Bozeman Pass Wildlife Channelization ITS Project

FINAL REPORT

by

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16. Abstract

Animal-vehicle collisions (AVCs) are a growing concern as vehicle miles traveled and human encroachment into wildlife habitat continues to increase throughout the United States. Few studies have examined the application of intelligent transportation systems (ITS) to modify driver behavior to reduce these collisions. This study investigated the effectiveness of dynamic message signs (DMS), an ITS application, to disseminate seasonal animal movement advisories as a speed reduction tool on Interstate 90 in the Bozeman Pass area. Driver responses to wildlife advisory messages displayed via other sign applications were also evaluated in a driving simulator environment. In addition to evaluating driver responses to in an attempt to lower AVCs, wildlife-vehicle collisions and movements on Bozeman Pass were monitored on Bozeman Pass prior to the installation of 0.9 miles of wildlife exclusion fencing targeted on modifying wildlife movements; monitoring will continue after the installation to provide data to conduct a before-after analysis evaluating the effectiveness the wildlife exclusion fencing in terms of reducing AVCs and maintaining wildlife movements under the interstate via an existing bridge where the fence will be installed. The last component of this project documented impacts of AVCs on department of transportation maintenance operations.

The speed study and driver survey on Bozeman Pass suggested that wildlife advisory messages posted on permanent and portable DMSs can reduce motorist speeds and drivers likely had heightened awareness due to the wildlife advisories, thus reducing the safe stopping sight distance of motorists, with the most significant reductions observed during "dark" conditions when the likelihood of AVCs is highest. Driving simulation study results showed that, compared to the traditional static wildlife warning signs, test subjects were more likely to see enhanced wildlife advisory signs and enhanced signs prompted subjects to drive at decreased speeds and they were more able to quickly respond to wildlife crossing the road. Pre-fencing road-kill monitoring spanning from 2001 to 2005 documented nearly more than 1300 AVCs on Bozeman Pass. Monitoring of wildlife movements in the Montana Rail Link (MRL) bridge area also occurred prior to the installation of the wildlife fencing. Fencing will be installed in 2006 and monitoring will continue to determine the effectiveness of the fencing. The outcomes from the fencing evaluation will be combined with results from this project to provide a single, comprehensive report documenting the measures applied to increase driver safety and decrease impacts on wildlife in the Bozeman Pass region. Impacts on maintenance operations were challenging to quantify; a more in-depth assessment of the costs of wildlife carcass removal and disposal versus the expenses related to applying and maintaining different mitigation measures would help determine the most cost-efficient techniques to reducing AVCs. In conclusion, the evaluation of measures to reduce AVCs via driver and animal behavior modifications, and the preliminary assessment of the impacts of these issues on maintenance operations will help guide future decisions related to managing wildlife-transportation conflicts in the northern Rocky Mountain region.

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EXECUTIVE SUMMARY

Animal-vehicle collisions (AVCs) are a growing concern as vehicle miles traveled and human encroachment into wildlife habitat continues to increase throughout the United States. Measures to prevent AVCs such as wildlife exclusion fencing and wildlife passages can impose significant investments for transportation agencies. One potentially less expensive approach is to use intelligent transportation systems (ITS) to modify driver behavior to reduce these collisions. This study investigated the effectiveness of ITS to disseminate seasonal animal movement advisories as a speed reduction tool on interstate highways in the field and replicated in a virtual environment. The project consisted of the following components:

- A literature review to document previous research related to the subject;
- A field study in the Bozeman Pass region of Interstate 90 in Montana, to investigate the effectiveness of wildlife advisories posted on Dynamic Message Signs;
- A simulator study to investigate the relative impact of various types of message signs on driver behavior;
- Field monitoring of wildlife-vehicle collisions and movements on Bozeman Pass; and
- A survey of Montana Department of Transportation (MDT) division maintenance chiefs to document the impacts of AVCs on their operations.

Literature Review

The literature review focused on studies addressing the relationship between speed and animal-vehicle collisions, and driver responses to signs in the field as well as in a simulated environment. Researchers consulted an internal literature database of approximately 2,600 articles related to wildlife and transportation, the Proceedings from Transportation Research Board Annual Meetings, Transportation Research Information Services (TRIS) On-line, and other on-line literature search engines in the transportation engineering and wildlife ecology sectors. Principal findings included:

- Driver speed likely contributes to AVCs;
- Enhanced signs, with additional, unique features to catch the attention of drivers, have greater potential of impacting driver behaviors;
- Enhanced static animal advisory warning signs have been studied in a limited number of field studies with varying results; and
- Simulator studies indicate that dynamic warning messages have a short-term impact on driver speed, but that drivers often increase speeds later, resulting in ambiguous safety results.

In summary, the literature reveals significant variation in driver responses to enhanced signs. The potential to reduce speeds and AVCs using enhanced signs is likely to be affected by interactions between the sign’s characteristics (size, design, location), its message, the surrounding context (environment, time of day or season), the driver’s ability to see and understand the message, and the driver’s familiarity with the local conditions and potential risks in the area.

Field Study

In the field study, Dynamic Message Signs (DMSs) were used to post messages advising motorists to watch for wildlife moving across Interstate 90 in the Bozeman Pass region of southwestern Montana. One control and three treatment messages were displayed on two permanent and one portable DMS, and individual speeds were recorded to measure drivers' responses to these messages. The control message was comprised of a blank message and three treatment messages, which included a general transportation advisory message and two wildlife advisory messages. Field study results suggest the following:

- The wildlife advisory messages posted on DMS reduced average motorist speeds;
- Speed reductions associated with the wildlife advisory messages were greatest during "dark" conditions;
- A greater speed reduction was observed after drivers passed animal advisory messages on the portable DMS compared to the permanent DMS; and
- Responses to animal advisory messages on DMS waned over time and distance traveled past the signs.

Another component of the field study was a local public outreach campaign, in which press releases and radio public service announcements were disseminated regarding wildlife movements in the Bozeman Pass area. The driver survey conducted for the field study included questions regarding the public outreach effort, and provided qualitative feedback indicating that the publicity did reach drivers.

Driving Simulator Study

The driving simulator study examined driver responses to enhanced wildlife advisories as a potential means of reducing wildlife-vehicle collisions. The study was conducted in the WTI Driver Simulator Laboratory, in a scenario that replicated the Bozeman Pass environment used in the field study. Eighty-one participants were divided by age and gender into four groups. Each group was exposed to a different wildlife advisory sign treatment consisting of the following: (1) a standard sign with the text "Next 20 Miles", (2) a standard sign with flashing beacon with the text "Next 20 Miles", (3) a Dynamic Message Sign (DMS) with the text "Animal Crossing Next 20 Miles Be Alert"; and (4) a combination of a DMS with the text "Animal Crossing Next 20 Miles Be Alert" and a standard sign with a flashing beacon with the text "Next 20 Miles" located approximately 6 miles beyond the DMS sign. Results indicated the following:

- All enhanced signage treatments resulted in decreased speeds and an increased onset of braking distance (i.e. faster reaction time);
- The standard sign with flashing beacon demonstrated a statistically significant reduction in speed over the standard sign; and
- The combination treatment of the standard sign with flashing beacon and the DMS sign was "positively identified" most often, resulted in the least number of collisions with deer (in the simulated scenario), and provided the greatest statistically significant onset of braking distance.

