BOZEMAN PASS POST-FENCING WILDLIFE MONITORING

FHWA/MT-10-006/8173

Final Report

prepared for
THE STATE OF MONTANA
DEPARTMENT OF TRANSPORTATION

in cooperation with
THE U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

January 2011

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Final Report

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December 2010

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA/MT-10-006/8173	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Bozeman Pass Post-Fencing Wildlife Monitoring	5. Report Date December 2010 **6. Performing Organization Code**	
7. Author(s) Lance Craighead, PhD; April Craighead, MSc; Lauren Oechsli, MSc; Angela Kociolek, MSc	**8. Performing Organization Report No.**	
9. Performing Organization Name and Address Western Transportation Institute – Montana State University PO Box 174250 Bozeman, MT 59717-4250 Craighead Institute (formerly CERI; subcontractor) 201 S. Wallace Avenue, Suite B2D Bozeman, MT 59715	**10. Work Unit No.** 11. Contract or Grant No. MDT Project # 8173 MSU Index # 426899	
12. Sponsoring Agency Name and Address Research Programs Montana Department of Transportation 2701 Prospect Avenue PO Box 201001 Helena MT 59620-1001	13. Type of Report and Period Covered Final Research Report June 2007 – June 2010 14. Sponsoring Agency Code 5401	

15. Supplementary Notes Research performed in cooperation with the Montana Department of Transportation and the US Department of Transportation, Federal Highway Administration. This report can be found at http://www.mdt.mt.gov/research/projects/env/boz_wildlife.shtml

16. Abstract

The Bozeman Pass transportation corridor between Bozeman and Livingston, Montana, includes Interstate 90 (I-90), frontage roads, and a railroad. The highway was a suspected barrier and hazard to animal movement in the Bozeman Pass area, which is considered a corridor for wildlife moving north and south between the Greater Yellowstone Ecosystem and other habitat.

In 2007, wildlife connectivity measures were incorporated into the reconstruction of a Montana Rail Link bridge. These measures included wildlife exclusion fencing along approximately one mile of I-90, four jump-outs, cattle guards, and landscape design modifications. Data on wildlife crossings and animal–vehicle collisions (AVCs) were collected before and after construction to evaluate the effectiveness of the mitigation measures in reducing AVCs and allowing for animal movements under the highway.

Ungulate–vehicle collisions (UVCs) decreased significantly inside the fenced roadway post-installation. There has not been a significant increase in UVC rates at either the fence ends or in the study area as a whole. Track-bed and remote camera data indicate increased wildlife movement under the MRL bridge and through culverts. An analysis of road kill density before and after fencing suggests that one road kill hotspot was been mitigated but that others remain. Suggestions for further mitigation as well as modifications to the jump-outs and fence ends are presented.

Because the mitigation measures were added to a structure replacement project and largely made use of existing landscape features, the cost of the project was lower than direct installation of new mitigation measures. In three years post-fencing, the reduction in UVCs has resulted in savings that are greater than the cost of installation. Incorporating wildlife connectivity measures into scheduled road projects early in the planning stages can be a cost-effective way to reduce AVCs and preserve healthy wildlife populations.

17. Key Words **Wildlife crossings, animal–vehicle collisions, mitigation, effectiveness, underpasses, wildlife fencing, road kill, track-beds, remote cameras, corridors, culverts, hotspots, ungulates, carnivores**		18. Distribution Statement Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161.	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 39	22. Price

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ACKNOWLEDGMENTS

We would like to thank all of the volunteers who have provided us with road kill location data over the years. These include Kevin and Shannon Podruzny and Neal Anderson. We would also like to thank all of the dedicated Craighead Institute (formerly Craighead Environmental Research Institute) staff and interns who systematically collected road kill data, made early morning observations at the fencing site, and helped with data compilation. We would like to thank our key partners at the Western Transportation Institute: Amanda Hardy and Rob Ament. Finally, we would like to thank Deb Wambach and Pierre Jomini at MDT for their help and support.

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY vi
2. INTRODUCTION 1
Study Area 2
Mitigation Measures 4
3. METHODS 6
Data Collection 6
Data Analyses 9
4. RESULTS 12
Pass-wide Data Summary 12
Road kill 15
Track-bed 17
Jump-outs 19
Remote cameras 19
5. DISCUSSION and RECOMMENDATIONS 23
Pass-wide Assessment and Hotspots 23
Mitigation Effectiveness Assessment 24
Jump-outs 25
Financial Assessment 25
Design Recommendations 26
6. REFERENCES 29

FIGURES

Figure 1. Study area. ... 4
Figure 2. UVC totals by year, mileposts 309.5–333.0. ... 13
Figure 3. UVC totals by month, mileposts 309.5–333.0. Data from 2001 through 2009. ... 13
Figure 4. Distribution of UVCs along Bozeman Pass. ... 14
Figure 5. UVC hotspots along Bozeman Pass pre-fencing and post-fencing. ... 15
Figure 6. Mean UVC rates with 95 percent confidence intervals by section, pre- and post-fencing. ... 16
Figure 7. Pre- and post-fencing UVCs at individual mile markers within the fence. ... 16
Figure 8. Pre- and post-fencing UVCs within the fence and buffer stretches. ... 17
Figure 9. Mean ungulate crossings per day under the MRL bridge. ... 18
Figure 10. Mean vehicles per day, by month. ... 24

TABLES

Table 1. Camera deployment dates. ... 8
Table 2. Time periods for which data were pooled in analyses. ... 10
Table 3. Species of road kill documented along Bozeman Pass (I-90 mileposts 309.5–333.0) January 2001–June 2010. ... 12
Table 4. Mean UVCs per mile per year in the mitigation zone by time period. ... 15
Table 5. Species' tracks recorded in the MRL bridge track-bed. ... 18
Table 6. Jump-out track-bed data for survey period (August 2, 2007–July 1, 2010). ... 19
Table 7. Remote camera photographs near fence ends and jump-outs. Data are from January 1, 2008 to March 30, 2009. ... 20
Table 8. Remote camera photographs in culverts (MP 314.4). ... 21
Table 9. As-constructed mitigation costs ... 26

1. EXECUTIVE SUMMARY

The Bozeman Pass transportation corridor between Bozeman and Livingston, Montana, includes Interstate 90 (I-90), frontage roads, and a railroad. Summer annual daily traffic (ADT) was 8,000–10,000 and winter ADT was 12,000–17,000 during the course of this study. Data collected indicate the highway had become a hazard to wildlife and a barrier to animal movements in the Bozeman Pass area, which is considered a corridor for wildlife moving north and south between the Greater Yellowstone Ecosystem and other habitat.

In 2001, the Craighead Institute (formerly Craighead Environmental Research Institute [CERI]) independently began collecting field data on Bozeman Pass to determine the extent of animal–vehicle collisions (AVCs) and where such conflicts may best be mitigated. The project began with private funding and formed the basis of recommendations to the Montana Department of Transportation (MDT). Subsequent funding from MDT, the Federal Highway Administration (FHWA) and the Western Transportation Institute (WTI) resulted in a multi-year safety and wildlife connectivity study centered around Bozeman Pass and a Montana Rail Link (MRL) bridge reconstruction site. Each stage of funding resulted in unique project/contract titles: Bozeman Pass Wildlife Linkage and Highway Safety Study (Craighead et al. 2001), Bozeman Pass Wildlife Channelization Intelligent Transportation Systems (Hardy et al. 2006), and, finally, this project, Bozeman Pass Post-Fencing Wildlife Monitoring Project.

Data on wildlife crossings and AVCs were collected before and after installation of wildlife exclusion fencing (hereafter stated as “wildlife fencing” or simply “fencing”) to evaluate its efficacy in reducing AVCs and funneling animal movements under the highway via existing culverts and the MRL bridge. Data collection included 1) road kill surveys; 2) track-bed monitoring at fence ends, jump-outs, and under the MRL bridge; 3) remote camera monitoring at fence ends and culverts; 4) infrared counter and remote camera monitoring at jump-outs; and 5) opportunistic snow tracking at track-bed sites and along the length of the highway in the study area.

Ungulate–vehicle collisions (UVCs) have decreased significantly inside the fenced roadway since the installation of the wildlife fencing. There has not been a significant increase in UVC rates either at the fence ends or in the study area as a whole. In addition, track-bed and remote camera data indicate increased wildlife movement under the MRL bridge and through culverts. An analysis of road kill density “hotspots” before and after the fencing suggests one area of increased road kill has been mitigated by the fence but that others remain. Suggestions for further mitigation as well as modifications to the jump-outs and fence ends are presented.

Because wildlife mitigation measures were added to the bridge structure replacement project and tied into existing landscape features, the costs of this project were lower than constructing new wildlife crossing structures such as underpasses or overpasses. Increased usage under the bridge and through other structures (culverts and county road bridge) suggests that wildlife fencing leading to existing crossing structures is an effective method of reducing the risk to both motorists and wildlife while improving wildlife connectivity. Incorporating wildlife connectivity measures into scheduled road projects early in the planning stages can be a cost-effective way to reduce AVCs and preserve healthy wildlife populations.

2. INTRODUCTION

Wildlife on highways pose a serious safety risk to humans. When people in vehicles encounter wildlife on roadways the effects can be life-threatening. Every year there are well over a million AVCs mostly involving deer (Huijser et al. 2008a). The cost of wildlife-related collisions are staggering with an estimated $1 billion yearly being paid out by insurance companies for automobile repairs, and approximately 200 people losing their lives (Huijser et al. 2008a). In an effort to decrease human and wildlife mortality, transportation planners in the past few decades in the United States have established AVC reduction programs, which include activities from statewide and regional planning through site-specific mitigations (Huijser et al. 2008a).

