 24.3	2009-2010	No	47° 5'53.01"N, 114° 2'31.96"W
Jocko River	10	18.83	Jocko River 1	Box culvert	6.9 x 6.9 x 147.6	2.1 x 2.1 x 45	2005-2006	0.38	47°10'31.34"N, 114° 5'54.11"W
	11	18.86	Jocko River 2	Box culvert	6.9 x 6.9 x 141.1	2.1 x 2.1 x 43	2005-2006	0.38	47°10'33.43"N, 114° 5'55.52"W
	12	18.90	Jocko River 3	Box culvert	6.9 x 6.9 x 131.2	2.1 x 2.1 x 40	2005-2006	0.38	47°10'35.48"N, 114° 5'56.71"W
	13	18.98	Jocko River bridge	Over span bridge	54.5 x 17.1 x 393.7	16.6 x 5.2 x 120	2005-2006	0.38	47°10'39.21"N, 114° 5'58.73"W
Ravalli Curves	14	22.97	RC 377	Box culvert	7.9 x 7.9 x 122.0	2.4 x 2.4 x 37.2	2006-2007	3.74	47°13'30.37"N, 114° 8'34.49"W
	15	23.21	RC 381 (Spring Cr.)	Over span bridge	98.4 x 15.1 x 39.4	30 x 4.6 x 12	2006-2007	3.74	47°13'39.78"N, 114° 8'47.95"W
	16	24.20	RC 396	Large culvert	22.5 x 15.7 x 72.2	6.86 x 4.78 x 22	2006-2007	3.74	47°14'17.77"N, 114° 9'39.89"W
	17	24.82	RC 406	Large culvert	22.5 x 15.7 x 84.0	6.86 x 4.78 x 25.6	2006-2007	3.74	47°14'41.89"N, 114°10'8.12"W
	18	25.77	RC 422 (Side Channel)	Over span bridge	98.4 x 17.1 x 39.4	30 x 5.2 x 12	2006-2007	3.74	47°15'27.43"N, 114°10'5.20"W
	19	26.07	RC 426	Box culvert	3.9 x 5.9 x 89.9	1.2 x 1.8 x 27.4	2006-2007	3.74	47°15'42.00"N, 114°10'6.72"W
	20	26.13	RC 427	Small culvert	6.7 x 4.9 x 82.0	2.05 x 1.5 x 25	2006-2007	3.74	47°15'44.58"N, 114°10'9.73"W
	21	26.28	RC 431	Box culvert	5.9 x 3.9 x 80.1	1.8 x 1.2 x 24.4	2006-2007	3.74	47°15'50.55"N, 114°10'17.00"W
	22	26.39	RC 432 (Copper Cr.)	Large culvert	25.4 x 16.7 x 60.0	7.75 x 5.1 x 18.3	2006-2007	3.74	47°15'54.98"N, 114°10'22.65"W
Ravalli Hill	23	28.11	RH 1	Large culvert	24.0 x 17.1 x 128.0	7.3 x 5.2 x 39	2006-2007	1.09	47°17'7.75"N, 114°10'42.99"W
	24	28.38	RH 2	Large culvert	24.0 x 17.1 x 102.4	7.3 x 5.2 x 31.2	2006-2007	1.09	47°17'17.82"N, 114°10'29.37"W
	25	30.48	Pistol Creek 1	Large culvert	24.0 x 17.1 x 131.2	7.3 x 5.2 x 40	2006-2007	No	47°18'6.74"N, 114° 8'7.23"W
	26	30.68	Pistol Creek 2	Large culvert	24.0 x 17.1 x 131.2	7.3 x 5.2 x 40	2006-2007	No	47°18'12.50"N, 114° 7'55.51"W
	27	31.77	Sabine Creek	Large culvert	24.0 x 12.0 x 47.9	7.32 x 3.65 x 14.6	2006-2007	0.12	47°18'46.26"N, 114° 6'56.42"W
	28	32.45	Mission Creek	Over span bridge	54.5 x 16.1 x 131.2	16.6 x 4.9 x 40	2006-2007	0.22	47°19'10.80"N, 114° 6'19.75"W
	29	33.81	Post Creek 1	Large culvert	24.0 x 15.6 x 94.5	7.32 x 4.75 x 28.8	2006-2007	0.07	47°20'13.97"N, 114° 5'48.82"W
	30	34.09	Post Creek 2	Large culvert	24.0 x 15.6 x 72.2	7.32 x 4.75 x 22	2006-2007	0.07	47°20'28.51"N, 114° 5'48.43"W
	31	34.40	Post Creek 3	Large culvert	24.0 x 15.6 x 64.0	7.32 x 3.9 x 19.5	2006-2007	0.11	47°20'44.42"N, 114° 5'48.30"W
	32	34.51	Post Creek 4	Small culvert	5.9 x 3.9 x 129.9	1.8 x 1.2 x 39.6	2006-2007	No	47°20'50.48"N, 114° 5'48.40"W
	33	34.75	Post Creek 5	Small culvert	7.9 x 7.9 x 104.0	2.4 x 2.4 x 31.7	2006-2007	No	47°21'2.55"N, 114° 5'48.63"W
	34	36.40	Post Creek 6	Small culvert	5.9 x 3.9 x 96.1	1.8 x 1.2 x 29.3	2006-2007	No	47°22'28.68"N, 114° 5'48.05"W
	35	36.73	Post Creek 7	Small culvert	5.9 x 3.9 x 104.0	1.8 x 1.2 x 31.7	2006-2007	No	47°22'46.17"N, 114° 5'48.46"W
	36	48.75	Spring Creek 1	Large culvert	27.9 x 9.8 x 145.7	8.5 x 3.0 x 44.4	2007-2008	0.15	47°32'57.89"N, 114° 6'47.20"W
	37	49.27	Spring Creek 2	Large culvert	27.9 x 9.8 x 170.3	8.5 x 3.0 x 51.9	2007-2008	0.09	47°33'29.16"N, 114° 6'46.99"W
	38	50.96	Mud Creek	2 Large culverts	42.0 x 13.8 x 52.3	12.8 x 4.2 x 15.94	2007-2008	0.16	47°34'53.10"N, 114° 6'47.09"W
	39	57.76	Polson Hill	2 Large culverts	22.0 x 12.0 x 52.0	6.71 x 3.66 x 15.85	2004-2005	0.87	47°40'34.97"N, 114° 6'29.95"W

*[1] As seen by the animals, *[2] Wildlife fence, *[3] West side highway only

A2. The length of the fenced road sections, measured as “road length fenced”. This ignores additional fence length as a result of the fences not always running perfectly parallel to the highway.