In conjunction with the speed study recommendations regarding seasonal use and placement of enhanced signs, it appears that the use of multiple enhanced animal advisory signs, on a seasonal and site-specific basis, has greater potential to increase driver awareness and potentially decrease speeds in hopes of reducing animal-vehicle collisions compared to the use of the standard, static wildlife warning signs. Further driver simulator studies would be useful in exploring what types, combinations of, and appropriate distances between enhanced signs maximize driver awareness and speed reductions.

Wildlife Monitoring

Due to the short-term nature of this project, the ultimate variable of interest, animal-vehicle collision rates, could not be evaluated in terms of the effect of the DMS messages in a statistically sound manner. However, this project allowed the continuation of wildlife traffic mortality and movement monitoring that was initiated to assess the effect of wildlife fencing that is being installed and landscape modifications that have been incorporated into the reconstruction of the Montana Rail Link underpass near the Bear Canyon interchange on I-90. The monitoring efforts consisted of:

- Road-kill data collection and analysis. From 2001-2005, researchers conducted more than 500 road kill surveys and documented more than 1300 AVCs. Most AVCs occurred in June, July, September, October and November during those years. Two regions with higher than average numbers of AVCs across the study area were identified; and
- Monitoring of wildlife behaviors and movements in the Montana Rail Link (MRL) overpass area of I-90. Using tracking beds, researchers were able to establish crossing rates under I-90 for deer. Remote motion- and heat-sensing cameras verified the presence of numerous other species in the overpass area.

Maintenance Operations Impacts

To better understand how and to what degree the Montana Department of Transportation's (MDT) Maintenance Operations are impacted by AVCs, researchers developed and delivered a survey to Maintenance Chiefs in all maintenance divisions in the state in August 2005. Survey questions sought to qualitatively characterize the approaches, issues, expenses, and challenges related to road killed carcass removal in the various divisions. Twelve surveys were completed by 14 individuals and returned by October 2005. Results are summarized, below:

- Maintenance operations opportunistically remove, dispose of and report animal carcasses from the roadways in their divisions as part of routine road inspection duties;
- Reporting appears to vary somewhat from division to division; e.g., some divisions report all animal carcasses observed, while others may not report domestic animal carcasses or carcasses that were moved but not removed and disposed of outside of the right-of-way, or there were a few divisions that reported carcass locations to the nearest mile marker while most divisions reported locations to the nearest tenth of a mile;
- Effort and expenses associated with these duties is challenging to quantify because this task is lumped with other "debris removal" activities associated with routine road inspections; however some divisions estimated that these duties may comprise 1-3% of their division's annual budget; and
- Signs are currently the main mitigation measure used in most if not all divisions, but several efforts (e.g., wildlife fencing and crossing structures, animal-detection/driver-warning system) are newly installed or planned in some divisions.

At this time, it is not clear how much effort is required to maintain other mitigation techniques such as wildlife fencing and crossings or animal-detection systems, nor is it apparent how well the mitigation may perform. Hence, assessment of the trade-offs of proactive investments in mitigation versus the time and expense for removing and disposing carcasses may be premature given the relatively new or planned mitigation installations.

Summary of Recommendations

Based on the field speed study's results, the driver simulator study results, and the literature, researchers suggest that enhanced animal advisory signs can affect driver behavior with the potential of reducing animal-vehicle collisions. However, overuse or inappropriate use of such signs may result in drivers becoming complacent to the importance of these signs. A brief summary of recommendations regarding the use of enhanced wildlife advisory signs follow:

- If using DMS to deliver animal advisory messages, follow guidelines on message construction;
- If using enhanced standard signs, use larger-than-typical sizes and fonts and consider including flashing lights, bright flagging, and reflective backing;
- Apply signs as close to specific areas where there is documentation of concentrated animal movements or AVCs, understanding that driver responses will be greatest where they first see the sign;
- Apply or activate signs when animal movements and AVCs peak, typically at night during the fall months;
- Consider the characteristics of the driving population, favoring areas where local motorists may be more aware of AVCs and animal movements. Consider using enhanced signs in conjunction with education outreach and/or public relations campaigns advising drivers of the risks of AVCs;
- Driver simulator studies would be useful in exploring what types, combinations of, and appropriate distances between enhanced signs maximize driver awareness and speed reductions; and
- Driver surveys may also provide useful insight that may allow for adaptive management of the use of these signs.

Regarding the on-going wildlife monitoring efforts to assess the effectiveness of the wildlife fencing and landscaping efforts that will be installed in the fall of 2006 at the Montana Rail Link (MRL) bridge, researchers recommend the following:

- Three to five years of post-fencing monitoring would be an optimal investment of energy in order to make reasonable quantitative comparisons between the pre- and post-fencing AVC data to determine the effect of the fencing. The minimum estimated detectable decline in ungulate-vehicle collisions (UVCs) for three to five years of post-fencing monitoring in the areas to be fenced ranged from 36-27%, while the minimum detectable decline in the area to be fenced plus 0.2 miles adjacent to the fence area ranged from 31-19% given three to five years of post-fencing monitoring.
- Attention must be given to the seasonal differences in UVC and crossing rates by ensuring equal sampling sessions between fall, winter, and summer seasons;

- The UVC and crossing rate data should be assessed annually to determine effectiveness. Effectiveness was defined (by panel consisting of staff from MDT, Montana Fish, Wildlife and Parks, and American Wildlands) as a reduction in UVCs and any degree of wildlife movements under the MRL bridge; and
- Consider adaptive management options if data indicate wildlife fencing does not reduce AVCs or limits wildlife movements.

To better assess the cost-effectiveness of investments in proactive efforts to address AVC issues versus current expenditures and resources dedicated to responding to AVC occurrences, an additional focused assessment of maintenance operations (beyond this study's qualitative survey) is recommended. If the investment of time to post seasonal DMS wildlife advisories is relatively minimal and drivers respond to the messages either by reducing speed, increasing awareness, or both, there may be a "payoff" in terms of fewer collisions with animals, fewer carcasses to remove and report over the years. If divisions have DMS and/or enhanced signs available for seasonal animal advisories, documentation of the effort to deploy these measures and long term monitoring of AVC rates and carcass removals at these sites before and after the deployments could help quantify these trade-offs (i.e., a meta-analysis across all deployment sites in the state to increase statistical power to detect changes in AVC rates and carcass reporting), while proactively increasing the potential for drivers to reduce speeds, increase awareness and ultimately respond faster to avoid a collision with an animal.