One of the most effective measures to reduce AVCs is by incorporating wildlife mitigation features in road construction and upgrades (Forman et al. 2003). Methods typically include installing wildlife fencing and jump-outs in conjunction with a variety of underpasses, overpasses, elevated spans, or culverts animals can use to traverse safely from one side of road to the other (Clevenger and Huijser 2010; Clevenger et al. 2001; Forman et al. 2003; Huijser et al. 2008b). Such crossing structures have been evaluated in many areas (Langton 1989; Yanes et al. 1995; Foster and Humphrey 1995; Land and Lotz 1996; Boarman and Sazaki 1996; Roof and Wooding 1996; Forman and Hersperger 1996; Jackson 1996,1999; Simonyi et al. 1999; MacDonald and Smith 1999; Veenbaas and Brandjes 1999; Jones 2000; Clevenger 1999, Clevenger and Waltho 1999, 2000; Gibeau and Heuer 1996; Leeson 1996; Paquet and Callaghan 1996; Paquet et al.1996), and those evaluations have demonstrated underpasses and extended bridge spans are an effective means to increase permeability for some species of wildlife. Similar measures have been used in Europe for decades (Iuell et al. 2003). These structures target a wide variety of species depending on the size of the structure, ranging from amphibians, reptiles and small mammals to large ungulates and carnivores (Forman et al. 2003).

While many of these structures are effective in reducing road kill they can be very expensive, for example, a wildlife overpass could cost millions of dollars. In some instances, the cost of mitigation can be lessened by incorporating the structures into planned upgrades and rebuilds of roads already scheduled by departments of transportation. In many cases bridges and culverts already exist in areas where AVCs occur. Simply installing fencing that guides animals through these structures, while preventing them from accessing the highway surface, can effectively reduce AVCs at a fraction of the cost of installing new crossing structures.

In addition to safety concerns, there is a growing body of research that details the mainly negative impacts roads have on wildlife populations. Wildlife move across the landscape to meet daily, seasonal (migration), and lifetime (dispersal) needs. Highways often intersect wildlife movement routes. When animals are confronted with roads, they face the potential for direct mortality, injury, displacement, habitat fragmentation, loss of habitat connectivity and even genetic isolation (Clevenger and Wierzchowski 2006; Clevenger et al. 2001; Corlatti et al. 2009; Forman et al. 2003; Forman and Alexander 1998; Proctor et al. 2002, 2004) depending upon the highway location, topography, design, and traffic. The most direct effects are mortality and injury. Currently, 21 federally listed threatened or endangered animal species in the United States have been documented as species for which road mortality is a major threat to survival (Huijser et al. 2008a). Indirect effects impact animals by reducing their effective habitat and interfering with necessary movement. Connectivity is a measure of the extent to which organisms, in this case wildlife, can move between habitat patches (Taylor et al. 1993). Roads can often form a barrier to such movement, and when this happens there can be effects on wildlife populations and longer-term effects on genetic variability (Riley et al. 2006; Mumme et al. 2000; Marsh et al. 2008; Proctor et al. 2002, 2004).

In 2001, CERI independently began collecting field data on Bozeman Pass to identify accurate road kill locations and to document wildlife movement along I-90 between Bozeman and Livingston, Montana from milepost (MP) 309.5–333.0. The project, known as the Bozeman Pass Wildlife Linkage and Highway Safety Study, was initiated by CERI with private funding. Data analyses from the project highlighted areas of higher than average road kill near Bozeman and other areas closer to Livingston (Craighead et al. 2001). One of these areas of high road kill was in the vicinity of the MRL bridge (MP 314.1) that was scheduled to be rebuilt in 2005. In 2003, a continuation of the project focusing on the site of the planned MRL bridge reconstruction was funded by MDT. In 2004, additional state and federal funding was acquired for the Bozeman Pass Wildlife Channelization Intelligent Transportation Systems (ITS). A portion of the ITS project budget supported pre-construction wildlife field data collection. Analysis of data from 2001-2005 led to recommendations to incorporate wildlife connectivity measures into the reconstruction of the MRL bridge and a final report was completed in June 2006 (Hardy et al. 2006). The recommended measures included wildlife fencing along approximately one mile of eastbound and westbound lanes, cattle guards, and landscape design modifications. These measures were incorporated into the project design by MDT and MRL. MDT and FHWA proposed that some of the remaining funds from the ITS budget be applied to support post-construction field data collection for evaluating the effectiveness of wildlife fencing. WTI provided additional funding for this final phase known as the Bozeman Pass Post-Fencing Wildlife Monitoring Project. Field data collection began after the wildlife fence and four jump-outs were completed as a part of the bridge reconstruction in 2007. Post-fencing data was collected from August 2007 through June 2010.

The post-fencing mitigation study area was limited to the area between Bozeman and Jackson Creek (MP 309.5–319.0). Road kill data, however, continued to be collected throughout the entire study area using other sources of funding to identify areas that may serve as mitigation sites in the future. Wildlife movements were documented using a track-bed and remote cameras.

Study Area

Bozeman Pass (I-90, MP 309.5–333.0) is located in south-western Montana, approximately 88 km (55 miles) north of Yellowstone National Park. The study area in and around Bozeman Pass encompasses approximately 908 km^2 (350 $miles^2$) and includes the cities of Bozeman and Livingston. I-90 bisects the area, with Bozeman on the western edge and Livingston on the eastern edge. The MRL line runs parallel to the highway, crossing underneath at MP 321 and 314. A frontage road also runs parallel to the highway for a portion of that distance. The distance between Bozeman and Livingston is approximately 33.6 km (21 miles). Summer annual daily traffic (ADT) was 8,000–10,000 and winter ADT was 12,000–17,000 during the course of this study. For reference, in Canada's Banff National Park, wildlife movements were found to be impaired by 300 to 5,000 vehicles per day (Alexander et al. 2005). Railway traffic through the Bozeman Pass area is also a factor, with approximately 30 trains using the tracks daily, moving under the MRL bridge at approximately 48 kph (30 mph) (Dewey Lonnes, Montana Rail Link, pers. comm.).

Bozeman Pass is surrounded by a mosaic of residential, agricultural and public lands. The landscape varies from shrub-grassland communities near Bozeman and Livingston to coniferous forests in the middle section of Bozeman pass. Elevation varies from 1398 meters (4586 feet) at its low point near Livingston to 1733 meters (5685 feet) at the top of the pass.

The Bozeman Pass area includes a large amount of wildlife habitat on both public and private lands and serves as a wildlife connectivity link between the Gallatin and Absaroka mountain ranges in the south and the Bridger and Bangtail Mountains in the north. The wildlife habitat in the area is somewhat fragmented by human development and transportation routes. Regionally, Bozeman Pass has been identified as an important wildlife corridor connecting wildlife habitat in the Greater Yellowstone Ecosystem in the south, through the Bridger and Big Belt Mountains, to the Northern Continental Divide Ecosystem in the north (Craighead et al. 2001; Hardy et al. 2006; Walker and Craighead 1997; Ruediger et al. 1999). I-90 is a significant barrier to wildlife movement in the region (Figure 1). Accordingly, as this project developed, the Craighead Institute and other partners simultaneously worked to maintain habitat on both sides of the highway near the wildlife fencing site to ensure animals crossing here would have secure habitat beyond the roadway. Safe highway crossings are a key feature in larger efforts for comprehensive natural resource management and to promote conservation and sustainable use. Larger conservation approaches include components such as integrated planning, the exploration of a variety of mitigation options, and performance measurement (Brown 2006).

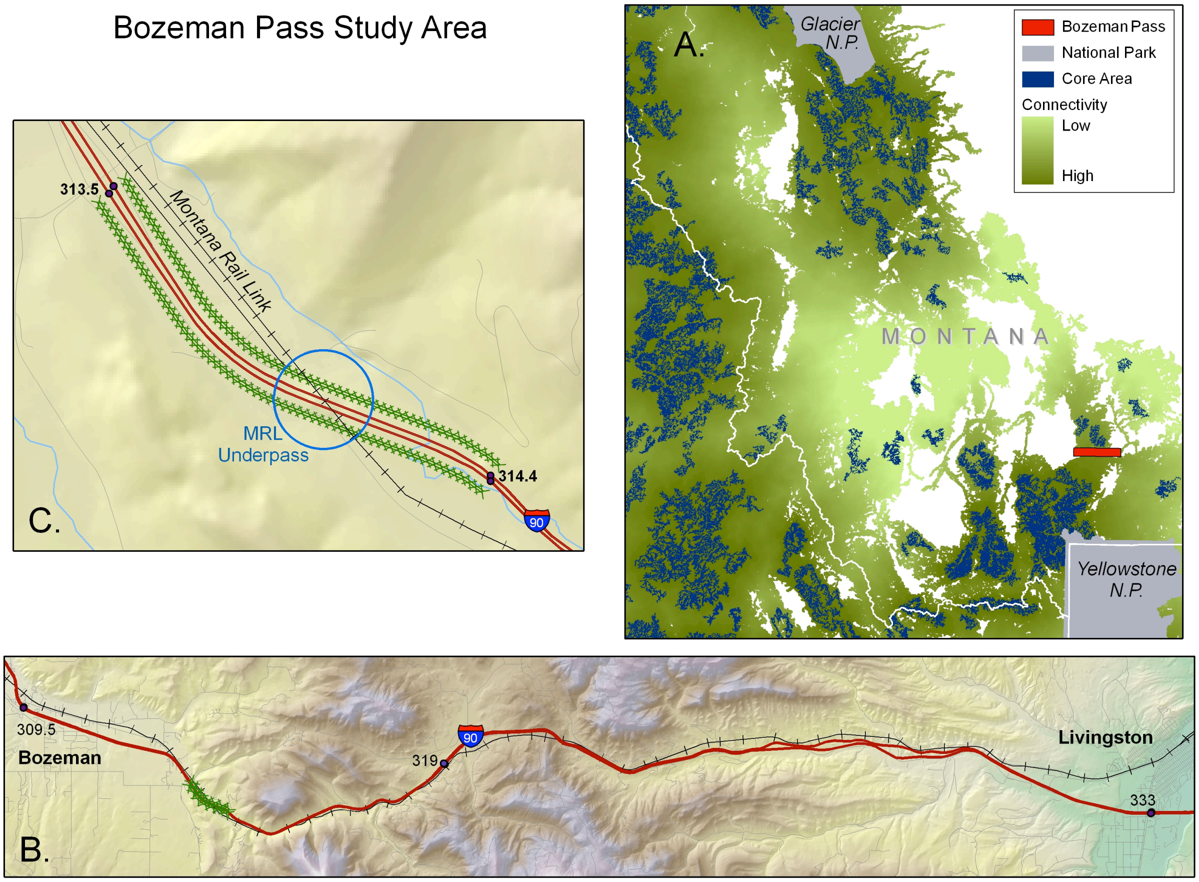

Figure 1. Study area.
"A" locates Bozeman Pass within regional wildlife connectivity. "B" depicts the I-90 corridor across Bozeman Pass from MP 309.5-333.0. MP 319.0 identifies the eastern end of the mitigation zone. "C" represents the site of wildlife fencing (hatch marked symbols between MP 313.5-314.4) and the MRL bridge (underpass).