Name fenced section		Mi reference post		Length (mi)			Road length with wildlife fences on both sides
		west	east	west	east		
Evaro	start	9.33	9.30	1.70	1.70		1.67
	end	11.03	11.00				
Schley	start	11.86	no fence	0.14	0.00		0.00
	end	12.00	no fence				
Jocko	start	18.72	18.75	0.41	0.38		0.38
	end	19.13	19.13				
Ravalli Curves	start	22.93	22.93	3.74	3.75		3.74
	end	26.67	26.68				
Ravalli Hill	start	27.53	27.56	1.12	1.09		1.09
	end	28.65	28.65				
Sabine Creek	start	31.73	31.74	0.13	0.15		0.12
	end	31.86	31.89				
Mission Creek	start	32.32	32.32	0.21	0.22		0.22
	end	32.53	32.53				
Post Creek 1	start	32.77	32.75	0.09	0.07		0.07
	end	32.86	32.82				
Post Creek 2	start	34.04	34.03	0.07	0.08		0.07
	end	34.11	34.11				
Post Creek 3	start	34.32	34.32	0.13	0.11		0.11
	end	34.45	34.42				
Spring Creek 1	start	48.66	48.66	0.15	0.17		0.15
	end	48.81	48.83				
Spring Creek 2	start	49.22	49.25	0.12	0.09		0.09
	end	49.34	49.34				
Mud Creek	start	50.84	50.85	0.16	0.18		0.16
	end	51.00	51.03				
Polson Hill	start	57.22	57.19	1.03	0.90		0.87
	end	58.25	58.09				
Total road length fenced (mi)				9.18	8.87		8.71

B. The reconstruction time period for the different road sections along US 93 North (based on Peccia & Associates 2015).



Highway section code on map	Name road section	Mile reference post	Reconstruction period
A	Evaro-McClure Road	6.5-12.9	10 Sep 2008 - 8 Oct 2010
B	McClure Rd-N of Arlee Couplet	12.9-18.1	27 Oct 2008 - 21 Jul 2011
C	N of Arlee-Vic White Coyote Rd	18.1-20.2	15 Nov 2004 - 15 Nov 2006
D	Vic White Coyote Rd - S of Ravalli	20.2-26.7	6 Mar 2006 - 24 Oct 2007
E	S of Ravalli-Medicine Tree	26.7-31.4	24 Apr 2006 - 1 Dec 2008
F	Medicine Tree-Vic Red Horn Rd	31.4-36.8	20 Apr 2006 - 9 Jun 2009
G	Ninepipe wetland area	36.8-48.4	Not reconstructed yet
H	Spring Creek Rd-Minesinger TRL	48.4-55.7	7 Sep 2007 - 25 Jun 2009
I	Minesinger Trail-MT 35	55.7 58.7	19 Apr 2005 - 12 Oct 2006

C. The number of reported carcasses of large wild mammals and large mammal-vehicle crashes in the Evaro, Ravalli Curves and Ravalli Hill areas (fenced road sections and control areas).

Evaro					**Ravalli Curves**					**Ravalli Hill**			
Treatment	**Year**	**Carcasses**	**Crashes**		**Treatment**	**Year**	**Carcasses**	**Crashes**		**Treatment**	**Year**	**Carcasses**	**Crashes**
Fenced	2002	4	1		Fenced	2002	7	5		Fenced	2002	0	1
Fenced	2003	1	1		Fenced	2003	0	5		Fenced	2003	0	1
Fenced	2004	1	1		Fenced	2004	5	0		Fenced	2004	0	0
Fenced	2005	2	2		Fenced	2005	6	2		Fenced	2005	1	2
Fenced	2006	0	3		Fenced	2008	1	2		Fenced	2008	0	0
Fenced	2007	2	0		Fenced	2009	2	2		Fenced	2009	1	0
Fenced	2008	1	3		Fenced	2010	3	3		Fenced	2010	0	0
Fenced	2011	0	0		Fenced	2011	5	0		Fenced	2011	1	0
Fenced	2012	2	1		Fenced	2012	3	0		Fenced	2012	1	1
Fenced	2013	1	0		Fenced	2013	4	1		Fenced	2013	3	1
Fenced	2014	3	1		Fenced	2014	7	2		Fenced	2014	0	0
Fenced	2015	0	0		Fenced	2015	2	2		Fenced	2015	0	1
Control	2002	7	2		Control	2002	4	1		Control	2002	0	0
Control	2003	3	1		Control	2003	0	5		Control	2003	0	0
Control	2004	3	3		Control	2004	0	0		Control	2004	1	0
Control	2005	0	1		Control	2005	2	0		Control	2005	0	0
Control	2006	0	0		Control	2008	1	5		Control	2008	2	0
Control	2007	0	3		Control	2009	8	3		Control	2009	1	0
Control	2008	0	0		Control	2010	5	3		Control	2010	1	3
Control	2011	12	3		Control	2011	3	1		Control	2011	0	0
Control	2012	8	2		Control	2012	7	5		Control	2012	4	0
Control	2013	3	1		Control	2013	7	7		Control	2013	2	1
Control	2014	3	2		Control	2014	16	3		Control	2014	1	0
Control	2015	5	3		Control	2015	11	2		Control	2015	1	1

D. Characteristics of the pellet group transects and number of black pellet groups found. Grey cells indicate transects not surveyed because of reconstruction or because data collection was completed for those transects.

Area	Hwy segment	Latitude	Longitude	East/west	Compass bearing	2004	2005	2008	2009	2010	2011	2012	2013	2014	2015
Evaro	131	47° 2'38.72"N	114° 4'53.40"W	E	95	0	2				10				
Evaro	131	47° 2'38.72"N	114° 4'53.40"W	W	288							5	3	8	8
Evaro	141	47° 3'11.32"N	114° 4'41.68"W	W	250							4	4	9	10
Evaro	147	47° 3'29.90"N	114° 4'33.62"W	W	260						0	2	6	6	18
Evaro	147	47° 3'29.90"N	114° 4'33.62"W	E	80	0	0								
Evaro	151	47° 3'43.79"N	114° 4'28.26"W	E	90	14	2				0	6	6	5	4
Evaro	158	47° 4'4.14"N	114° 4'16.10"W	W	273	5	11				3	8	13	14	4
Evaro	160	47° 4'7.51"N	114° 4'10.69"W	E	85	11	1				13				
Evaro	168	47° 4'17.73"N	114° 3'41.94"W	E	130	20	3				0	1	15	10	26
Evaro	169	47° 4'18.38"N	114° 3'40.11"W	W	325	11	0				0	8	12	4	7
Evaro	172	47° 4'25.89"N	114° 3'18.22"W	E	125	5	13				0	0	10		3
Evaro	172	47° 4'25.89"N	114° 3'18.22"W	W	310									0	12
Evaro	177	47° 4'31.17"N	114° 3'0.88"W	W	315	5	8				0	0	7	10	10
Evaro	180	47° 4'36.00"N	114° 2'50.41"W	W	310	2	4				1	0	1	7	12
Evaro	181	47° 4'37.51"N	114° 2'47.90"W	E	124	6	5				3	0	7	4	17
Ravalli Curves	388	47°13'56.37"N	114° 9'11.48"W	E	49	1	0	1	0	1	0	0			
Ravalli Curves	396	47°14'17.88"N	114° 9'39.87"W	E	47	4	4	0	0	3	0	2			
Ravalli Curves	406	47°14'40.41"N	114°10'7.50"W	E	78	1	3	2	0	4	0	3			
Ravalli Curves	409	47°14'48.65"N	114°10'10.69"W	E	74	4	2	13	7	4	0	0			
Ravalli Curves	411	47°14'54.16"N	114°10'13.30"W	E	74					25	9	3			
Ravalli Curves	412	47°14'59.96"N	114°10'16.29"W	E	70	10	0	13	3						
Ravalli Curves	415	47°15'8.95"N	114°10'20.25"W	W	348	0	4	2	5	1	0	1			
Ravalli Curves	418	47°15'17.80"N	114°10'17.43"W	W	300	0	0	2	0	1	0	0			
Ravalli Curves	422	47°15'27.18"N	114°10'5.28"W	W	296	1	0	0	5						
Ravalli Curves	425	47°15'36.79"N	114°10'3.04"W	W	250	0	0	0	2	1	0	0			
Ravalli Curves	429	47°15'48.10"N	114°10'13.84"W	E	45	0	1	0	0	0	0	0			
Ravalli Curves	431	47°15'50.54"N	114°10'16.94"W	E	45	4	0	0	0	0	0	0			
Ravalli Hill	461	47°17'10.91"N	114°10'37.76"W	E	138	0	0	0	0	0	1	0			
Ravalli Hill	464	47°17'19.25"N	114°10'27.98"W	E	121	0	2	0	0	0	0	0			
Ravalli Hill	466	47°17'25.82"N	114°10'22.37"W	E	127	0	0	0	0	2	0	0			