In conclusion, efforts to increase driver safety and decrease impacts on wildlife movements in the Bozeman Pass area uniquely address both driver and animal behaviors. The speed study and driving simulator study evaluated methods to modify driver behavior via relatively inexpensive applications of enhanced and targeted signs to deliver wildlife advisory messages at specific times and locations when and where drivers are most likely to encounter animals on the road. The wildlife monitoring efforts provided baseline data on animal-vehicle collisions and wildlife movements in the vicinity of an upcoming installation of wildlife fencing to limit wildlife from crossing the interstate risking colliding with passing vehicles; after fencing is installed, monitoring will continue in order to provide data to evaluate the effectiveness of the fencing in terms of reducing animal-vehicle collisions while providing safe passage under the interstate. The outcomes from the fencing evaluation will be combined with the results from this project to provide a single, comprehensive assessment that can be used to guide future decisions related to managing wildlife-transportation conflicts in the northern Rocky Mountain region.

1. INTRODUCTION

Animal-vehicle collisions are a growing safety, socio-economic, and ecological concern as vehicle miles traveled and human encroachment into wildlife habitat increases throughout the United States. Conover et al. (1995) estimated more than 1 million deer-vehicle collisions occur annually in the United States resulting in more than 200 fatalities, 29,000 injuries, and costing $1.1 billion in vehicle damage alone. Vehicle-related wildlife mortality can threaten some wildlife populations' long-term viability (Forman et al. 2002), which, in turn, can impact the ecological integrity of ecosystems. Transportation and natural resource agencies are searching for potential solutions to this ubiquitous "side effect" of transportation systems.

Numerous measures to reduce animal-vehicle collisions (AVCs) have been tried with varying degrees of success. Numerous overviews of AVC mitigation measures summarize the evidence, or lack thereof, of the effectiveness of these methods (Forman et al. 2002; Hedlund et al. 2004; Farrell et al. 2002; Knapp et al. 2004). Techniques that rely on altering animal behaviors include roadside-reflectors, vehicle-mounted whistles, repellents, intercept feeding, and wildlife fencing combined with passages under or over roads. The effectiveness of most of these measures is limited or uncertain. The most promising method is wildlife fencing (with wildlife passages to reduce habitat fragmentation), which has been shown to reduce AVCs by 80-90% (Clevenger et al. 2001; Ward 1982; Lavsund and Sandegren 1991). However, given the expense and long-term maintenance requirements that accompany such fencing and crossing installations, as well as residual clusters of AVCs that sometimes occur at the ends of the fence, and concerns about fencing becoming more of a barrier to wildlife movements than the unmitigated road may have been, there is ongoing interest in other measures that may be combined with fencing or applied independently to reduce AVCs.

While many mitigation options aim to influence animal behavior and movements in order to reduce AVCs, as described above, another tactic is to influence driver behavior in order to avoid these incidents. Educational outreach, public relation campaigns, speed limits and enforcement, and innovative signs can be used to inform and persuade drivers to adapt their behaviors in order to safely navigate particular conditions. Dynamic Message Signs (DMSs) have become a common way to deliver messages and advisories to motorists. Specific DMS applications include delivering traffic information, emergency information, route guidance, weather advisories, and speed control or advice. When appropriately used, DMSs are considered a useful tool to convey important information to drivers to ensure safer and more efficient use of the transportation system.

This study investigates driver responses to animal advisory messages delivered on DMSs as a potential method of reducing speed with the goal of reducing animal-vehicle collisions. Researchers from the Western Transportation Institute at Montana State University (WTI) assessed driver responses in terms of changes in speed and feedback obtained via driver surveys, both in the field and a driving simulator. The field site selected for study was on Interstate 90 (I-90) on Bozeman Pass, a region with a north-south wildlife movement corridor and existing DMSs for east-west I-90 travelers, in southwestern Montana (Figure 1).

Due to the short-term nature of this project, the ultimate variable of interest – animal-vehicle collision rates – could not be evaluated directly in a statistically sound manner. However, this project allowed the continuation of wildlife traffic mortality and movement monitoring that was initiated to assess the effect of wildlife fencing that is being installed and landscape modifications that have been incorporated into the reconstruction of the Montana Rail Link underpass near the Bear Canyon interchange on I-90. These data will be used in a before-after evaluation of the wildlife fencing as a method to reduce animal-vehicle collisions; additionally, the monitoring data will document wildlife movements under I-90 in order to address the equally important issue of habitat connectivity.