This area is rich in wildlife, including black bear (*Ursus americanus*), mountain lion (*Puma concolor*), bobcat (*Felis rufus*), elk (*Cervus elephas*), moose (*Alces alces*), mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), and a variety of smaller mammals, reptiles, and a diversity of bird species. Many of these species utilize this area in their daily, seasonal and lifetime dispersal movements. Grizzly bears (*Ursus arctos horribilis*) are occasionally seen in the area but none have been documented crossing I-90 or recorded as road kill.

Mitigation Measures

The MRL bridge is located approximately at milepost 314.1 and spans the railroad and access right-of-ways beneath I-90. After the bridge was rebuilt in 2005–2006, wildlife mitigation measures were installed, specifically wildlife fencing, jump-outs, cattle guards, and improved grading to enhance wildlife movement underneath the bridge. Wildlife fencing (1.2 meter [8 ft] high) was installed along 1.44 km (.9 mile) of I-90 encompassing the bridge. The wildlife fencing is located between MP 313.5 and 314.4 along both eastbound and westbound lanes. Four jump-outs were installed within the fenced areas to allow animals that became trapped on the highway a place to "jump out" to safety. Two jump-outs are located on each east- and west-bound lane at MP 313.9 and 314.2. These are constructed such that animals can exit the roadway but cannot walk back up onto the roadway (one-way). Jump-out walls range from about 6 to 8 feet high. To discourage animals from making "end runs" around the end of the fences, modifications were made to include cattle guards and modified fence ends. Two sets of double cattle guards, or Texas guards, were installed at the western termini of the fence at the Bear Canyon interchange access ramps. These were installed to deter animals from walking to the end of the fence and then walking up the access ramps to the highway. The eastern wildlife fence ends encompass a large double culvert and a steep embankment before tying into the traditional barbed wire fence that runs the length of the right-of-way.

3. METHODS

Data Collection

Road kill

Road kill data collection began in 2001 on Bozeman Pass. Biologists at Craighead Institute and volunteers drove along I-90 over the pass and recorded the date, location (to the closest 1/10th mile using mile markers), and species of road kills observed. Sex was recorded for carnivores and ungulates, if possible. Volunteers usually traveled Bozeman Pass during the five weekdays on their way to work, and Craighead Institute personnel drove the pass during the weekend in search of road kills. Interesting or unusual road kills were further investigated by Craighead Institute personnel. This survey methodology continued through 2002. A more standardized survey protocol began in 2003, with Craighead Institute personnel driving I-90 between Bozeman and Livingston three times a week to collect road kill data. Driver speed for Craighead Institute personnel was kept between 88 and 105 kph (55–65 mph) during the surveys. Through June 30, 2010, the pass was surveyed 1,272 times between MP 309.5–333.0, representing 85,478 km (53,424 miles).

Searches of agency records provided additional wildlife collision data. Road kill data were obtained from a variety of sources including Montana Fish, Wildlife and Parks and MDT. Maintenance crews from MDT recorded and removed dead animals from the right-of-way if the animal posed a threat to driver safety. These animals, typically moose, elk, deer and other large species, were often picked up promptly, before Craighead Institute personnel were able to record them. Supplemental data from MDT maintenance reports included in this project represent carnivores, moose and elk. MDT reports of deer species (mule and white-tailed) were not included due to the difficulty in reconciling duplicate records. At a minimum, supplemental data contained the date, location, and species killed.

Power analyses were applied to the pre-fencing ungulate-vehicle collision (UVC) data to determine what degree of change in UVC rates would be statistically detectable when comparing pre- and post-fencing road kill data (Hardy et al. 2006). Results from the power analyses (power =0.8; a = 0.05) indicated a three to five year post-fencing study would be sufficient to allow quantitative comparisons (Hardy et al. 2006). The post construction monitoring period included three years of data collection through June 30, 2010.

Track-bed

To determine the number and species of animals crossing beneath the MRL bridge, a sand track-bed was constructed on the north side of the railroad tracks. The track-bed was approximately 46 meters (150 ft) long and 2.5 meters (8 ft) wide. Due to the configuration of the highway and railroad, the track-bed covered approximately two-thirds the width of the passage; construction closer than 25 feet to the railroad was prohibited. Because it was not possible to census the entire area for animal movements, the track-bed observations provided an index of crossing activity. However, observations of snow tracks during winter indicated that very few animals crossed underneath the bridge without also crossing the track-bed.

Track-bed surveys began in October 2003 and continued through October 2004 when bridge reconstruction began. During the construction phase, equipment, materials and fill were present at the track-bed site making it impossible to maintain and monitor the track-bed until construction was completed. Accordingly, the track-bed was rebuilt in the fall of 2006. The fencing was completed in the spring of 2007. Post-fencing track-bed monitoring commenced in August 2007.

Prior to construction, the track-bed was surveyed and then raked every three to four days on average. The number of tracks counted was divided by the number of days lapsed since the previous survey to provide a count of tracks per day.

After consulting with a WTI statistician, an alternate method was used for post-construction surveys. Surveys were conducted on four consecutive days every other week. The bed was raked at the beginning of the week, then counted and raked every day for the next four days to provide a count of tracks per day. This was done to avoid confusion resulting from occasionally large numbers of tracks accumulating over multiple days (Hardy et al. 2006). During winter months, tracks would freeze and weather events confounded track identification. Therefore, post-construction track-bed surveys were conducted May through October.

Jump-outs

Initially, the jump-outs were monitored using small track-beds constructed at the top of the jump-out and supplemented with Trailmaster motion-sensor counters. The counters soon proved unreliable and were replaced with RECONYX motion-sensor cameras (see below). Jump-out track-beds were surveyed in conjunction with the main track-bed surveys (May 1–October 31). Photos from the jump-out cameras were downloaded periodically.

Remote cameras

In the pre-construction period, Trailmaster cameras were used with passive infrared (IR) beam or active IR beam triggers. These cameras used film that was then developed and printed to determine the animal/event that triggered the camera. Photo-monitoring was initiated in 1998. Cameras were placed in paired culverts (two culverts side by side) at MP 314.4 (east and west, on eastbound), 314.8 (east only, on eastbound), and 315.0 (west only, on eastbound) (Table 1).

Due to deep, fast-moving water the west culvert at MP 314.8 and the east culvert at MP 315 were not monitored. The camera in the west culvert at MP 315.0 was stolen in July 2004, whereupon a new camera was hidden outside the culvert, reducing its performance.

Post-construction, RECONYX digital motion-sensor cameras were used and increased security measures were taken to avoid theft. Cameras were placed inside locked security boxes at the eastern fence ends and secured to the guardrail with locking cables. At the western fence end a single camera was attached to the bridge supports at the Bear Canyon exit bridge underpass using locking cables. It was accessible only by ladder. Cameras were deployed in the culverts at MP 314.4, the only culverts within the post-construction study area. They were attached to the ceiling of the culvert and secured with locking cables in a location where they were accessible only by ladder.

Table 1. Camera deployment dates.

Pre-fencing			Post-fencing		
Film Camera Location (MP and side of highway)	**Start date**	**End date**	**RECONYX Camera Location (MP and side of highway)**	**Start date**	**End date**
-	-	-	deer trail 309.6 eastbound	2-23-10	7-06-10
-	-	-	farm culvert 311.0 eastbound	12-05-08	5-01-10
-	-	-	Bear Canyon exit bridge 313.5 eastbound	06-19-07	07-10-10
-	-	-	NW jump out 313.8	08-22-08	06-29-10
-	-	-	SW jump out 313.8	9-05-08	6-29-10
MRL bridge 314.0 eastbound	8-17-04	5-4-05	-	-	-
-	-	-	NE jump out 314.1	08-22-08	06-18-10
-	-	-	SE jump out 314.1	09-07-08	06-18-10
-	-	-	NE fence end 314.4	6-13-07	6-18-10
-	-	-	SE fence end 314.4	6-13-07	6-18-10
east culvert 314.4 eastbound	2-19-98	1-23-05	east culvert 314.4 eastbound	6-16-07	7-06-10
west culvert 314.4 eastbound	1-1-98	7-22-04*	west culvert 314.4 eastbound	7-28-07	7-15-10
east culvert 314.8 eastbound	1-14-02	7-15-04	-	-	-
west culvert 315.0 eastbound	7-21-03	7-17-04*/ 11-21-05[R]	-	-	-
-	-	-	farm culvert 329.1 westbound	2-02-09	5-01-10
-	-	-	farm culvert 329.8 eastbound	1-11-09	4-02-10

* indicates camera was stolen. [R] indicates end date of replacement camera.

Cameras were maintained for constant monitoring and the photos were downloaded periodically. Maintenance of the culvert cameras could not be done during periods of high water at spring runoff, but batteries were sufficient to power the cameras through these periods. Initially, rechargeable AA batteries with 2200 mAh capacity were used but these were replaced with rechargeable C batteries with 3000 mAh, 3500 mAh, and finally 5000 mAh capacity as these became available.

As mentioned in the previous section, RECONYX digital motion-sensor cameras were also used to monitor jump-outs. Cameras were placed inside locked security boxes and secured to either the wildlife fence (NE and SE cameras) or to the guardrail (NW and SW cameras) with locking cables. These cameras were deployed because the Trailmaster motion-sensor counters proved unreliable, and the cameras offered a better system for identification of species at the tops of the jump-outs than relying on tracks alone.

During the post-fencing period additional RECONYX remote cameras were placed at the ends of existing culverts and underpasses that were used for farming and ranching purposes (see farm culverts in Table 1). One camera was placed at a box culvert near MP 311.0 connecting the Montana State University experimental farm with grazing land across I-90 to the south. Another camera was placed at MP 329.1 and a third at 329.8 where culverts connected a ranch south of the Interstate with grazing lands to the north. The cameras were used to determine whether the culverts were being used by wildlife as well as by domestic animals.