E. The effectiveness of the road sections with wildlife fences on both sides of US 93 North in reducing wildlife-vehicle collisions.

Fenced area	Start and end point fence (mi reference post)	Crossing structures considered suitable for ungulates (deer and larger) (n)	Road length fenced (both sides of highway) (Appendix A) mi	Road length fenced (both sides of highway) (Appendix A) km	Before-After comparison: Carcasses/yr Before	Before-After comparison: Carcasses/yr After	Before-After comparison: Crashes/yr Before	Before-After comparison: Crashes/yr After	Reduction (%) Carcasses	Reduction (%) Crashes	Reduction (%) Average carcasses and crashes (data used in graph)
Evaro	9.3-11.0	6	1.7	2.7	1.57	1.20	1.57	0.40	23.57	74.52	49.0
Jocko River	18.7-19.1	1	0.4	0.6	0.67	0.78	0.33	0.00	0.00	100.00	50.0
Ravalli Curves	22.9-26.7	5	3.7	6	4.50	3.38	3.00	1.50	24.89	50.00	37.4
Ravalli Hill	27.5-28.7	2	1.1	1.7	0.25	0.75	1.00	0.38	0.00	62.00	31.0
Sabine Creek	31.7-31.9	1	0.1	0.2	0.00	1.50	0.25	0.38	0.00	0.00	0.0
Mission Creek	32.3-32.5	1	0.2	0.3	0.00	0.25	0.75	0.00	0.00	100.00	50.0
Post Creek 1	32.8-32.9	1	0.1	0.1	0.00	0.38	0.50	0.00	0.00	100.00	50.0
Post Creek 2	34.0-34.1	1	0.1	0.1	0.25	1.38	0.00	0.38	0.00	0.00	0.0
Post Creek 3	34.3-34.5	1	0.1	0.2	1.00	0.00	0.75	0.00	100.00	100.00	100.0
Spring Creek 1	48.7-48.8	1	0.2	0.2	0.00	0.00	0.00	0.29	n/a	0.00	0.0
Spring Creek 2	49.2-49.3	1	0.1	0.1	0.00	0.14	0.20	0.14	0.00	28.57	14.3
Mud Creek	50.8-51.0	1	0.2	0.2	0.40	0.14	0.00	0.29	65.00	0.00	32.5
Polson Hill	57.2-58.3	1	0.9	1.4	0.00	0.89	2.33	1.33	0.00	42.92	21.5

F. Bear collision data along US 93 North (mi reference post 7.1-59.0) between 1998-2015.

Observation date	Mile reference post	Species	Gender	Comments	Reported by	Source
24-Jun-95	18.9				MHP/MDT	Hardy *et al.* (2007)
20-May-97	10.1				MHP/MDT	Hardy *et al.* (2007)
30-Aug-98	18.8				MHP/MDT	Hardy *et al.* (2007)
14-Sep-98	31.8				MHP/MDT	Hardy *et al.* (2007)
27-Oct-98	12.8				MHP/MDT	Hardy *et al.* (2007)
23-Nov-98	25.9				MHP/MDT	Hardy *et al.* (2007)
26-Nov-98	26.1	Black Bear				MDT carcass
9-Jan-99	25.9	Black Bear				MDT carcass
29-Jun-99	7.5				MHP/MDT	Hardy *et al.* (2007)
1-Oct-00	32.3				MHP/MDT	Hardy *et al.* (2007)
3-Jun-02	37.8	Grizzly Bear				MDT carcass
8-Jun-02	7.6				MHP/MDT	Hardy *et al.* (2007)
18-Jun-02	7.3	Black Bear				MDT carcass
28-Jul-02	7.5				MHP/MDT	Hardy *et al.* (2007)
19-Sep-02	8				MTFWP	Hardy *et al.* (2007)
19-Sep-02	8				MTFWP	Hardy *et al.* (2007)
19-Sep-02	8				MTFWP	Hardy *et al.* (2007)
11-Oct-02	12.2	Black Bear				MDT carcass
22-Apr-03	7.6	Black Bear				MDT carcass
28-May-03	25.1				MHP/MDT	Hardy *et al.* (2007)
2-Sep-03	18.7				MHP/MDT	Hardy *et al.* (2007)
23-Sep-03	12.5	Black Bear				MDT carcass
26-Sep-03	7.8				MTFWP	Hardy *et al.* (2007)
1-Oct-03	13.1	Black Bear				MDT carcass