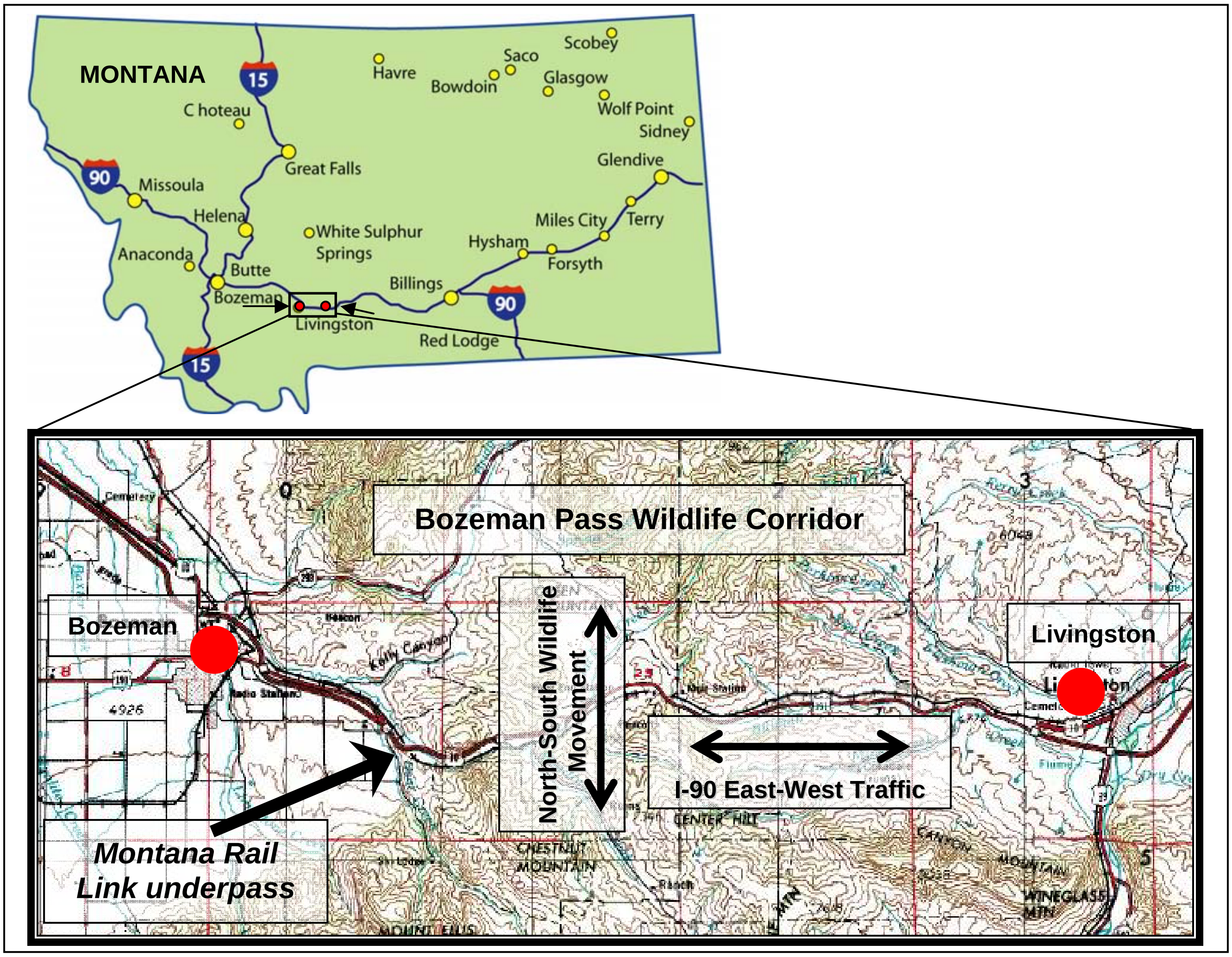

Figure 1. The Bozeman Pass study area on Interstate 90 between the towns of Bozeman and Livingston in southwestern Montana.

1.1. Literature Review

The literature review focused on studies addressing the relationship between speed and animal-vehicle collisions, and driver responses to signs in the field as well as in a simulated environment. While not a completely exhaustive review, researchers searched WTI's internal literature database of approximately 2,600 articles related to wildlife and transportation in addition to searching the Proceedings from Transportation Research Board Annual Meetings, Transportation Research Information Services (TRIS) On-line, and other on-line literature search engines in the transportation engineering and wildlife ecology sectors.

1.1.1. Speed as a Contributing Factor to AVCs

Driver speed likely contributes to AVCs. Considering speed and collisions in general (i.e., all types of collisions, not just AVCs), Elvik (2005) conducted a meta-analysis of 98 studies and found a strong relationship between change in speed and number of accidents and severity of injuries. Of the few studies that have specifically addressed AVC rates relative to speed, most have found positive correlations between these variables. Gunther et al. (1998) assessed AVC rates on Yellowstone National Park (YNP) roads, finding a significantly higher AVC rate on the stretch of road with a posted speed limit of 88 km/hr (55 mph) (and observed speeds over the speed limit) compared to the park roads with posted speed limits of 72 km/hr (45 mph) or lower; they concluded that speed was the primary factor contributing to AVCs in YNP. Case (1978) found speed to be significantly positively correlated with animal-vehicle collisions involving nine species of animals on Interstate 80 in Nebraska. Rolley and Lehman (1992) found a positive relationship between raccoon road-kills and speed in Indiana. Allan and McCullough (1976) observed increasing deer-vehicle collisions with increasing speeds in Michigan. While the evidence is not overwhelming, it appears that speed may be a contributing factor to AVCs.

1.1.2. Field Studies on the Use of Signs to Influence Speed & AVCs

According to the Manual on Uniform Traffic Control Devices (MUTCD), warning signs "call attention to unexpected conditions…to situations that might not be readily apparent to road users" and "alert road users to conditions that might call for a reduction of speed or an action in interest of safety and efficient traffic operations (FHWA 2000)." Traditional diamond yellow warning signs are commonly used to warn drivers of unexpected situations including wildlife crossing highways. However, it is commonly believed, and in some cases demonstrated, that drivers become complacent to the importance or meaning of traditional, static, diamond yellow warning signs (Pojar et al. 1975; Putman 1997; Sullivan and Messmer 2003; Sullivan et al. 2004; Al-Ghamdi and AlGadhi 2004, Vest and Stamatiadis 2005).

Enhanced signs, with additional, unique features to catch the attention of drivers, have greater potential of impacting driver behaviors. Vest and Stamatiadis (2005) summarized literature on the general use of warning signs combined with devices such as flags and lights to reduce speeds and found that where hazards were not obvious, speed reduction of 3.2-4.8 km/hr (2-3 mph) could be expected, and where hazards were more clearly explained by the sign or obvious to the driver, speed reduction was likely to be greater and the driver probably paid closer attention.

Enhanced static animal advisory warning signs have been studied in a limited number of field studies with varying results. In a unique study that used fencing to localize where deer cross the road and where enhanced "animal crosswalk" signs were installed to warn drivers of this crossing hazard, Lehnert and Bissonette (1997) found that drivers did not reduce speeds, and the observed reduction in deer-vehicle collisions was not statistically significant. Pojar et al. (1975) found motorists reduced speeds in response to a lighted, animated deer crossing sign in Colorado, but deer-vehicle collisions were not effectively reduced. Sullivan et al. (2004) installed temporary, enhanced signs during high-risk periods at mule deer migration corridors in Utah, Nevada, and Idaho and observed reduced speeds and a 50% reduction in deer-vehicle collisions, although there was an indication that the effect on speed was reduced over time. Al-Ghamdi and AlGadhi (2004) tested a standard camel crossing warning sign with six other enhanced designs and quantified statistically significant mean speed reductions of 3-7 km/hr

(1.9-4.3 mph) 500 m (1,640 ft) before and after signs that were double the size of the standard warning sign and included high-visibility reflective backing.

Animal-detection/driver warning systems dynamically activate enhanced warning signs when animals have been detected near or on the road. Gordon et al. (2004) demonstrated that in general, most drivers did not slow in response to activated animal-detection signs, but that drivers were more likely to decrease speeds at night or when they saw experimentally-placed deer decoys. Huijser and McGowan (2003) provide a thorough overview of dynamic animal-detection/driver warning systems in North America and Europe, and in that overview, cite two European studies by Muurinen and Ristola (1999) and Kistler (1998) that showed drivers passing activated animal warning signs may only reduce speeds if conditions are wet or icy or when the signs included a speed limit. Nonetheless, Kistler (1998) reported an 82% reduction in AVCs.