During the winter of 2009–2010 a RECONYX camera was placed at MP 309.6 where deer had created a well-worn path in the snow crossing the Interstate. The purpose was to get an estimate of how many deer were successfully crossing the highway at this location. There were also regular deer paths at MP 309.8.

Data Analyses

Data from the entire Bozeman Pass study area (MP 309.5–333.0) were examined to identify yearly or monthly trends. Post-fencing data were then used to compare the spatial distribution of locations with high density UVCs. Hardy et al. (2006) used a criterion of three standard deviations above the mean to define a road kill "hotspot." Due to errors in underlying data, that criterion was adjusted to two standard deviations above the mean. This criterion was then applied to the post-fencing data to explore spatial changes in mortality due to the fencing.

A second analysis of high density UVC areas was conducted using a more spatially explicit methodology. "SANET – A Spatial Analysis on Networks" (Okabe et al. 2009) software is specifically designed to analyze data that lie along a network, such as a roadway. It was employed to perform network density analyses to elucidate changes in the locations of high density UVC areas from pre- to post-fencing, as well as to identify additional sections of highway that may be of mitigation interest. In SANET, the band width determines the distance along the network within which the algorithm will include carcass occurrences in calculating a local density. As it moves along the network, the estimator is re-calculated at each step and the resulting image is a network segmented into UVC density estimations. The cell width is user defined and describes approximately the length of the road segments for which the estimator is calculated. In this study, the band width was set at 550 meters and the cell width at 10 meters.

Sections of roadway representing the top 25 percent and 50 percent of UVC density clusters were identified to assess the spatial location of UVC hotspots along Bozeman Pass.

Road kill

Pre-mitigation data indicated UVC rates were significantly higher within the proposed mitigation zone than elsewhere along the highway using 2001–2004 data (Hardy et al. 2006). This analysis was expanded to include all pre-mitigation UVC data (January 1, 2001 to April 4, 2005) and recomputed to verify that UVC rates remained significantly higher within the zone.

During the bridge reconstruction period, traffic patterns were restricted to two lanes and speeds were reduced to 56 kph (35 mph). Recorded UVC numbers dropped sharply during this time. UVC data were therefore divided by period (Table 2). To determine if the disruption and changes in traffic during the interim period affected UVC rates, pre-fencing and interim data were compared both inside and outside the fenced zone. A significant difference in UVC rates during the interim period would require those interim data to be omitted from further analysis.

Table 2. Time periods for which data were pooled in analyses.

Period	Start Date	End Date	Number of Days
Pre-construction	1-8-01	3-31-05	1544
Interim	4-1-05	7-4-07	825
Post-construction	7-5-07	6-30-10	1092

To determine the effectiveness of the fence in reducing UVC rates, a series of two- and one-tailed t-tests were computed on UVC means both spatially and temporally. Spatial comparisons examined UVC rates inside and outside the fence, while temporal comparisons examined UVC rates pre- and post-fencing. Research has indicated that while wildlife fencing decreases ungulate mortality within fenced areas, outside the fenced area a majority of animals get killed at fence ends (Clevenger et al. 2001). To account for this possible end run effect, a buffer of an additional 0.2 miles (322 meters) of roadway was added to each end of the fenced area, and road kill occurrences within the buffer were included with those from the fenced zone for some analyses (Hardy et al. 2006). In these cases where data from the actual fenced section and the buffer areas were combined, the data set is referred to as "fence/buffer."

Track-bed

In addition to reducing mortality caused by the highway, the mitigation project intended to ensure connectivity or passage across the highway corridor (beneath the bridge), allowing local and regional movements to continue. To test the effects of the fencing and bridge re-build on animal movements underneath the highway, we conducted a one-sided t-test on the mean number of tracks per day observed in the track-bed to see if use had increased post-fencing. Track-bed data were broken down into pre- and post-mitigation periods. Since the survey methods were slightly different in the pre- and post-fencing periods, only those data collected in a single 24-hour pre-fencing period were used to compare to the post-fencing data. That is, if more than one day elapsed between raking the track-bed and reading the tracks, those data were excluded from analysis.

Jump-out track-beds

Track-bed data for jump-outs were only collected post-fencing since the jump-outs were constructed at the same time as the fence. The number of animal tracks was recorded using the jump-outs and augmented by remote cameras (see below).

Remote cameras

Remote camera data for the fence ends and jump-outs were only collected during the post-fencing period and are summarized in the results section. Although there were hundreds of photos from remote cameras at the mile post 314.4 culverts, statistical comparisons between pre- and post-construction were not feasible due to pre-and post-fencing differences in camera type and survey effort. However, the culvert photos provide an index of animals using the culverts.

4. RESULTS

Pass-wide Data Summary

Between January 2001 and June 2010, 2,272 animals representing 49 different species of mammals, birds and reptiles were recorded as road kill on Bozeman Pass between Bozeman and Livingston, Montana (Table 3). The majority of animals killed were ungulates (44%), followed by meso-carnivores (27%), birds (11%), medium-sized rodents (8%), small rodents (4%), unknown (3%), domestics (2%), large carnivores (1%), and reptiles (0.2%).

Table 3. Species of road kill documented along Bozeman Pass (I-90 mileposts 309.5–333.0) January 2001–June 2010.
Note: Dashes represent 0 records; 2010 column represents six months of data.

SPECIES	2001	2002	2003	2004	2005	2006	2007	2008	2009	*2010*	TOTAL
Badger	--	--	--	4	2	3	--	1	1	*1*	**12**
Beaver	--	--	2	1	--	--	1	5	--	--	**9**
Bird (Other)[1]	--	3	2	7	13	15	40	28	47	*12*	**167**
Bird (Owl)[2]	--	5	3	8	9	5	7	7	12	*2*	**58**
Bird (Raptor)[3]	2	4	1	1	1	2	1	1	2	--	**15**
Black Bear	1	5	8	3	3	3	2	--	--	--	**25**
Bobcat	--	--	--	1	1	--	2	--	--	--	**4**
Cat (Domestic)	--	--	4	4	6	2	5	13	4	*3*	**41**
Coyote	5	5	13	7	8	5	6	7	6	*5*	**67**
Deer (Mule)	28	36	33	33	20	9	13	9	4	*12*	**197**
Deer (Whitetail)	25	30	44	40	38	41	66	76	60	*40*	**460**
Unknown Deer	30	40	41	31	36	34	28	24	18	*8*	**290**
Dog (Domestic)	--	--	--	3	1	--	--	--	--	*2*	**6**
Elk	5	2	20	2	8	1	7	2	3	--	**50**
Fox	4	4	2	4	--	3	3	2	1	--	**23**
Marmot	--	2	6	1	2	1	2	5	1	--	**20**
Mink	--	--	1	--	--	--	1	--	2	--	**4**
Moose	--	--	4	--	1	1	2	1	--	--	**9**
Mountain Lion	1	2	1	--	--	--	--	1	1	--	**6**
Muskrat	--	--	--	--	--	--	--	--	--	*3*	**3**
Pine Marten	--	1	--	--	--	--	--	--	--	--	**1**
Porcupine	2	2	7	11	2	2	4	4	5	*1*	**40**
Rabbit/Hare	3	5	9	14	14	8	14	18	7	*8*	**100**
Raccoon	15	14	37	23	16	20	23	23	19	*5*	**195**
Skunk	13	28	41	36	30	31	44	36	31	*15*	**305**
Small Mammal/ Ground Squirrel	--	--	1	6	7	10	12	14	20	*9*	**79**
Snake	--	--	--	1	--	1	2	--	1	--	**5**
Unknown	2	4	5	20	7	9	13	4	12	*1*	**77**
Weasel	--	--	--	--	--	1	2	--	--	--	**3**
Wolf	1	--	--	--	--	--	--	--	--	--	**1**
TOTAL	137	192	285	261	225	207	300	281	257	*127*	**2,272**

1. Includes American Crow, American Robin, Black-billed Magpie, Blue Grouse, Brown-headed Cowbird, Canada Goose, Common Raven, Eastern Meadowlark, Gray Partridge, Great Blue Heron, Mallard, Ring-necked Pheasant, Rock Pigeon, Ruffed Grouse, Rufous-breasted Towhee, Western Tanager, Wild Turkey, and unknown duck and bird species.

2. Includes Great Horned Owl, Long-eared Owl, and unknown owl species.

3. Includes Red-tailed Hawk, Northern Harrier, and unknown raptor species.

It is important to note that the number of animals killed on the roadway is presumed to be greater than the number whose deaths are recorded (e.g., animals get hit and then die some distance from the roadway, people pick up road kill for personal uses, or road kill become obscured by vegetation or topographical features). In many cases, scavengers will drag carcasses away from the roadside (Antworth et al. 2005; Slater 2002). Road kill data from Craighead Institute and other agencies only represent an index of the actual number of animals hit.

UVC totals across the entire study area fluctuated yearly over the span of the study with peaks in 2003 and 2007 and a low in 2006 (Figure 2). It is probable that 2010 will also represent a year of increased road kill given the numbers seen in the first six months, which in most years accounts for about 40 percent of the yearly total. Seasonally, most ungulates were killed in the autumn months of October and November, followed by a smaller peak in the summer months of June and July (Figure 3). Road kill in winter generally tends to be low.

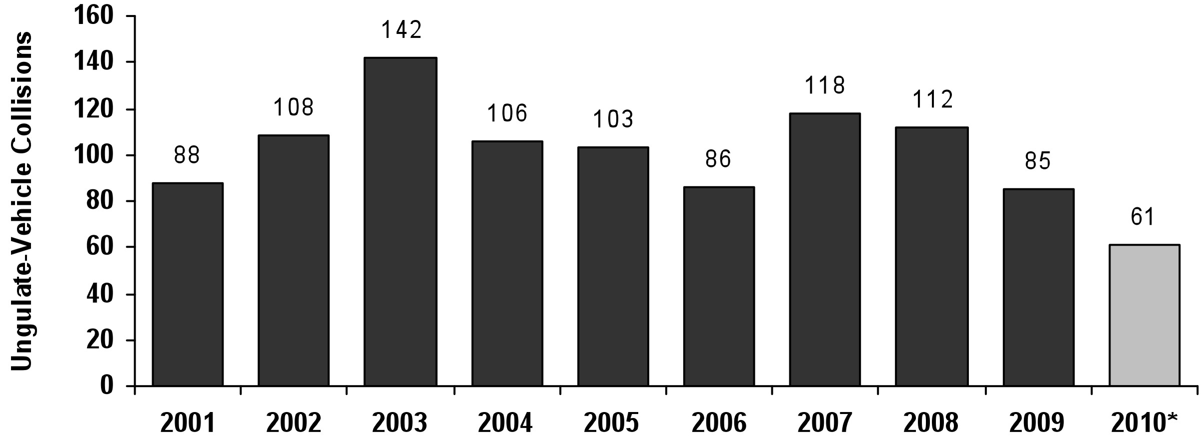

Figure 2. UVC totals by year, mileposts 309.5–333.0.
2010* represents the first six months only.