Continued on next page

Observation date	Mile reference post	Species	Gender	Comments	Reported by	Source
15-Oct-03	14.3	Black Bear				MDT carcass
30-Oct-03	34.5	Black Bear				MDT carcass
26-Jul-04	13				MTFWP	Hardy *et al.* (2007)
8-Sep-04	13				MTFWP	Hardy *et al.* (2007)
19-Aug-05	24.5				MHP/MDT	Hardy *et al.* (2007)
8-Oct-08	9	Black Bear	UNK	hit in evaro. Head cut off	MORAN	CSKT
1-Sep-09	23.5	Black Bear	UNK		Tribal Game Wardens	CSKT
1-May-10	41.3	Grizzly Bear	UNK		Tribal Game Wardens	CSKT
10-Aug-10	11	Black Bear	UNK		Tribal Game Wardens	CSKT
10-Aug-10	30	Black Bear	UNK		Tribal Game Wardens	CSKT
1-Sep-10	26	Black Bear	UNK		Tribal Game Wardens	CSKT
1-Oct-10	14	Black Bear	UNK		Tribal Game Wardens	CSKT
1-Oct-10	31	Black Bear	UNK		Tribal Game Wardens	CSKT
1-Oct-10	32	Black Bear	UNK		Tribal Game Wardens	CSKT
1-Sep-11	15	Black Bear	UNK	three bears hit at once	Tribal Game Wardens	CSKT
1-Sep-11	15	Black Bear	UNK	three bears hit at once	Tribal Game Wardens	CSKT
1-Sep-11	15	Black Bear	UNK	three bears hit at once	Tribal Game Wardens	CSKT
1-Sep-11	21	Black Bear	UNK		Tribal Game Wardens	CSKT
2-Nov-11	33.5	Black Bear				MDT carcass
2-Nov-11	33.5	Black Bear				MDT carcass
25-Apr-12	33.148	Black Bear				MDT carcass
25-Apr-12	33.148	Black Bear				MDT carcass
1-May-12	34.6	Grizzly Bear	UNK		Tribal Game Wardens	CSKT
1-Sep-12	35	Grizzly Bear	UNK	cub	Tribal Game Wardens	CSKT
27-Sep-12	13.498	Black Bear				MDT carcass
1-Oct-12	31	Black Bear	UNK		Tribal Game Wardens	CSKT

Continued on next page

Observation date	Mile reference post	Species	Gender	Comments	Reported by	Source
1-Nov-12	24	Black Bear	UNK		Tribal Game Wardens	CSKT
1-Apr-13	15	Black Bear	UNK	Dirty corner	Tribal Game Wardens	CSKT
1-Aug-13	68	Black Bear	male	Large 10-75?? (McElderry)	Tribal Game Wardens	CSKT
1-Oct-13	37	Grizzly Bear	UNK	Dead about 1 yr right on Post creek, behind guard rail	WBIO	CSKT
1-Aug-14	8	Black Bear	UNK		Tribal Game Wardens	CSKT
1-Sep-14	50	Black Bear	UNK		Tribal Game Wardens	CSKT
1-May-15	11	Black Bear	Male	Actual date unknown. Only month reported	Tribal Game Wardens	CSKT
1-Aug-15	68.2	Black Bear	UNK	Actual date unknown. Only month reported	tribal Game Wardens	CSKT
1-Sep-15	12	Black Bear	UNK	Actual date unknown. Only month reported	Tribal Game Wardens	CSKT
1-Sep-15	12	Black Bear	FEMALE	Actual date unknown. Only month reported	Tribal Game Wardens	CSKT
1-Sep-15	13	Black Bear	FEMALE	Actual date unknown. Only month reported	Tribal Game Wardens	CSKT
1-Sep-15	14	Black Bear	UNK	Actual date unknown. Only month reported	Tribal Game Wardens	CSKT
1-Oct-15	23	Black Bear	UNK	Actual date unknown. Only month reported	Tribal Game Wardens	CSKT
1-Oct-15	46	Grizzly Bear	MALE	Actual date unknown. Only month reported	Tribal Game Wardens	CSKT
1-Oct-15	51	Black Bear	UNK	CUB	Tribal Game Wardens	CSKT

G. Characteristics of the 29 wildlife crossing structures that were monitored for wildlife use.

Area	Structure name	Structure type	Reference post (mi)	Coordinates (latitude, longitude) based on satellite images	Dimensions (as seen by the animals) Width x height x length (m)*[1]	Construction period	Associated with wildlife fence (road length) (mi)
Evaro	Railroad bridge	Bridge	9.68	47° 4'12.07"N, 114° 3'58.15"W	103.5 x 9.7 x 12.0	2009-2010	1.67
	Finley Creek 1	Culvert	10.04	47° 4'20.48"N, 114° 3'34.37"W	7.95 x 5.55 x 32.0	2009-2010	1.67
	Finley Creek 2	Culvert	10.28	47° 4'25.96"N, 114° 3'18.08"W	7.95 x 5.55 x 21.9	2009-2010	1.67
	Overpass	Overpass	10.34	47° 4'27.21"N, 114° 3'13.87"W	60 x n/a x 63.0	2009-2010	1.67
	Finley Creek 3	Culvert	10.53	47° 4'31.27"N, 114° 3'0.98"W	7.75 x 5.1 x 24.7	2009-2010	1.67
	Finley Creek 4	Culvert	10.82	47° 4'41.20"N, 114° 2'43.70"W	7.95 x 5.55 x 25.3	2009-2010	1.67
Ravalli Curves	RC 377	Box culvert	22.97	47°13'30.37"N, 114° 8'34.49"W	2.4 x 2.4 x 37.2	2006-2007	3.74
	RC 381 (Spring Cr.)	Bridge	23.21	47°13'39.78"N, 114° 8'47.95"W	30 x 4.6 x 12	2006-2007	3.74
	RC 396	Culvert	24.20	47°14'17.77"N, 114° 9'39.89"W	6.86 x 4.78 x 22	2006-2007	3.74
	RC 406	Culvert	24.82	47°14'41.89"N, 114°10'8.12"W	6.86 x 4.78 x 25.6	2006-2007	3.74
	RC 422 (Jocko)	Bridge	25.77	47°15'27.43"N, 114°10'5.20"W	30 x 5.2 x 12	2006-2007	3.74
	RC 426	Box culvert	26.07	47°15'42.00"N, 114°10'6.72"W	1.2 x 1.8 x 27.4	2006-2007	3.74
	RC 427	Culvert	26.13	47°15'44.58"N, 114°10'9.73"W	2.05 x 1.5 x 25	2006-2007	3.74
	RC 431	Box culvert	26.28	47°15'50.55"N, 114°10'17.00"W	1.8 x 1.2 x 24.4	2006-2007	3.74
	RC 432 (Copper Cr.)	Culvert	26.39	47°15'54.98"N, 114°10'22.65"W	7.75 x 5.1 x 18.3	2006-2007	3.74
Ravalli Hill	RH 1	Culvert	28.11	47°17'7.75"N, 114°10'42.99"W	7.3 x 5.2 x 39	2006-2007	1.09
	RH 2	Culvert	28.38	47°17'17.82"N, 114°10'29.37"W	7.3 x 5.2 x 31.2	2006-2007	1.09
Isolated	North Evaro	Culvert	8.77	47° 3'32.62"N, 114° 4'32.19"W	7.75 x 5.1 x 25.8	2009-2010	No
	Schley Creek	Culvert	11.90	47° 5'35.03"N, 114° 2'26.26"W	7.75 x 5.1 x 30	2009-2010	0.14*[2]
	N Finley Creek	Culvert	12.24	47° 5'53.01"N, 114° 2'31.96"W	7.75 x 5.1 x 24.3	2009-2010	No
	Pistol Creek 1	Culvert	30.48	47°18'6.74"N, 114° 8'7.23"W	7.3 x 5.2 x 40	2006-2007	No
	Pistol Creek 2	Culvert	30.68	47°18'12.50"N, 114° 7'55.51"W	7.3 x 5.2 x 40	2006-2007	No
	Mission Creek	Bridge	32.45	47°19'10.80"N, 114° 6'19.75"W	16.6 x 4.9 x 40	2006-2007	0.22
	Post Creek 1	Culvert	33.81	47°20'13.97"N, 114° 5'48.82"W	7.32 x 4.75 x 28.8	2006-2007	0.07
	Post Creek 2	Culvert	34.09	47°20'28.51"N, 114° 5'48.43"W	7.32 x 4.75 x 22	2006-2007	0.07
	Post Creek 3	Culvert	34.40	47°20'44.42"N, 114° 5'48.30"W	7.32 x 3.9 x 19.5	2006-2007	0.11
	Spring Creek 1	Culvert	48.75	47°32'57.89"N, 114° 6'47.20"W	8.5 x 3.0 x 44.4	2007-2008	0.15
	Spring Creek 2	Culvert	49.27	47°33'29.16"N, 114° 6'46.99"W	8.5 x 3.0 x 51.9	2007-2008	0.09
	Polson Hill	2 Culverts	57.76	47°40'34.97"N, 114° 6'29.95"W	6.71 x 3.66 x 15.85	2004-2005	0.87