1.1.3. Driver Simulator Studies on the Use of Signs to Influence Speed & AVCs

Driving simulation studies can control much of the variability that may influence driving behavior while testing subjects in a safe environment. Driving simulation studies have been used to evaluate driver comprehension of traffic signals (Knodler et al. 2002). Speed has been shown to be a valid dependent variable for measuring driver responses to various scenarios in a simulated environment (Godley et al., 2002), and braking response times have been used to measure driver responses (Broen and Chiang, 1996). In one driving simulation study, Hopkins et al. (1997) exposed a small group of subjects (n = 8) to scenarios with traditional warning signs and rectangular signs with flashing features and found the latter treatment resulted in greater deceleration responses. In a simulator study assessing driver responses to DMS messages regarding adverse driving conditions, Ulfarsson et al. (2002) found that DMS messages significantly reduced mean speeds, but significantly increased speed variation and drivers accelerated, compensating for lower speeds, with the speed reduction effect diminished 10 km past the DMS. Similarly, Boyle and Mannering (2004) used a simulator to examine driver responses to in-vehicle messaging and messages delivered via DMS, both advising drivers of inclement weather conditions. They found that drivers did slow down when they encountered adverse driving conditions, but that drivers tended to compensate for speed reductions by increasing speeds further down the highway, and concluded that the net safety results were ambiguous. Specifically related to wildlife warning signs, Hammond and Wade (2004) found that enhanced wildlife warning signs with a flashing beacon effectively reduced driver speeds.

In summary, the literature reveals significant variation in driver responses to enhanced signs. The potential to reduce speeds and AVCs using enhanced signs is likely to be affected by interactions between the sign's characteristics (size, design, location), its message, the surrounding context (environment, time of day or season), and the driver's ability to see and understand the message. This study fills a gap in the literature given the lack of published information regarding the use of DMS to warn drivers about animal movements.

2. FIELD STUDY

Landscape features, such as mountain passes, are natural conduits for wildlife movement. Forest Service biologists have identified Bozeman Pass as a high-priority, key linkage area for wildlife movements between the Greater Yellowstone Ecosystem and habitats to the north that connect to the Bob Marshall/Glacier Ecosystems in the Northern Rockies (Ruediger et al. 1999). Located between the growing communities of Bozeman and Livingston, Montana, Bozeman Pass accommodates a transportation corridor including Interstate 90 (I-90), frontage roads and the Montana Rail Link (MRL) railroad. This east-west transportation corridor accommodates, on average, 12,000 vehicles a day through this wildlife linkage area. This traffic may be a barrier to north-south wildlife movements; if not an impassable barrier, it is a hazard (for both people and wildlife) when animals try to cross the highway.

As the region and traffic volumes grow, conflicts between motorists and wildlife are likely to increase on Bozeman Pass. Physical measures such as wildlife fencing and underpasses aimed at influencing wildlife movements can reduce these conflicts, but given the extent of the wildlife movement area on Bozeman Pass, these mitigation techniques are not practical on such a large scale. Increasing driver awareness and decreasing speeds when the risk of encountering wildlife is greatest (in the fall, at night) may offer a cost-effective alternative to physical installations. Intelligent Transportation Systems (ITS) apply different technologies to inform drivers of pertinent information; Highway Advisory Radio (HAR) and Dynamic Message Signs (DMS) are two examples of ITS technologies commonly used to disseminate real-time information to drivers. With two existing, permanent DMS located between Bozeman and Livingston, and an additional portable DMS, the Bozeman Pass corridor provided an ideal opportunity to experimentally deliver animal advisory messages to drivers and evaluate drivers' responses to the messages.

Using a local public outreach campaign, including press releases, radio public service announcements, and messages on the DMS on Bozeman Pass, project partners delivered information regarding seasonal wildlife movements in the Bozeman Pass area. To assess how drivers responded to these efforts, WTI researchers conducted a speed study and corresponding driver survey. Although the researchers are ultimately interested in animal-vehicle collision (AVC) occurrences, it would take many years to collect an adequate sample size to quantitatively test whether such advisories reduced AVCs; therefore the researchers focused on the more proximate response variable that likely contributes to AVCs: observed speeds. The survey further qualified drivers' comprehension of and responses to the animal advisory messages, and provided some feedback regarding the extent to which the public outreach campaign was received by Bozeman Pass drivers.

2.1. Study Area

This study took place on I-90 between mileposts 309 to 330 over Bozeman Pass (elevation 1,741m; 5,712 ft) between Bozeman (elevation 1,462m; 4,795 ft) and Livingston (elevation 1,373m; 4,503 ft), in mountainous, rural southwest Montana (Figure 1). This east-west transportation corridor includes frontage roads and a railroad parallel to I-90. Two and three interchanges in Livingston and Bozeman, respectively, provide access to and from I-90, while another four interchanges provide local access to and from I-90 between these two towns. The annual average daily traffic traveling on I-90 over the pass was 12,754 vehicles in 2004

(Montana Department of Transportation 2005). Posted speed limits are 120km/h (75 mph) for passenger vehicles and 105 km/hr (65 mph) for trucks. At the east and west peripheries of the study area, the Livingston and Bozeman communities were home to an estimated 7,062 and 32,414 residents, respectively in 2004 (US Census Bureau 2005).

One permanent DMS is located at milepost 311 for eastbound drivers as they drive from Bozeman toward Livingston. A second permanent DMS is located at milepost 330.5 for westbound drivers as they travel from Livingston to Bozeman. Prior to this study, "TRAVEL INFO CALL 511 BEFORE YOU DRIVE" had been posted on the permanent DMSs whenever no other advisory information needed to be posted. For this study, one portable DMS was temporarily located at milepost 314.8 to distribute messages to westbound drivers moving through the area with the greatest numbers of annual observed road kill (Figure 2).

Many animals including elk (*Cervus elaphus)*, moose (*Alces alces)*, deer (*Odocoileus* spp. including both white-tail and mule deer), black bear (*Ursus americanus)*, mountain lions (*Felis concolor)*, coyotes (*Canus latrans)*, wolves *(Canus lupus)*, foxes (*Vulpes fulva)*, and other smaller animals travel from the north and south through the pass, and have been reported killed on I-90 due to vehicle collisions. A total of 1,336 road killed animals of 37 different species were reported between 2001 and 2005 on I-90 over Bozeman Pass. The greatest number of carcasses per mile found on the west side of the pass between mileposts 313 and 315 (Craighead Environmental Research Institute, unpublished data).