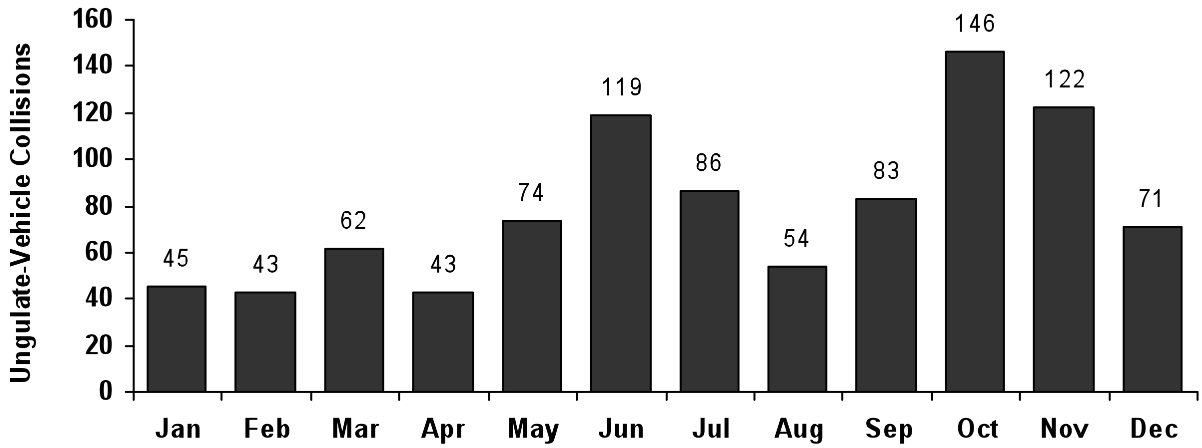

Figure 3. UVC totals by month, mileposts 309.5–333.0. Data from 2001 through 2009.

UVCs tend to be spatially clustered along I-90 on Bozeman Pass. As reported in Hardy et al. (2006, amended); eight 1/10-mile stretches were identified as road kill "hotspots." These occurred at MP 309.9, 310.1, 312.2, 312.8–312.9, 313.2, and 313.8–313.9. The last two were contained by the wildlife fencing installed in the fall of 2006. The same analysis was conducted using the post-fencing data for the entire Bozeman Pass. Eleven 1/10-mile stretches in five clusters were identified, occurring at MP 309.5–309.9, 312.8–312.9, 320.9, 328.3–328.4, and 332.5 (Figure 4).

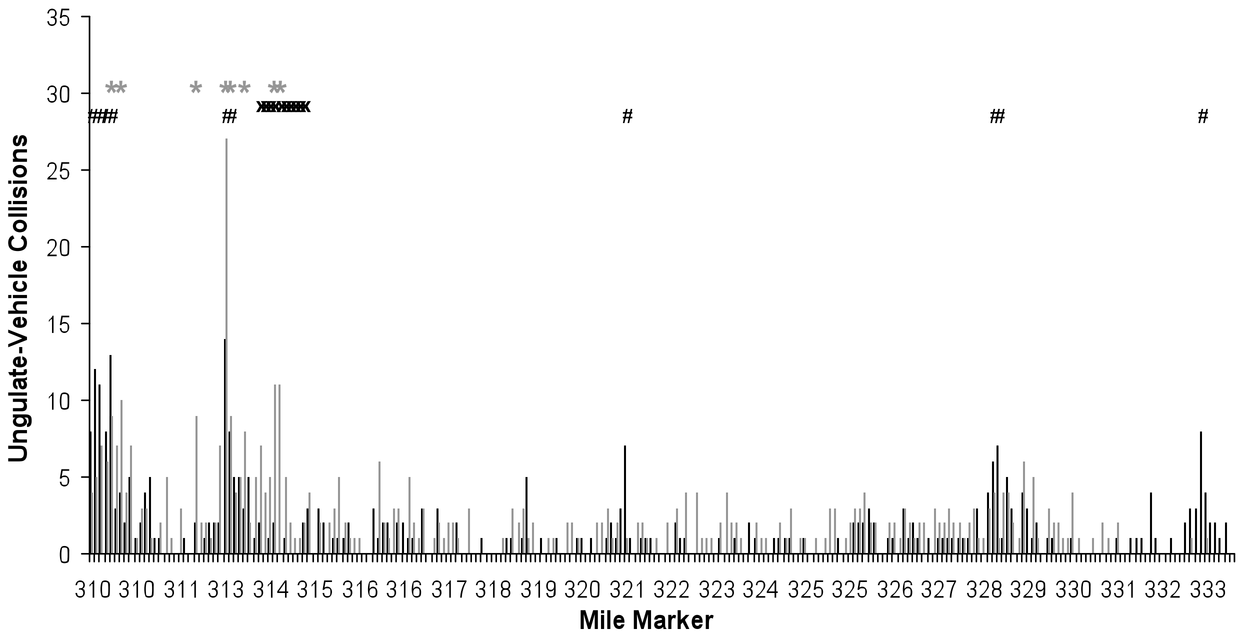

Figure 4. Distribution of UVCs along Bozeman Pass.
Pre-fencing data are shown in gray, with hotspots identified by a gray *. Post-fencing data are shown in black, with hotspots identified by a black #. The location of the wildlife fencing is indicated with a series of bold black Xs.

The network kernel density function in SANET resulted in similar "hotspot" results (Figure 5). Pre-fencing data resulted in three clusters representing 25 percent of the total UVC density pass-wide. These occurred at MP 309.7–310.2, 312.6–313.1, and 313.6–314.0. Post-fencing data resulted in two clusters representing 25 percent of the total UVC density pass-wide. These occurred at MP 309.5–310.1, 312.7–313.1. The hotspot initially present in the area to be fenced no longer appears, suggesting that one significant UVC hotspot was successfully mitigated by the fencing.

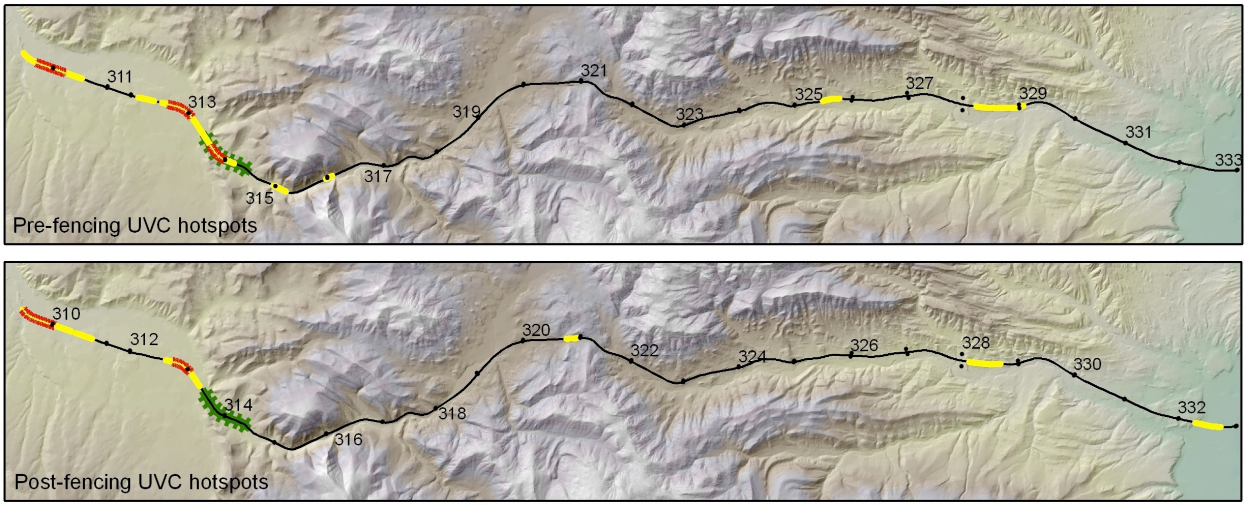

Figure 5. UVC hotspots along Bozeman Pass pre-fencing and post-fencing.
Double (red) and thick (yellow) sections represent areas that account for 25 percent and 50 percent of the pass-wide UVC density, respectively. Numbered points are mileposts and the series of hatch marks (green) represents the location of the wildlife fencing.

Road kill

Within the mitigation zone (MP 309.5–319.0) prior to fencing, there were significantly more UVCs in the proposed fenced area (fence) compared with the area outside of the proposed fenced area (outside) (data set January 1, 2001–March 31, 2005; one-tailed T-test, P=.06) (Table 4). This finding confirms the conclusion from Hardy et al. (2006) this area had higher than average road kill and justifies the placement of the mitigation fencing along this stretch of highway.

During the interim period of construction and fencing (April 1, 2005–July 4, 2007), UVC rates were reduced in the mitigation zone. This reduction was likely due to a combination of factors. As shown in Figure 2, there was a pass-wide dip in road kill during 2006, though 2005 and 2007 represent average road kill years. The construction activities in the mitigation study zone resulted in lower traffic speeds and two-lane traffic patterns during this time. Regardless of confounding influences, the mean number of UVCs in the mitigation zone during the interim period was significantly lower than during the pre-fencing period both inside and outside the fenced area (paired t-test, P=.01 [outside], P<.01 [fence]). All interim data were therefore omitted from further analyses.

Table 4. Mean UVCs per mile per year in the mitigation zone by time period.