*[1] See Appendix A1 for English units, *[2] west side highway only

H1. Certain identification of species, crossed structures, summary data 2008 for tracking data for period 23 May 2008 – 31 December 2008 (correction factor for cameras not applied). Note: Data from RC 377 were based on wildlife camera.

2008											
Species	RC 377	RC 381	RC 396	RC 406	RC 422	RC 426	RC 427	RC 431	RC 432	RH 459	RH 463
Deer spp. (*Odocoileus* spp.)	0	241	431	98	107	0	0	2	13	104	68
Coyote (*Canis latrans*)	0	9	276	81	66	62	22	70	91	48	65
Domesticated cat (*Felis catus*)	0	73	2	34	0	9	5	14	37	6	3
Raccoon (*Procyon lotor*)	0	3	9	8	23	7	4	0	81	0	0
Bobcat (*Lynx rufus*)	0	0	4	5	12	8	8	4	11	26	32
Human	0	13	3	79	0	0	1	1	8	4	0
Black bear (*Ursus americanus*)	0	1	2	2	9	8	27	1	26	8	0
Dom. dog (*Canis lupus familiaris*)	0	0	0	32	0	0	0	0	0	0	0
Mice and voles (Myomorpha)	0	0	2	13	0	0	0	0	0	2	0
Birds (Aves)	0	0	0	14	0	0	0	0	0	0	0
Dom. cat or West. Str. Skunk	0	2	4	2	0	0	0	0	3	0	1
Medium sized mammal	0	1	0	7	0	0	0	0	0	1	0
Horse (*Equus caballus*)	0	0	3	0	1	0	0	0	0	0	0
Medium or large sized mammal	0	0	1	1	1	0	0	0	0	0	1
unknown	0	0	0	0	2	0	0	0	2	0	0
Mountain lion (*Felis concolor*)	0	0	0	1	1	0	0	0	0	1	0
Dom. dog or coyote	0	0	0	2	0	0	0	0	0	0	0
Dom. dog or wolf (*Canis lupus*)	0	1	0	1	0	0	0	0	0	0	0
Red fox (*Vulpes vulpes*)/dom. dog	0	0	1	0	0	0	0	0	0	0	0
Large sized mammal	0	0	0	0	0	0	0	0	0	1	0

H2. Certain identification of species, crossed structures, summary data 2009 for tracking data for period 1 January 2009 – 31 December 2009 (correction factor for cameras not applied). Note: Data from RC 377 were based on wildlife camera.

2009											
Species	RC 377	RC 381	RC 396	RC 406	RC 422	RC 426	RC 427	RC 431	RC 432	RH 459	RH 463
Deer spp. (*Odocoileus* spp.)	0	427	812	65	119	0	0	0	7	163	144
Coyote (*Canis latrans*)	0	135	162	119	111	34	24	57	63	2	31
Domesticated cat (*Felis catus*)	0	102	28	117	1	1	4	7	68	9	12
Human	0	15	10	147	2	0	1	0	5	6	1
Bobcat (*Lynx rufus*)	0	2	3	54	9	12	26	8	25	31	11
Black bear (*Ursus americanus*)	1	0	3	0	34	10	35	2	37	27	3
Raccoon (*Procyon lotor*)	0	13	13	18	18	6	2	1	27	2	8
Domesticated dog (*Canis lupus familiaris*)	0	0	4	101	0	0	0	0	0	0	0
Birds (Aves)	0	0	11	73	1	0	0	0	3	0	3
Western striped skunk (*Mephitis mephitis*)	0	3	28	5	0	2	0	0	4	4	7
Dom. cat or West. Str. Skunk	0	7	7	3	0	0	0	2	5	5	2
Medium sized mammal	0	4	0	5	1	1	0	1	3	2	4
Dom. dog or wolf (*Canis lupus*)	0	0	0	19	0	0	0	0	0	1	0
Mountain lion (*Felis concolor*)	0	0	0	0	0	2	3	0	1	10	0
Red fox (*Vulpes vulpes*)	0	0	0	5	1	0	0	0	0	0	0
Small or medium sized mammal	0	0	0	5	0	0	0	0	0	0	0
Dom. dog or coyote	0	5	0	0	0	0	0	0	0	0	0
unknown	0	1	0	0	0	0	0	0	2	0	0
American badger (*Taxidea taxus*)	0	0	0	0	0	0	0	0	0	0	3
Duck (Anatidae)	0	0	0	0	0	0	0	0	2	0	0
Elk (*Cervus canadensis*)	0	0	0	0	0	0	0	0	0	2	0
Northern river otter (*Lontra canadensis*)	0	0	0	0	0	0	0	0	2	0	0
Large sized mammal	0	0	0	0	0	0	0	0	0	1	0

H3. Successful wildlife crossings through the structures in the Evaro area between 1 January 2011 and 31 December 2015 based on cameras.