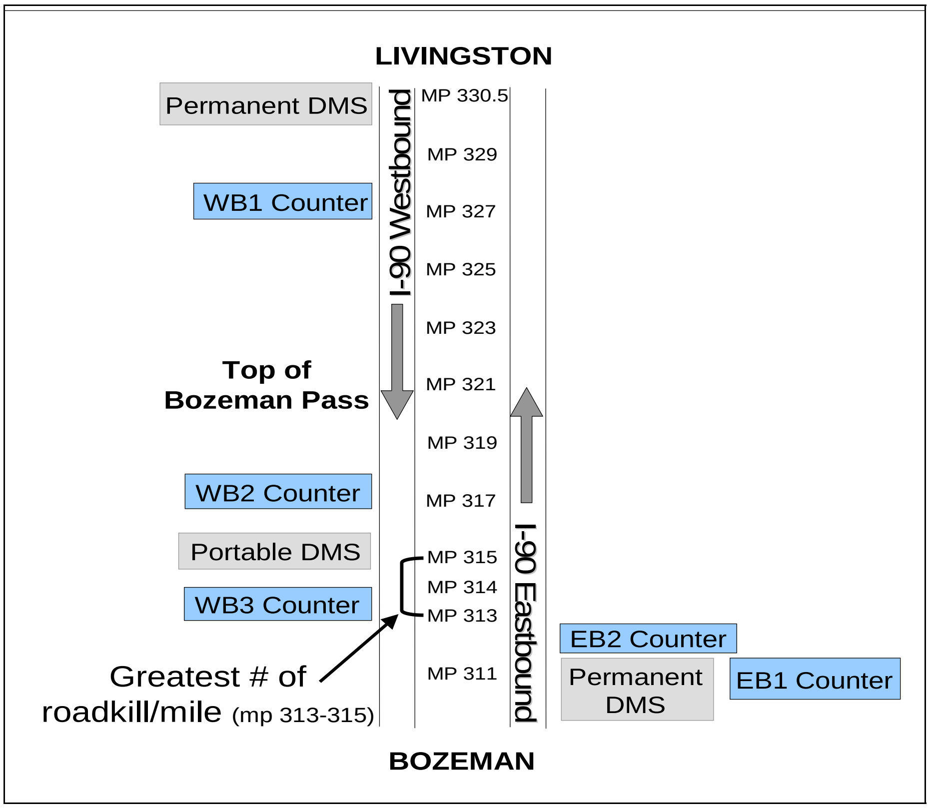

Figure 2. Schematic of locations of dynamic message signs (DMS) and eastbound (EB) and westbound (WB) traffic counters on Interstate-90 on Bozeman Pass, between Livingston and Bozeman, Montana.

2.2. Field Study Methods

The field study targeted Bozeman and Livingston local residents as well as non-resident travelers over Bozeman Pass. Information regarding driver awareness of seasonal animal movements was delivered to the public via a public outreach campaign and DMS on I-90 over Bozeman Pass in September and October 2004. Speed data were collected and analyzed and driver surveys provided additional qualitative information regarding drivers' responses to the DMS messages and public awareness campaign.

2.2.1. Public Outreach Campaign

Collaborating partner, American Wildlands, launched a local outreach campaign aimed at increasing public awareness of seasonal wildlife movements and animal vehicle collisions on Bozeman Pass. This campaign, entitled, "*Driving with Wildlife in Mind*", focused on the wildlife corridor on I-90 through Bozeman Pass. The campaign used public service announcements on local radio stations, and a street theater event to promote driver safety awareness of seasonal animal movements.

A press release containing facts about animal-vehicle collisions and tips for avoiding collisions was distributed on September 29, 2004. In addition, a "wildlife traffic report" was broadcast from radio stations in Bozeman and Livingston. The radio public service announcement reminded drivers that Bozeman Pass serves a wildlife corridor and that extra caution should be taken when traveling over the pass.

An educational exhibit with the same information was displayed in the window of First Security Bank on Main Street in downtown Bozeman. This venue also hosted a one-day street theater event where people dressed as wildlife passed out fliers to individuals passing by the bank. Similar to the press release, these fliers contained facts about animal-vehicle collisions and tips for avoiding collisions. See Appendix A for the fact sheet used in the press release, fliers, and radio public service announcements.

2.2.2. DMS Messages

Two existing permanent DMSs and one portable DMS were used to deliver messages to eastbound and westbound motorists. A single, portable DMS was placed (as topography, guardrails, and road curvature would allow for safe set-up and operation) prior to the two mile stretch that had the most reported road kills per mile per year. The single portable DMS was visible to westbound drivers whereas eastbound drivers, having just driven past the permanent DMS two miles prior to the section with the greatest amount of kills, did not pass a portable DMS (Figure 2).

One control and three treatment messages were posted on the DMS from 5:00 PM to 9:00 AM, (the time of day most AVCs generally occur) for sixteen consecutive days from September 17, 2004 to October 2, 2004 (the season that most AVCs generally occur). The control message was a blank DMS conveying no information to motorists. The treatment messages included a general message about traveler information, a general wildlife advisory message, and a similar wildlife advisory with an updated tally of the number of animals observed hit on Bozeman Pass for the year. The wildlife messages posted on the permanent DMS referred to the entire Bozeman Pass area while the wildlife messages posted on the portable DMS referred to the localized two mile stretch where the highest concentration of carcasses had been recorded. Messages on the permanent DMS were displayed in one continuous frame (no blinking or alternating frames or lines) while the portable DMS used two alternating frames to deliver the messages. Each control and treatment message for both the permanent and portable DMS was posted on four different evenings during the sixteen day study period; the order in which they were posted was determined randomly. The same message was posted on both permanent DMS in a given day, but the theme of the message on the portable DMS may have been different than what was posted on the permanent DMS. The specific messages read as follows:

Permanent DMS (single frame):

- Control – blank
- Treatment 1 – "TRAVEL INFO CALL 511 BEFORE YOU DRIVE"
- Treatment 2 – "ANIMAL CROSSING NEXT 20 MILES BE ALERT "
- Treatment 3 – "XXX ANIMALS HIT NEXT 20 MILES THIS YEAR"

Portable DMS (frame 1 – frame 2):

- Control – blank
- Treatment 1 – "TRAVEL INFO – CALL 511"
- Treatment 2 – "WATCH FOR ANIMALS – NEXT 2 MILES"
- Treatment 3 – "XXX ANIMALS HIT – NEXT 2 MI THIS YEAR"

Table 1 shows when each message was posted during the study on both types of DMS signs. Prior to this study, "TRAVEL INFO CALL 511 BEFORE YOU DRIVE" was posted on the permanent DMS when no other advisory information needed to be posted. For this study, no messages were posted from 9:00 AM to 5:00 PM (all DMS were blank throughout the day) and that particular message was used as one of the treatment messages posted from 5:00 PM to 9:00 AM.

The Craighead Environmental Research Institute regularly surveyed I-90 across Bozeman Pass for animal carcasses hit by vehicles and provided data to update the total number of animals hit over the pass (displayed by the permanent DMS) and the number hit over the two-mile section stretch where the highest concentration of carcasses were reported annually (displayed by the portable DMS).

2.2.3. Speed Data Collection

To examine the effect of the control and treatment messages on average speeds, individual speed and vehicle classification data were collected using pneumatic road tube counters placed within strata before, at, and after the locations of the permanent and portable DMS. Because the permanent westbound DMS was located just after an on-ramp, there was no counter placed prior to that DMS to avoid skewed data from vehicles entering I-90 and accelerating prior to that DMS. Similarly, the eastbound DMS was located relatively close to an on-ramp so the traffic counter was placed at rather than before the DMS. The locations of the traffic counters relative to the locations of the DMS in the study area are summarized in Table 2.

Two vehicle classes were considered in this study: passenger cars and heavy vehicles. Using the Federal Highway Administration Classification Scheme (2004), passenger vehicles were represented by classes 1, 2, 3, and 5 while heavy vehicles (herein referred to as "trucks") were represented by classes 4, 6, 7, 8, 9, 10, 11, 12, and 13. Data collected from each traffic counter in the eastbound and westbound directions were analyzed separately for passenger vehicles and trucks.