Stretch	Pre-fence	Interim	Post-fence
Fence	11.6	2.2	2.7
Outside	6.9	4.8	7.3
Entire Zone	7.4	4.5	6.8

Analyses of pre- and post-fencing road kill data identified the fenced stretch as the only area where mean UVC rates were changed (Figure 6). In other words, the mitigation fencing has significantly reduced UVC rates in only the fenced area (one-tailed t-test, P=.004). In the four and a quarter years of pre-fence monitoring, 49 ungulates were killed in the area to be fenced, accounting for 17 percent of all UVCs in the study area. In the three years of post-fence monitoring, only eight ungulates have been killed there, accounting for 4 percent of all UVCs, and half of those were found at the fence ends (Figure 7).

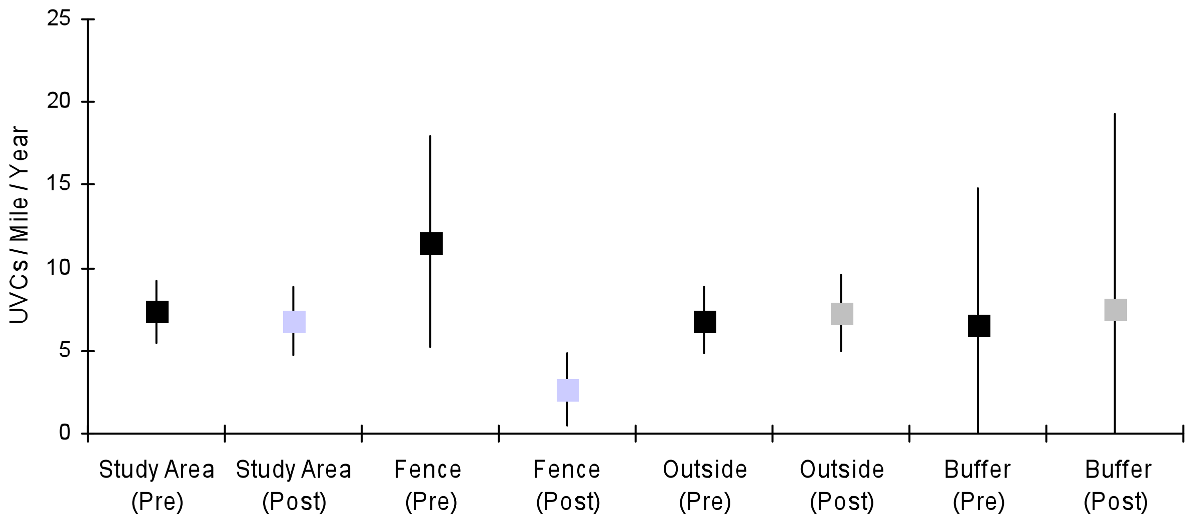

Figure 6. Mean UVC rates with 95 percent confidence intervals by section, pre- and post-fencing.

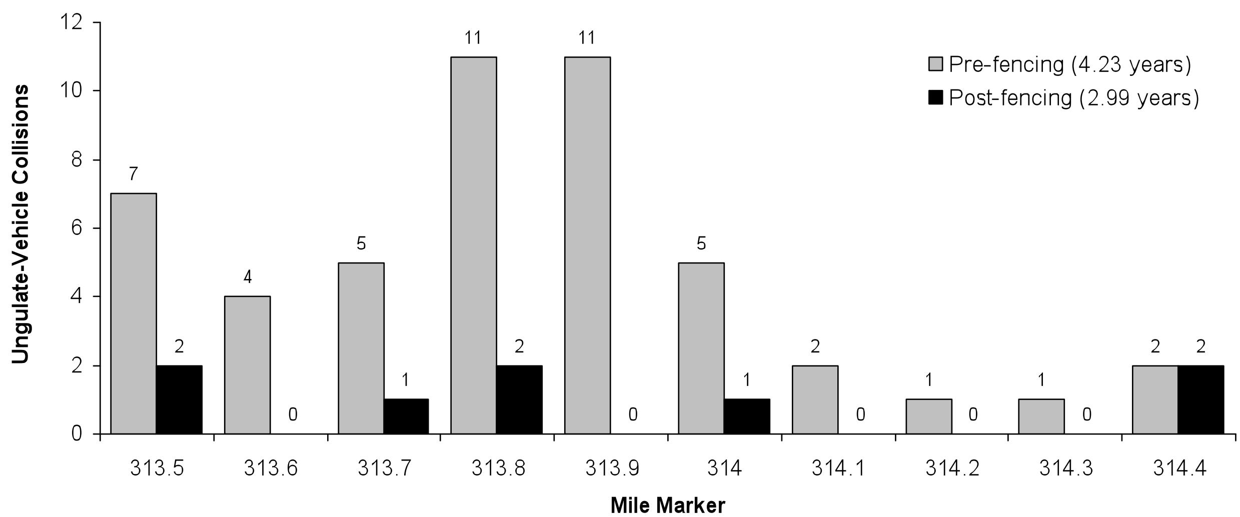

Figure 7. Pre- and post-fencing UVCs at individual mile markers within the fence.

To assess the end-run effect, data from the buffer stretches were combined with those of the fenced stretch and reanalyzed. The significant reduction is still apparent (one-tailed t-test, P=.01). Focusing on the buffer sections alone, it appears that there has not been a significant change in UVCs attributable to attempted end-run activity at the end of the fence (two-tailed t-test, P=.8). However, due to a very small sample size, such an effect would have to be extreme to be detectable statistically. Nonetheless, an examination of pure numbers supports the conclusion of no effect in the buffer areas (Figure 8). Additionally, the fencing resulted in no significant change on the UVC rates outside the fenced area, nor in the study zone as a whole (pre- and post-fencing comparison of means: two-tailed t-tests, P=.6 [outside]; P=.5 [study area]).

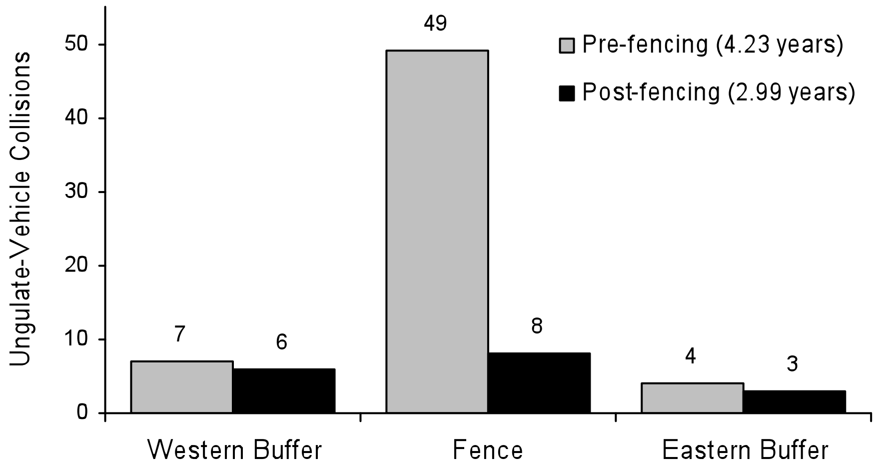

Figure 8. Pre- and post-fencing UVCs within the fence and buffer stretches.

Track-bed

Track-bed data from beneath the MRL bridge show a relatively constant suite of species using the passage (Table 5). Species of interest that appear in only the post-fencing dataset include black bear, mountain lion and moose. Elk were not recorded post-fencing. It should be kept in mind that the track-bed data are just a sample; species other than deer are recorded infrequently, and no definitive conclusions can be drawn from their inclusion in one or the other dataset.

Table 5. Species' tracks recorded in the MRL bridge track-bed.

Species	MRL bridge	
	Pre-fencing	Post-fencing
Black Bear		X
Mountain Lion		X
Fox	X	X
Canid	X	X
Felid	X	X
Raccoon	X	X
Skunk	X	X
Weasel	X	X
Moose		X
Elk	X	
Deer	X	X
Marmot	X	
Rabbit	X	X
Small Mammal	X	X
Snake	X	X
Bird	X	X
Horse	X	
Human	X	X
Dog (domestic)	X	X
Cat (domestic)	X	X

After the mitigation fencing was installed, the mean number of daily ungulate crossings under the MRL bridge significantly increased from 4.6 to 7.2 crossings per day (two-tailed t-test, P= .01). On a monthly basis from May through October, the largest increase in ungulate crossings per day occurred in the months of September and October (Figure 9).

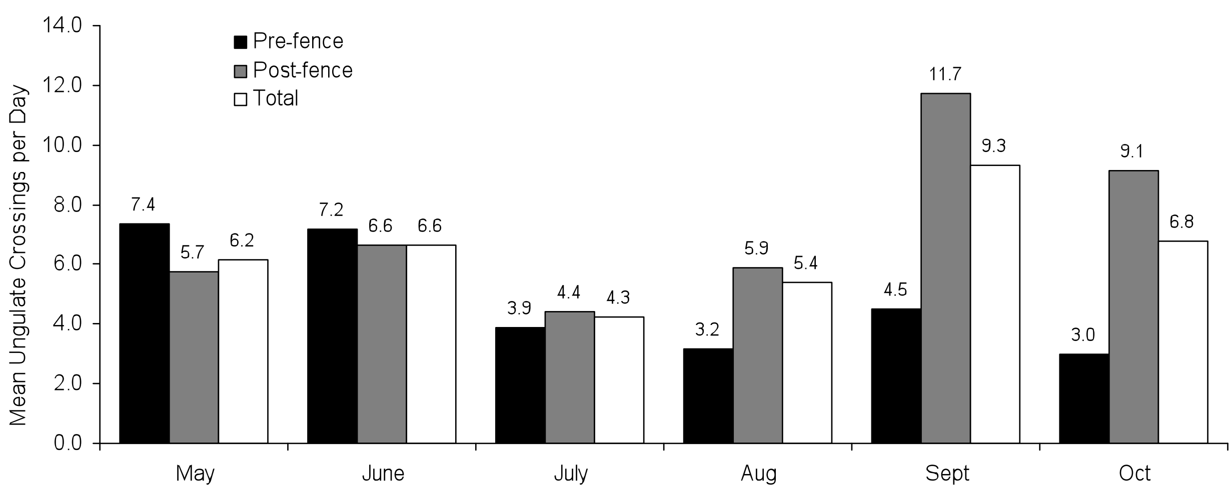

Figure 9. Mean ungulate crossings per day under the MRL bridge.