Evaro	Cameras 1 Jan 2011 - 31 Dec 2015							
Species	Total (N)	Total (%)	Railroad	Finley Creek 1	Finley Creek 2	Overpass	Finley Creek 3	Finley Creek 4
White-tailed deer (*Odocoileus virginianus*)	23870	82.71	12404	2900	382	6076	911	1197
Domesticated cat (*Felis catus*)	1272	4.41	408	541	105	127	28	63
Human data collector	803	2.78	139	175	104	139	137	109
Black bear (*Ursus americanus*)	605	2.10	27	87	140	30	194	127
Other birds (Aves)	383	1.33	356	6	0	19	2	0
Mule deer (*Odocoileus hemionus*)	382	1.32	8	2	14	27	282	49
Human	293	1.02	53	172	15	32	16	5
Wild turkey (*Meleagris gallopavo*)	269	0.93	207	23	2	36	0	1
Domesticated dog (*Canis lupus familiaris*)	262	0.91	19	22	43	6	10	162
Bobcat (*Lynx rufus*)	149	0.52	1	3	26	18	10	91
Coyote (*Canis latrans*)	134	0.46	5	4	19	59	6	41
Raccoon (*Procyon lotor*)	124	0.43	100	9	3	5	4	3
Deer spp. (*Odocoileus* spp.)	70	0.24	33	2	2	1	16	16
Cattle (*Bos taurus*)	66	0.23	48	17	0	1	0	0
Mountain lion (*Felis concolor*)	58	0.20	2	5	25	6	6	14
Rabbits and hares (Lagomorpha)	31	0.11	0	1	0	2	28	0
Elk (*Cervus canadensis*)	30	0.10	0	0	0	24	1	5
Western striped skunk (*Mephitis mephitis*)	17	0.06	5	2	0	5	3	2
Human and dog	13	0.05	7	2	1	1	0	2
Human and bicycle	8	0.03	8	0	0	0	0	0
Red fox (*Vulpes vulpes*)	6	0.02	0	0	0	6	0	0
Unknown	5	0.02	1	0	0	0	0	4
Human and ATV	3	0.01	1	0	0	2	0	0
Moose (*Alces americanus*)	3	0.01	0	0	0	3	0	0
Other	2	0.01	0	1	0	1	0	0
Northern river otter (*Lontra canadensis*)	1	0.00	1	0	0	0	0	0
Dom. dog or coyote	1	0.00	1	0	0	0	0	0
Bear spp (*Ursus* spp.)	1	0.00	0	1	0	0	0	0
Total	28861	100.00	13834	3975	881	6626	1654	1891

H4. Successful wildlife crossings through the structures in the Ravalli Curves area between 1 January 2010 and 31 December 2012 based on cameras. However, the data between 1 January 2010 and 26 February 2010 were based on tracking data and they were added to the table below. Deer tracks were corrected by factor 1.623 (see Chapter 9). Earlier tracking data from 2008 and 2010 were not well suited for species other than deer and black bear and were not included in the table below.

2010-2012	Tracking 1 Jan 2010 – 26 Feb 2010, cameras 26 Feb 2010 - 31 Dec 2012										
Species	Total (N)	Total (%)	RC 377	RC 381	RC 396	RC 406	RC 422	RC 426	RC 427	RC 431	RC 432
White-tailed deer (*Odocoileus virginianus*)	8677	58.54	0	2721	5061	87	145	5	1	10	647
Mule deer (*Odocoileus hemionus*)	1732	11.69	0	42	295	486	832	1	0	0	76
Human data collector	729	4.92	17	54	139	49	148	37	113	37	135
Deer spp. (*Odocoileus* spp.)	678	4.57	0	278	329	15	49	0	0	0	7
Coyote (*Canis latrans*)	485	3.27	0	55	189	37	60	67	13	33	31
Black bear (*Ursus americanus*)	458	3.09	2	2	7	25	66	27	80	2	247
Human	414	2.79	0	38	20	231	23	1	22	8	71
Raccoon (*Procyon lotor*)	374	2.52	4	31	19	8	27	94	77	48	66
Human and dog	296	2.00	0	3	0	285	2	0	2	0	4
Domesticated cat (*Felis catus*)	278	1.88	0	75	16	129	1	13	16	23	5
Bobcat (Lynx rufus)	236	1.59	0	0	7	24	47	31	61	33	33
Western striped skunk (*Mephitis mephitis*)	110	0.74	0	24	19	5	3	2	8	4	45
Domesticated dog (*Canis lupus familiaris*)	107	0.72	0	6	14	81	2	0	0	0	4
Rabbits and hares (Lagomorpha)	84	0.57	0	1	0	9	4	42	26	0	2
Mountain lion (*Felis concolor*)	69	0.47	0	0	0	2	33	1	2	3	28
Birds (Aves)	39	0.26	0	0	8	0	1	7	13	0	10
North American beaver (*Castor canadensis*)	14	0.09	0	0	0	0	0	0	0	0	14
Bear spp. (*Ursus* spp.)	10	0.07	0	0	0	0	2	0	0	0	8
Northern river otter (*Lontra canadensis*)	8	0.05	0	0	0	0	0	1	0	0	7
Unknown	7	0.05	0	4	0	0	3	0	0	0	0
American badger (*Taxidea taxus*)	4	0.03	0	1	0	1	2	0	0	0	0
Yellow-bellied marmot (*Marmota flaviventris*)	3	0.02	0	0	0	0	2	0	1	0	0
Dom dog or coyote	3	0.02	0	2	1	0	0	0	0	0	0
Red fox (*Vulpes vulpes*)	2	0.01	0	0	0	1	0	0	0	1	0
Long-tailed weasel (*Mustela frenata*)	2	0.01	0	0	0	0	0	0	2	0	0
Horse (*Equus ferus caballus*)	2	0.01	0	0	2	0	0	0	0	0	0
Human and car	1	0.01	0	0	0	1	0	0	0	0	0
Total	14822	100.00	23	3337	6126	1476	1452	329	437	202	1440

H5. Successful wildlife crossings through the structures in the Ravalli Hill area between 1 January 2010 and 31 December 2012 based on cameras. However, the data between 1 January 2010 and 26 February 2010 were based on tracking data and they were added to the table below. Deer tracks were corrected by factor 1.623 (see Chapter 9). Earlier tracking data from 2008 and 2010 were not well suited for species other than deer and black bear and were not included in the table below.

2010-2012	Tracking 1 Jan 2010 – 26 Feb 2010, cameras 26 Feb 2010 - 31 Dec 2012			
Species	Total (N)	Total (%)	RH 1	RH 2
Mule deer (*Odocoileus hemionus*)	2592	61.25	1180	1412
Human data collector	236	5.58	91	145
White-tailed deer (*Odocoileus virginianus*)	207	4.89	128	79
Black bear (*Ursus americanus*)	202	4.77	181	21
Birds (Aves)	172	4.06	157	15
Bobcat (*Lynx rufus*)	157	3.71	119	38
Other	156	3.69	122	34
Human	129	3.05	126	3
Coyote (*Canis latrans*)	127	3.00	53	74
Mountain lion (*Felis concolor*)	87	2.06	82	5
Deer spp. (*Odocoileus* spp.)	50	1.18	29	21
Rabbits and hares (Lagomorpha)	35	0.83	15	20
Western striped skunk (*Mephitis mephitis*)	26	0.61	12	14
American badger (*Taxidea taxus*)	23	0.54	2	21
Raccoon (*Procyon lotor*)	14	0.33	13	1
Domesticated cat (*Felis catus*)	6	0.14	4	2
Dom. Dog or coyote	3	0.07	3	0
Bear spp. (*Ursus* spp.)	3	0.07	1	2
Unknown	2	0.05	2	0
Elk (*Cervus canadensis*)	2	0.05	0	2
Red fox (*Vulpes vulpes*)	1	0.02	0	1
Weasel spp. (*Mustela* spp.)	1	0.02	0	1
Grizzly bear (*Ursus arctos*)	1	0.02	0	1
	4232	100.00	2320	1912

H6. Successful wildlife crossings through the Isolated structures between 1 January 2011 and 30 June 2015 based on cameras.