Other variables that might influence speeds included precipitation, time of day, and time of week. Precipitation data were available from the Road Weather Information Station located at the top of Bozeman Pass. Time of day was categorized as light, dusk/dawn, and dark, with the dusk/dawn period designated as an hour between light and dark, spanning one half hour before and one half hour after sunset and sunrise. Day of week was categorized as weekday or weekend.

Table 1. Schedule for posting experimental treatment messages on two permanent and one portable DMS on I-90 on Bozeman Pass.

Day[1]	Permanent DMS[2] MESSAGE	Portable DMS (WB only)[2] MESSAGE		Day	Permanent DMS[2] MESSAGE	Portable DMS (WB only)[2] MESSAGE	
		FRAME 1	FRAME 2			FRAME 1	FRAME 2
1	blank	WATCH FOR ANIMALS	NEXT 2 MILES	9	TRAVEL INFO CALL 511 BEFORE YOU DRIVE	WATCH FOR ANIMALS	NEXT 2 MILES
2	ANIMAL CROSSING NEXT 20 MILES BE ALERT	26 ANIMALS HIT	NEXT 2 MI THIS YEAR	10	blank	TRAVEL INFO	CALL 511
3	161 ANIMALS HIT NEXT 20 MILES THIS YEAR	TRAVEL INFO	CALL 511	11	185 ANIMALS HIT NEXT 20 MILES THIS YEAR	34 ANIMALS HIT	NEXT 2 MI THIS YEAR
4	TRAVEL INFO CALL 511 BEFORE YOU DRIVE	26 ANIMALS HIT	NEXT 2 MI THIS YEAR	12	ANIMAL CROSSING NEXT 20 MILES BE ALERT	blank	blank
5	TRAVEL INFO CALL 511 BEFORE YOU DRIVE	blank	blank	13	192 ANIMALS HIT NEXT 20 MILES THIS YEAR	blank	blank
6	TRAVEL INFO CALL 511 BEFORE YOU DRIVE	TRAVEL INFO	CALL 511	14	blank	blank	blank
7	174 ANIMALS HIT NEXT 20 MILES THIS YEAR	WATCH FOR ANIMALS	NEXT 2 MILES	15	ANIMAL CROSSING NEXT 20 MILES BE ALERT	TRAVEL INFO	CALL 511
8	blank	29 ANIMALS HIT	NEXT 2 MI THIS YEAR	16	ANIMAL CROSSING NEXT 20 MILES BE ALERT	WATCH FOR ANIMALS	NEXT 2 MILES

[1]Each message was posted overnight, from 5:00 PM to 9:00 AM the following day, a total of four times for each sign type (permanent or portable DMS), beginning September 17, 2004.

[2]Messages referring to the numbers of animals hit changed according to most current data available from daily road-kill surveys that occurred through the area indicated on the message (e.g., "NEXT 20 MILES" or "NEXT 2 MILES").

Table 2. Location of eastbound (EB) and westbound (WB) traffic counters over Bozeman Pass, relative to dynamic message signs (DMS).

Counter	milepost (mp)	Counter location relative to westbound *permanent DMS at mp 330.5*	Counter location relative to eastbound *permanent DMS at mp 311*	Counter location relative to westbound *portable DMS at mp 314.8*
EB 1	311	--	at DMS	--
EB 2	312	--	1.5 km (~1.0 m) after	--
WB 1	327.8	4.5 km (2.8 m) after	--	20.9 km (13 m) before
WB 2	317.4	21.1 km (13.1 m) after	--	4.9 km (2.6 m) before
WB 3	314	26.6 km (16.5 m) after	--	1.3 km (0.8 m) after

2.2.4. Speed Data Analysis

Speed observations at each counter location were compared between treatment types; no comparisons were made between different counters. The influence of the DMS messages and other covariates (as well as all pair-wise combinations of interactions between the treatments and covariates) on speed was analyzed using a general linear model ANOVA (analysis of variance; $\alpha = 0.05$) and Tukey's method. The statistical software package Minitab was used for analysis and diagnostic tests.

Safe stopping sight distances (SSD) were determined for passenger vehicles and trucks based on the reduction in mean speed observed when the treatment messages were posted compared to when the control message (blank) was posted. Assumptions in this analysis included: perception-reaction time of 2.5 seconds, level grade, and a coefficient of friction of 0.3478 (AASHTO 2001).

2.2.5. Field Study Driver Survey

Because drivers may see, understand, and respond to travel advisory information without changing their speed (e.g., drivers may have increased alertness, increased scanning of the right-of-way, maintained speed but turned off "cruise control"), WTI researchers developed a driver survey to further qualify driver responses to the animal advisory messages. In addition, the survey provided demographic information and drivers' personal experiences with animal-vehicle conflicts, both of which may influence how drivers interpret and act in response to animal advisory messages.

2.2.5.1. Field Study Survey Instrument

The survey tool was formatted as a postcard with return postage to encourage drivers to return the completed surveys (Figure 3). Question 1 asked drivers how often they drive Bozeman Pass each month. Questions 2 and 3 asked drivers specifically about the DMS messages posted on the day the survey was distributed (identified by the unique date stamp) and how the message may have influenced driving behaviors. Question 4 asked if drivers had seen or heard the public information campaign, to gauge how that effort reached Bozeman Pass drivers. The last 4 questions provided insight into drivers' sightings of animals on the Pass, as well as their experiences with animal-vehicle collisions, and where they reside.

Please answer all of the following questions for the Montana Department of Transportation (MDT).

YOUR OPINIONS ARE IMPORTANT TO US!

1. **On average, how many trips per month do you make between Bozeman and Livingston on I-90?**

   ____

2. **Did you see a message on the electronic message sign(s) on I-90 between Bozeman and Livingston today ____________________ and what did the message relate to? (check only one)**
   - ☐ did not travel between Bozeman & Livingston today
   - ☐ do not remember ☐ no message
   - ☐ high winds ☐ road construction
   - ☐ animal crossings ☐ 511 travel information
   - ☐ oversize loads ☐ "Buckle up, it's the law"

3. **Describe if or how you modified your driving behavior based on the message? (check all that apply)**
   - ☐ did not modify driving behavior
   - ☐ slowed down ☐ turned off "cruise control"
   - ☐ increased alertness for unexpected events
   - ☐ other ____________________________

4. **Have you seen or heard newspaper or radio publicity about avoiding animal-vehicle collisions?**

   ☐ YES ☐ NO

PLEASE RETURN BY OCTOBER 8, 2004

5. **How often do you see animals (dead or alive) on or near I-90 between Bozeman and Livingston? (Circle only one)**

   Very Frequently Frequently Sometimes Rarely Never

6. **Have you ever been involved in an animal-vehicle collision?**

   ☐ YES ☐ NO

7. **Have you ever been involved in an animal-vehicle collision between Bozeman and Livingston?**

   ☐ YES ☐ NO

8. **Where do you live? (city and state)**

   ____

Comments regarding the I-90 transportation corridor between Bozeman and Livingston and animal-vehicle collisions?