Jump-outs

During the post-fencing monitoring period, 42 of 164 surveys resulted in track identification. A total of 62 different tracks were recorded in the four jump-outs, representing at least eight species of mammals and reptiles (Table 6). The majority of tracks occurred at the NE and SE jump-outs. Marmots were living in the vicinity of these jump-outs and using them as a latrine site, which explains their over-represented presence. In almost three full years of data collection, only twelve sets of tracks from large-bodied animals have been identified in the jump-out track-beds. Unfortunately, in most cases, using tracks alone, it is unclear if the animal actually used the jump-out. The exception being during winter when coyote tracks indicated that the animal jumped and the impact site was clearly seen in the snow about 15 feet from the base of the wall. Animals were also recorded using remote cameras as discussed below.

Table 6. Jump-out track-bed data for survey period (August 2, 2007–July 1, 2010).

	Jump-out track-beds			
Species	NE	NW	SE	SW
Black Bear	1	0	0	0
Cat (domestic)	1	1	2	2
Canid	4	0	2	0
Deer	1	6	2	2
Marmot	15	3	8	0
Rabbit	2	0	2	0
Small mammal	2	1	3	0
Snake	1	1	0	0
Total	27	12	19	4

Remote cameras

Post-fencing data indicated that animals are reliably being photographed in the vicinity of the fence ends and jump-outs (Table 7). Pre- and post-fencing photograph comparisons at jump-outs and fence ends are not applicable in this study because there was no pre-fencing coverage. The RECONYX cameras have proven to be more sensitive and more reliable than the Trailmaster cameras and motion sensors that were used previously. Mice, voles, small birds and even flying grasshoppers were regularly recorded.

Table 7. Remote camera photographs near fence ends and jump-outs. Data are from January 1, 2008 to March 30, 2009.

Dashes represent 0 records.

Species	Fence Ends	West Jump Out		East Jump Out	
		NW	SW	NE	SE
Bird	18	66	156	125	75
Black Bear	--	--	--	1	1
Mountain Lion	--	1	--	1	--
Coyote	4	--	--	4	--
Raccoon	1	--	--	8	4
Skunk	1	--	--	4	--
Weasel	1	--	--	--	--
Deer	13	15	4	2	2
Marmot	1	--	--	592	243
Rabbit	4	--	--	2	7
Chipmunk	--	--	--	5	4
Mouse	11	--	--	4	2
Unknown Mammal	1	3	--	--	--
Human	10	2	1	1	2
Cat (domestic)	--	7	7	--	--

Fence-end cameras

Given the constraints experienced in setting up cameras, these monitoring techniques are limited in determining if animals successfully cross at the fence ends. We deployed only a single camera at each fence end, facing away from traffic toward the fence opening. When cameras faced traffic, even when sheltered by a guardrail, they quickly became covered with snow, mud, grime, etc., and in some cases cameras were damaged. If it had been possible to place two cameras at the fence end facing opposite directions it is likely that more animals would have been recorded on both sides of the highway as they crossed. Nevertheless, the data indicate that some mammals are trying to cross the highway at the fence ends, and in a few instances an animal was photographed jumping onto the highway at one camera, and exiting the highway at the other camera. In most cases however, animals were only recorded by one of the fence-end cameras, either entering or exiting.

Jump-out cameras

At the jump-out track beds the cameras often recorded animals whose tracks were not detectable. The cameras successfully recorded most of the animals (coyotes) that actually exited via jump-outs. No deer were recorded actually using the jump-outs to exit the fenced-in area although many were observed looking over the edge of the jump-out. The majority of photos taken were of birds, including, magpies, ravens, and crows, which tended to flock near the jump-outs. A variety of mammals was photographed at the fence ends or in the vicinity of the jump-outs; a marmot den was located near the NE jump-out and marmots used the jump-out track bed for sunning and as a latrine.

Culvert cameras

Pre- and post-fencing photograph comparisons in the culverts are also not applicable in this study because the data from pre-fence Trailmaster cameras were unreliable and the data record is incomplete. However, data show that the same suite of species is utilizing the culverts to pass underneath the highway both pre- and post-fencing (Table 8). Animals associated with aquatic habitats dominate the suite using the culverts. The exceptions are black bears, domestic dogs, birds and humans. The data also indicate that the east culvert (which has little or no water most of the year) is used more heavily than the west culvert (which usually contains about 2 feet of water).

Table 8. Remote camera photographs in culverts (MP 314.4). Dashes represent 0 records.

Species Photographed	Culvert at MP 314.4 (west)		Culvert at MP 314.4 (east)	
	Pre-fencing	Post-fencing	Pre-fencing	Post-fencing
Bird	--	--	9	7
Duck	1	--	--	--
Water ouzel	--	22	--	26
Frog	1	--	--	--
Black bear	1	3	--	11
Raccoon	1	5	82	63
Mustelid	--	--	7	1
Mink	--	--	--	27
Deer	--	--	--	1
Beaver	--	--	5	2
Unknown Mammal	--	--	4	--
Human	--	2	8	8
Dog (domestic)	2	--	4	--

Farm culvert cameras

The additional remote cameras placed at the ends of existing culverts/underpasses that were installed for farming/ranching use recorded virtually no use by wildlife. The camera at a box culvert near MP 311.0 connecting the Montana State University experimental farm with grazing land across the Interstate to the south recorded a few deer and foxes but none were photographed entering or leaving the culvert. The camera placed at MP 329.1 regularly recorded use by horses and domestic cats but no wildlife. The camera at MP 329.8 where culverts connect a ranch south of the Interstate with grazing lands to the north recorded horses, cattle, people on horseback, and farm vehicles. One pronghorn antelope was photographed near the entrance to the culvert, but not going into it.

Deer path camera

The RECONYX camera at MP 309.6 photographed a number of deer entering and leaving the highway at a point where they had created a well-worn path in the snow crossing the Interstate. Deer continued to use this after the snow was gone. As mentioned there were also regular deer paths at MP 309.8. Road killed whitetail deer were often found near these crossing points during the winter. This is also a “hotspot” area year round despite the fact that there is residential development to the south and commercial development to the north. It is likely to remain a hotspot even as adjacent development continues because there are open access points through the subdivision to the south and a relatively open campground to the north.

5. DISCUSSION and RECOMMENDATIONS

Pass-wide Assessment and Hotspots

Over the nine and a half years of data collection along Bozeman Pass, all large-bodied wild animals known to inhabit the area were documented as road kill, with the exception of wolverine and grizzly bear. The yearly fluctuation of UVCs along Bozeman Pass is not surprising, given that similar variability is seen in the population dynamics of many ungulate species. The UVC peaks in any given year can be attributed to an increase in population size (there simply being more animals on the landscape surrounding the highway), as well as a possible increased movement of ungulates.

The seasonal fluctuations are indicative of the migratory movement patterns of ungulates to some extent, particularly white-tailed deer. Two road kill peaks were identified—one in summer (June) and one in autumn (October–November). Other studies have shown an increase in roadkill in the spring/summer months, ranging from May through August (Clevenger et al. 2003; Huijser et al. 2008a; Grilo et al. 2009). The autumn peak is mirrored by an increase in movement underneath the highway in track-bed counts, but the summer peak is not as pronounced. Hardy et al. (2006) suggested the summer road kill peak may correspond with green-up, and the increased animal movement may be in response to forage availability. Ramakrishnan and Williams (2006) reported that for most of the year, the number of white-tailed deer males and females involved in accidents were relative to their proportion in the population. However, during the breeding season (fall), there were a higher proportion of males involved in accidents. So there is also a sex-specific behavioral component to road kill. However, the road kill peak may also be the result of increasing traffic volume on the highway. Higher traffic volumes increase the likelihood of collisions (Waller et al. 2006).

The road kill spike that occurs in the summer (May–July) is not accompanied by as great an increase in ungulate crossings under the bridge as during autumn. This suggests that the summer road kill spike may be just as likely a result of increased traffic volume than of increased animal movement (Figure 10). It is likely that the majority of deer tracks recorded on the track bed are white-tailed deer, which are observed regularly in the area. Females do not travel as widely during the period when they have fawns (Ozoga et al. 1982, Scanlon and Vaughan 1985) so the track-bed may be recording mainly local movements of resident animals in spring and summer. The autumn spike in road kill occurs during the period from September to November, a time when traffic volume is decreasing. However, track-bed data show a corresponding spike in the number of tracks per day beneath the bridge. It appears that at least localized animal movement increases in the autumn, perhaps due to breeding activity (Ramakrishnan and Williams 2006) as well as hunting season (Sudharsan et al. 2006).

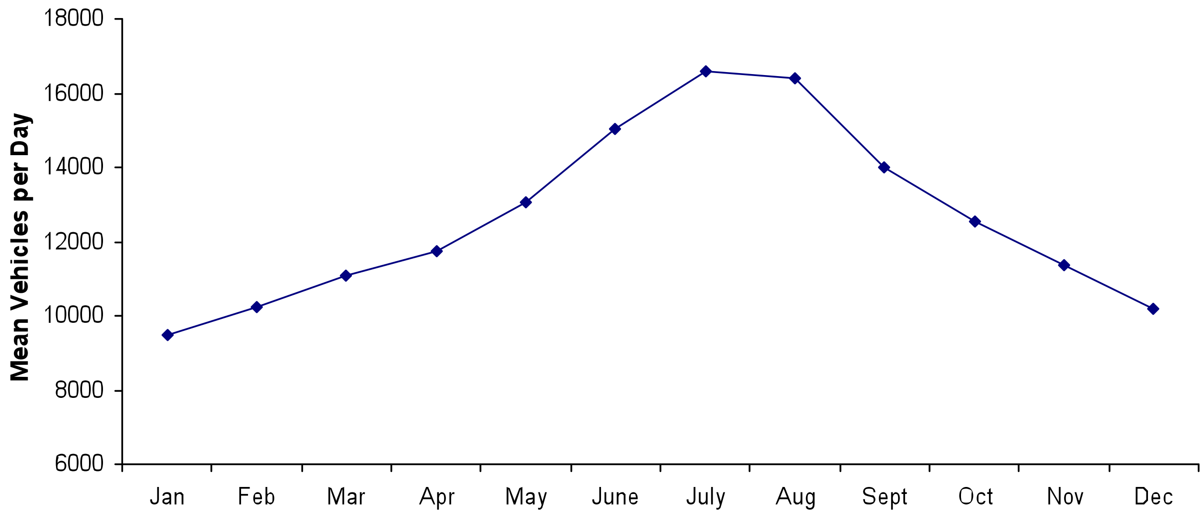

Figure 10. Mean vehicles per day, by month.
Data from MDT's Automatic Traffic Recorder reports, 2003-2009, recorder A-71 (MP 323.15). Reports available from http://www.mdt.mt.gov/publications/datastats/traffic_atr.shtml

Before the fencing was installed, eight 1/10-mile stretches were identified as road kill hotspots. Using the post-fencing data for the entire Bozeman Pass, eleven 1/10-mile stretches in five clusters were identified. The SANET network kernel density analysis showed that prior to fencing, three hotspots accounted for the top 25 percent of all pass-wide UVC density. These hotspots were all located between Bozeman and the Jackson Creek exit. Installation of the fence resulted in the disappearance of the one hotspot where the fence was located. Post-fencing, two significant UVC hotspots remain, still accounting for the top 25 percent of all pass-wide UVC density. Their locations remain essentially unchanged from the pre-fencing period, lying between Bozeman and the fenced area. The more western hotspot appears to continue beyond the extent of the study area, along the edges of Bozeman, and it would require additional assessment to determine its boundary.