2011-2015	Cameras 1 Jan 2011 - 30 June 2015													
Species	Total (N)	Total (%)	North Evaro	Schley Creek	E.F. Finley Cr.	Pistol Creek 1	Pistol Creek 2	Mission Creek	Post Creek 1	Post Creek 2	Post Creek 3	Spring Creek 1	Spring Creek 2	Polson Hill
White-tailed deer (*Odocoileus virginianus*)	33155	70.01	386	70	13	689	943	605	3621	11307	10964	67	107	4383
Domesticated dog (*Canis lupus familiaris*)	4889	10.32	1420	707	169	12	6	2452	5	2	19	0	6	91
Domesticated cat (*Felis catus*)	2967	6.26	394	173	483	49	131	34	76	245	773	159	123	327
Raccoon (*Procyon lotor*)	1385	2.92	137	130	252	48	18	69	203	226	101	12	15	174
Human	933	1.97	371	83	49	22	15	167	6	17	131	6	2	64
Red fox (*Vulpes vulpes*)	686	1.45	0	0	0	0	0	117	0	4	5	88	318	154
Mule deer (*Odocoileus hemionus*)	659	1.39	0	0	0	6	0	2	0	0	6	0	0	645
Human data collector	583	1.23	81	60	63	78	58	32	27	59	96	5	5	19
Other birds (Aves)	460	0.97	0	7	2	48	67	39	46	119	80	21	19	12
Western striped skunk (*Mephitis mephitis*)	419	0.88	0	2	0	8	7	11	18	36	10	63	75	189
Black bear (*Ursus americanus*)	270	0.57	24	20	2	45	11	128	0	0	2	0	0	38
Coyote (*Canis latrans*)	212	0.45	4	3	0	60	21	4	3	1	3	2	3	108
Human and dog	119	0.25	30	10	1	3	0	5	0	29	20	0	0	21
Rabbits and hares (Lagomorpha)	111	0.23	0	20	89	0	2	0	0	0	0	0	0	0
Ring-necked pheasant (*Phasianus colchicus*)	97	0.20	0	0	0	0	0	0	0	25	70	0	0	2
Human and ATV	67	0.14	3	0	0	29	4	0	0	0	0	2	0	29
Deer spp. (*Odocoileus* spp.)	56	0.12	0	0	0	3	1	1	8	13	18	0	0	12
Cattle (*Bos taurus*)	53	0.11	29	3	4	0	0	17	0	0	0	0	0	0
Unknown	42	0.09	0	0	0	3	1	24	2	6	1	2	0	3
Human on bicycle	35	0.07	13	11	11	0	0	0	0	0	0	0	0	0
Grizzly bear (*Ursus arctos*)	28	0.06	0	0	0	9	0	0	0	0	19	0	0	0
Other	30	0.06	0	0	0	0	1	21	2	2	2	2	0	0
Bobcat (*Lynx rufus*)	26	0.05	0	3	0	18	5	0	0	0	0	0	0	0
Mountain lion (*Felis concolor*)	13	0.03	0	1	0	0	0	1	0	0	0	0	0	11
American badger (*Taxidea taxus*)	11	0.02	0	0	0	1	9	0	0	0	0	0	0	1
Human and horse	10	0.02	0	0	5	0	5	0	0	0	0	0	0	0
American mink (*Mustela vison*)	9	0.02	0	0	0	0	0	0	5	1	0	3	0	0
Wild turkey (*Meleagris gallopavo*)	7	0.01	4	0	0	0	0	0	0	1	2	0	0	0
Porcupine (*Erethizon dorsatum*)	4	0.01	0	0	0	0	0	0	0	0	0	2	0	2
Northern river otter (*Lontra canadensis*)	4	0.01	0	0	0	0	0	0	1	0	3	0	0	0
Yellow-bellied marmot (*Marmota flaviventris*)	4	0.01	0	0	0	0	0	1	0	3	0	0	0	0

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Table continued from previous page														
Species	Total (N)	Total (%)	North Evaro	Schley Creek	E.F. Finley Cr.	Pistol Creek 1	Pistol Creek 2	Mission Creek	Post Creek 1	Post Creek 2	Post Creek 3	Spring Creek 1	Spring Creek 2	Polson Hill
Human and car	3	0.01	0	0	0	0	0	0	0	0	0	0	0	3
Bat (Chiroptera)	2	0.00	0	0	0	0	0	0	0	1	0	0	1	0
Dom. dog or coyote	2	0.00	0	0	0	0	0	0	0	0	0	0	0	2
Bear spp. (*Ursus* spp.)	2	0.00	0	0	0	0	1	0	0	0	1	0	0	0
Domesticated goat (*Capra aegagrus hircus*)	2	0.00	2	0	0	0	0	0	0	0	0	0	0	0
Human on skis	1	0.00	0	0	0	1	0	0	0	0	0	0	0	0
Long-tailed weasel (*Mustela frenata*)	1	0.00	0	1	0	0	0	0	0	0	0	0	0	0
Great horned owl (*Bubo virginianus*)	1	0.00	0	0	0	1	0	0	0	0	0	0	0	0
Weasel spp. (*Mustela* spp.)	1	0.00	0	0	0	0	0	0	0	0	0	1	0	0
	47359	100.00	2898	1304	1143	1133	1306	3730	4024	12097	12325	434	674	6290

I. Estimated deer and back bear highway crossings in the Evaro, Ravalli Curves and Ravalli Hill areas based on Hardy *et al.* (2007), and the standardized deer and black bear crossings for the period 15 June – 15 October.