Considering the relatively short time period of these studies, all areas identified either during the pre- or post-fencing periods should be considered as likely hotspots. The section of highway between the fencing site and the outskirts of Bozeman, because of its relatively short length (about 4 miles) could be considered in its entirety as a high-risk area for UVCs.

Mitigation Effectiveness Assessment

Road kill data from this study indicate that the installation of wildlife fencing and jump-outs has significantly reduced UVCs - and thus motorist safety - in the fenced area, with no accompanying significant increase in UVCs outside the fenced area. Specifically, the end-run effect, or increased road kill at fence ends, has not occurred. Animals still try to cross at the fence ends, as road kill data and photo monitoring document, but no more or less than before fence installation. Data from the track-bed underneath the bridge show an increase in ungulate use. Taken together, these results indicate the effectiveness of fencing in excluding animals from the highway, thereby making it safer for motorists, while maintaining habitat connectivity under the bridge. At least in the area of the fencing, this project has also increased the safety of the highway for motorists. Data also indicate that few animals are utilizing the jump-outs as an effective means of exiting the highway, though at least one species, coyotes, have successfully exited in this fashion. Culvert monitoring has documented the long term use by a variety of animals and people as a means to cross safely beneath the highway.

Jump-outs

Modifications to the Bozeman Pass jump-outs are warranted. Our data suggested that most animals did not use the jump-outs as a means of exiting the highway. There are only two documented photos of a coyote jumping off the jump-out away from the highway. There were several instances of tracks indicating that deer milled around the jump-outs but there were never any definitive data (tracks or photos) indicating that they actually jumped off the jump-outs. One series of photos shows a group of five to six deer at the top of the NW jump-out, many of which lay down in the snow for 45 minutes or so during the night. Eventually the deer moved off in the direction of the highway. Other photos showed that deer looked over the edge of the NE jump-out but would then turn away trying to find another way to exit. In many instances the deer simply turned away from the jump-out and then probably crossed back over the highway. The fact that there were no deer road kills within the fence associated with these photos indicates that the deer were able to successfully exit the fenced area without getting hit, perhaps over the guardrails, which become clogged with snow during winter.

The current design of the jump-outs may explain why animals are not using the jump-outs effectively. The face of the jump-out is made of cinderblocks placed at a 90-degree angle to the surrounding environment and parallel to the fence. The top of the jump-out where the track-bed is located is approximately eight to ten feet high at the NE, SE, and NW jump-outs. This is a difficult jump with a difficult flat landing area, even for a deer. The landing area is also probably difficult to see clearly at night.

Another jump-out design shortcoming is found at the point where the fence and the jump-out connect. Currently there is a gap that some animals may be able to pass through between the fence ends and the cinderblock. Craighead Institute personnel placed debris and rubble in these gaps when possible but were unable to build up a sufficient barrier at all jump-outs. In one instance a deer inside the fence squeezed out between the wall and the fence at the NE jump-out in order to avoid a researcher observing from the highway. It probably would not have attempted this without being inadvertently pressured, but it demonstrated that even deer could fit through this gap. Cameras at the jump-outs did not document any animals passing through this gap but it is easy to see how this could happen. One black bear appeared on the edge of the jump-out wall but could have either been following the fence to the jump-out or climbing up the edge of the jump-out.

Financial Assessment

The Bozeman Pass project highlights the effectiveness of reducing UVC through wildlife mitigation strategies such as wildlife fencing, jump-outs and modified earthwork. It shows that fencing projects alone can be added to help direct animals through existing structures. It also highlights the need for innovative monitoring techniques pre- and post-mitigation to provide quantitative measures of effectiveness.

Costs for this project were much lower than new wildlife crossing structures because the fencing was added to a structure replacement project for an existing bridge which functions as a wildlife underpass. While the cost of the mitigation techniques is not inexpensive, working with transportation managers and planners before planned rebuilds and upgrades can keep costs to a minimum. The cost of the planned MRL bridge rebuild in 2005–2006 was approximately six to eight million dollars (Deb Wambach, MDT, pers. comm.). The actual cost of the wildlife fencing and jump-outs was $104,269.46 (Lisa Durbin, MDT, pers. comm.) (Table 9), which increased the total cost of the re-construction project by only about 1.25 percent. However, the cost for the bridge re-build was larger than most other infrastructure projects so although the wildlife costs were about 1 percent of the total, that percentage would be higher in many other circumstances, based on total contract price (Deb Wambach, MDT, pers. comm.). Such investments are intended to increase motorist safety and benefit wildlife. It is only a fraction of the cost that insurance companies pay out yearly for reported UVCs.

Table 9. As-constructed mitigation costs

Mitigation	Cost ($US)
Barrier fencing	21,542.81
Single panel fencing	6,381.60
Double panel fencing	18,065.05
Jump-outs	22,280.00
7.2m cattle guards	36,000.00
Total	**104,269.46**

During the post-fencing monitoring period, there were a total of eight UVCs in the fenced area (four within the fence, four at the fence ends), compared with 49 in the pre-fence period. Note that the post-fence time period was shorter than the pre-fence time period (1092 and 1544 days respectively). If we want to compare equivalent numbers before and after fencing we could estimate that 0.70 of the 49 animals recorded pre-fencing, or approximately 35 UVCs, were killed during the same length of time as the post-fence period. Thus by adjusting for the differences in length of each period, an estimated net of 27 UVCs was avoided due to the fence (35=27+8). This is only a rough estimate for purposes of discussion since road kill rates are not constant and vary according to season, weather, traffic density, etc. However, as a rough illustration, if an average cost of $6,617 per collision (Huijser et al. 2009) is assumed, approximately $178,659 has been saved by society, nearly double the cost of the project. The overall benefits of the fencing to animals, drivers, and society are already being realized.

Design Recommendations

Fencing

It would be advisable to extend additional wildlife fencing from the Bear Canyon exit to the Main Street exit (MP 309.5) at Bozeman, approximately four miles. This recommendation assumes appropriate wildlife underpasses are available or that additional ones could be constructed. Currently, there is one farm road with a box culvert at MP 311.0 that would probably be used by wildlife if they were directed there by fencing. There is also a county road and underpass at MP 310.8 that may be used effectively by wildlife if the highway is fenced. While end-runs at the eastern edge of the fence have not proven to have increased due to the fencing, extending the fence (about 0.5 miles) to encompass the culverts at 314.9 on the south side of the highway and into a steep hillside on the north, may reduce AVCs in this area. This would allow animals to utilize both the culverts at MP 314.8 and at MP 314.9, especially the drier easternmost culverts, to pass safely underneath the highway. Photo data from the cameras indicate that a variety of species currently utilize those culverts.

Underpasses

If funding were available a better solution would be to construct new underpasses near the hotspot sites around MP 309.7 and 313.0 since there are no existing structures immediately adjacent to those sites. Similarly on the Livingston side of Bozeman Pass, underpasses may be effective if built close to the hotspots near MP 321, 325, 328, and 332. Although the existing underpasses near MP 328 were not observed to be used by wildlife, a better design of culvert, underpass, or elevated span that provides more space and visual openness should be much more effective (Clevenger and Huijser 2010).

Overpasses

Along with underpasses, overpasses in combination with wildlife fencing are the most cost-effective at reducing wildlife vehicle collisions (Huijser et al. 2008b). The best sites for an overpass would probably be near the hotspots at 315.0 or 316.0 because of the steep terrain and the proximity of the Interstate and the railroad. To be most effective an overpass should probably provide passage over both the highway and railroad (and/or frontage roads) and this area would require the least length of overpass. Data from overpasses in other locales suggest that even if the overpass is not exactly in a traditional travel route for animals are likely to learn of its location and begin to use it (Clevenger 1999). Locating a crossing structure where there is adequate habitat or compatible land use adjacent to the highway is one of the most important considerations (Clevenger and Huijser 2010, Huijser et al. 2008b).

Jump-outs

Placing a berm of dirt at the bottom of the jump-outs to provide a more sloped landing and less of a drop should improve the design so that animals may use jump-puts more willingly. This design would need to be tested with follow-up studies to determine its effectiveness. It is also worth inquiring among other practitioners to learn about their jump-out designs.

Placing large rocks or more cinderblocks to fill in the gaps between the fence and the jump-out walls would help ensure that animals would have to jump over the top and not use the gaps as a two-way pass-through area. Alternatively, increasing the gap between the wall and the fence and installing a one-way gate might also be effective. These modifications would be inexpensive and would reduce the risk of animals remaining inside the fence and eventually getting onto the highway.

Signage

Any application of temporary, seasonal signage warning drivers of wildlife crossing the road would be most effective during autumn when it appears there are more animals attempting to cross the highway. However, signs alone are relatively ineffective. When used as part of an animal detection system though, they can reduce AVCs about 87 percent (Huijser et al. 2008a).

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