Crossings based on Hardy *et al.* (2007)											
	Deer				Black bear				Period monitored		
Year	Evaro	Ravalli Curves	Ravalli Hill	Combined	Evaro	Ravalli Curves	Ravalli Hill	Combined	Start	End	days (n)
2003	516	1227	189	1932	24	66	39	129	18-Jun	29-Oct	133
2004	603	657	261	1521	24	135	6	165	25-Jun	16-Oct	113
2005	372	1035	336	1743	3	21	9	33	13-Jun	27-Oct	136

Standardized crossings for period 15 June - 15 October (122 days)								
	Deer				Black bear			
Year	Evaro	Ravalli Curves	Ravalli Hill	Combined	Evaro	Ravalli Curves	Ravalli Hill	Combined
2003	473	1126	173	1772	22	61	36	118
2004	651	709	282	1642	26	146	6	178
2005	334	928	301	1564	3	19	8	30

Corrected crossings to make them comparable to wildlife camera data (see Chapter X) for period 15 June - 15 October (122 days)										
	Deer				Black bear				Correction factor	
Year	Evaro	Ravalli Curves	Ravalli Hill	Combined	Evaro	Ravalli Curves	Ravalli Hill	Combined	Deer	Black bear
2003	768	1827	281	2876	24	66	39	129		
2004	1057	1151	457	2665	28	159	7	194		
2005	542	1507	489	2538	3	20	9	32	1.623	1.088
Mean	788.81	1494.95	409.30	2693.06	18.36	81.65	18.25	118.26		
SD	258.12	337.90	111.93	171.02	13.53	70.38	17.92	81.31		

Note: For the analyses 152 deer and 9 black bear crossings (camera at railroad bridge) were added to the 2003, 2004 and 2005 data.

J1. The construction costs for the crossing structures (Pers. com. Pat Basting, MDT). *1 See Appendix A1 for English units.

Structure	Structure type	Dimensions width x height, length (m) (animal's perspective)*[1]	Construction year	Construction costs (US $)		
				Total	Minimum for hydrology	Additional for wildlife
North Evaro	Corr metal culvert	7.75 x 5.1 x 25.8	2010	$385,923	$0	$385,923
Railroad bridge	Multi span bridge	103.5 x 9.7 x 12.0	2010	$3,134,633	$3,134,633	$0
Finely Creek 1	Corr metal culvert	7.95 x 5.55 x 32.0	2010	$478,467	$13,917	$464,550
Finely Creek 2	Corr metal culvert	7.95 x 5.55 x 21.9	2010	$438,157	$42,719	$395,438
Overpass	Wildlife overpass	60 x n/a x 63.0	2010	$1,884,650	$0	$1,884,650
Finely Creek 3	Corr metal culvert	7.75 x 5.1 x 24.7	2010	$354,126	$8,647	$345,479
Finely Creek 4	Corr metal culvert	7.95 x 5.55 x 25.3	2010	$410,398	$11,308	$399,090
Schley Creek	Corr metal culvert	7.75 x 5.1 x 30	2010	$601,796	$48,519	$553,277
East Fork Finley Creek	Corr metal culvert	7.75 x 5.1 x 24.3	2010	$462,109	$83,795	$378,314
Jocko Crossing 1	Concrete box culvert	2.1 x 2.1 x 45	2006	$80,852	$0	$80,852
Jocko Crossing 2	Concrete box culvert	2.1 x 2.1 x 43	2006	$77,228	$0	$77,228
Jocko Crossing 3	Concrete box culvert	2.1 x 2.1 x 40	2006	$86,315	$0	$86,315
Jocko River	Open span bridge	120 x 5.2 16.6	2006	$1,885,487	$53,720	$1,831,767
Schall Flats 1 (RC 377)	Concrete box culvert	2.4 x 2.4 x 37.2	2006	$107,524	$0	$107,524
Jocko/Spring Creek (RC 381)	Open span bridge	30 x 4.6 x 12	2006	$427,599	$84,942	$342,657
Ravalli Curves 1 (RC 396)	Corr metal culvert	6.86 x 4.78 x 22	2006	$221,000	$0	$221,000
Ravalli Curves 2 (RC 406)	Corr metal culvert	6.86 x 4.78 x 25.6	2006	$234,000	$0	$234,000
Jocko Side Channel (RC 422)	Open span bridge	30 x 5.2 x 12	2006	$431,884	$8,647	$423,237
Ravalli Curves 3 (RC 426)	Concrete box culvert	1.2 x 1.8 x 27.4	2006	$64,274	$0	$64,274
Ravalli Curves 4 (RC 427)	Plastic culvert	2.05 x 1.5 x 25	2006	$28,470	$0	$28,470
Ravalli Curves#5 (RC 431)	Concrete box culvert	1.8 x 1.2 x 24.4	2006	$58,376	$0	$58,376
Copper Creek (RC 432)	Corr metal culvert	7.75 x 5.1 x 18.3	2006	$195,000	$21,285	$173,715
Ravalli Hill 1	Corr metal culvert	7.3 x 5.2 x 39	2007	$387,500	$0	$387,500
Ravalli Hill 2	Corr metal culvert	7.3 x 5.2 x 31.2	2007	$387,500	$11,308	$376,192
Pistol Creek 1	Corr metal culvert	7.3 x 5.2 x 40	2007	$387,500	$37,211	$350,289
Pistol Creek 2	Corr metal culvert	7.3 x 5.2 x 40	2007	$387,500	$27,834	$359,666
Sabine Creek	Corr metal culvert	7.32 x 3.65 x 14.6	2007	$241,119	$25,766	$215,353
Mission Creek	Open span bridge	16.6 x 4.9 x 40	2007	$748,019	$45,455	$702,564
Post Creek 1	Corr metal culvert	7.32 x 4.75 x 28.8	2007	$351,993	$2,377	$349,616
Post Creek 2	Corr metal culvert	7.32 x 4.75 x 22	2007	$347,721	$2,377	$345,344
Post Creek 3	Corr metal culvert	7.32 x 3.9 x 19.5	2007	$302,246	$2,377	$299,869
Post Creek 4	Corr metal culvert	1.8 x 1.2 x 39.6	2007	$108,678	$8,647	$100,031
Post Creek 5	Corr metal culvert	2.4 x 2.4 x 31.7	2007	$150,145	$11,308	$138,837
Post Creek 6	Plastic coated corr	1.8 x 1.2 x 29.3	2007	$75,917	$2,377	$73,540
Post Creek 7	Plastic coated corr	1.8 x 1.2 x 31.7	2007	$88,535	$88,535	$0
Spring Creek 1	Conspan arches	8.5 x 3.0 x 44.4	2008	$325,000	$7,054	$317,946
Spring Creek 2	Conspan arches	8.5 x 3.0 x 51.9	2008	$325,000	$17,028	$307,972
Mud Creek	Conspan arches (2)	12.8 x 4.2 x 15.94	2008	$1,345,710	$35,336	$1,310,374
Polson Hill	SSPP Conc.footers	6.71 x 3.66 x 15.85	2005	$350,000	$17,028	$332,972

J2. The construction costs for wildlife fences, livestock fences, wildlife guards, jump-outs and gates (Pers. com. Pat Basting, MDT).

Mitigation measure	Costs (per m or per single unit)
Wildlife fences (8 ft (2.4 m) tall)	$38
Dig barrier for wildlife fences	$12
Wildlife friendly livestock fences	$9
Wildlife guard	$30,000
Jump-out	$6,250
Single panel access gate	$360
Double panel access gate	$550