____
____
____
____

THANK YOU FOR YOUR TIME [exit] [am pm]

Figure 3. Mail-in survey tool distributed to exiting Bozeman Pass drivers during the speed study.

2.2.5.2. Survey Distribution Locations

Surveys were distributed to drivers exiting from I-90 after Bozeman Pass and after they would have just seen DMS message treatment. Westbound drivers exiting at North 7th and North 19th Avenues in Bozeman, and eastbound drivers exiting at exit 333 in Livingston, were stopped at the end of the off-ramp. A team of two would approach the vehicle and ask if the driver would be willing to take the survey on behalf of MDT. Each team began with 166 surveys (with the goal of distributing 498 surveys between the three exits per distribution session); surveys that were not handed out were later counted to determine the total surveys disseminated at each exit during each distribution session.

2.2.5.3. Survey Distribution Schedule

Distributing surveys every day of the 16-day experiment was not feasible due to limited resources; therefore researchers subjectively set the goal of sampling half these days. To determine which days to distribute surveys, a random number generator selected, without replacement, 8 numbers between 1 and 16. Surveys were ultimately distributed on 7 of those 8 days, including Days 1, 5, 8, 11, 12, 13, and 16 (Table 1).

Each survey was dated (see question two in Figure 3) and marked according to whether the survey was distributed in the morning versus evening (see lower right corner of Figure 3) to distinguish one treatment from another on a given date. To maximize efficiency, surveys were distributed on each day during peak traffic periods between the hours of 7:00 AM-9:00 AM and 5:30 PM -7:30 PM, to ensure exiting drivers had seen the messages before exiting I-90. For example, given that each treatment was posted between 5:00 PM and 9:00 AM the following day, researchers assumed that westbound drivers exiting in Bozeman at 5:30 PM would have seen both the permanent and portable DMS if they had just driven from Livingston to Bozeman at the posted speed limit.

2.3. Field Study Results

The field study data collection occurred in September and October of 2004. Results for the various components of the field study are reported below.

2.3.1. Public Outreach Campaign

The press release distributed on September 29, 2004 was published in The Livingston Enterprise on September 30 (Day 14 of the field study); in the Bozeman Daily Chronicle on October 2 (Day 15 of the field study); and the Billings Gazette on October 3, 2004 (Day 16 of the field study). Estimated readership numbers for these three papers during this period was approximately 3,252 (Livingston Enterprise staff Mark Bolin, pers. comm.), 17,500 (Bozeman Daily Chronicle staff, pers. comm.), and 50,000 (Billings Gazette staff Misti Norris, pers. comm.), respectively. Bozeman NBC-affiliate television station KTVM 6/42 televised a piece based on the press release on September 29 (Day 14 of the field study). The radio public service announcement (PSA) was aired opportunistically on KGLT and Clear Channel affiliates (KISS-FM, KMMS-AM, KMMS-FM, KPRK-AM, KXLB-FM, KZMY-FM) from approximately mid-September 2004 thru the end of the year; however, the exact number of times, and times of day the messages were aired was not recorded, making it impossible to estimate the numbers of radio listeners that may have heard the PSA. A street theater event occurred on October 13, 2004, after the 16-day field experiment was completed (i.e., the driver survey responses did not reflect feedback regarding this event).

2.3.2. Field Speed Study

Because there were no significant precipitation events during our data collection period, this covariate, along with the small number of speed observations that occurred during the few light rain events, was excluded from further analyses. Upon screening the data, outliers (<30 mph) were removed from the dataset. A total of 133,178 passenger vehicle and 42,480 truck speed observations were included in the analyses. General characteristics of speeds (e.g., 85th percentile, minimum and maximum speeds) observed at each counter throughout the entire study (i.e., across all treatments, days of week, light conditions, and including both passenger vehicles and trucks) are summarized for this reduced dataset in Table 3. Sample size, mean speed, standard deviations and the range of observed speeds used in the analyses, are summarized by traffic counter location, vehicle type and treatment type in Table 4.

Table 3 Profile of (pooled truck and passenger vehicle) speeds (mph) observed during the study (over all treatments, days of week, and light conditions) at each traffic counter.

Counter	85th %tile	Highest speed	Lowest speed
EB1	81.6	97.9	34.7
EB2	85.4	98.6	35.9
WB1	77.6	95.9	36.0
WB2	75.2	92.3	33.8
WB3	77.9	94.6	36.5

Table 5 and Table 6 show ANOVA model results for passenger vehicles and trucks at the eastbound and westbound traffic counters, respectively. While no R^2 value for eastbound or westbound passenger vehicles and trucks exceeded 10%, the relationships between speed, DMS messages, and light conditions were consistent and statistically significant ($p<0.05$) at most counter locations for both passenger vehicles and trucks. Speeds decreased when the animal advisory treatment messages were displayed, except at the WB2 counter (located 13.1 miles after the permanent DMS and 2.6 miles prior to the portable DMS) where increased speeds were observed when treatment 3 was displayed. Speeds were typically greater on weekdays than weekends, with the exception of EB2 where the opposite relationship was observed. Speeds observed in "light" conditions were higher than in "dark" conditions and speeds obtained during dusk/dawn periods were lower than daytime conditions, but higher than nighttime conditions. Interactions between the DMS messages and light conditions were analyzed using the general linear model ANOVA (α = 0.05). The animal advisory messages (treatments 2 and 3) consistently resulted in the largest speed reductions during "dark" conditions for both passenger vehicles and trucks.

Table 4. Summary of speed data collected at each traffic counter location when the control and treatment messages were posted on dynamic message signs.

Counter		Passenger Vehicle Speed Data Summary				Truck Speed Data Summary			
		n	*Average speed (mph)*	*SD*	*Range*	*n*	*Average speed (mph)*	*SD*	*Range*
EB1	Overall	23976	74.8	7.6	69.9	8284	70.2	7.0	62.2
	Control	5463	74.8	7.9	57.4	1468	70.8	6.9	51.8
	Treatment 1	10160	75.6	7.6	69.9	3617	71.1	7.1	58.9
	Treatment 2	2473	74.7	7.9	59.6	1079	68.8	6.6	42.2
	Treatment 3	5879	73.6	7.3	62.8	2120	69.0	6.8	58.7
EB2	Overall	31431	78.3	8.5	76.1	12358	74.8	9.0	57.5
	Control	9753	78.5	8.3	76.1	3560	74.5	9.2	56.3
	Treatment 1	5658	81.5	9.1	58.5	2857	78.8	9.1	55.9
	Treatment 2	8968	77.3	8.1	76.1	3564	73.5	8.3	55.5
	Treatment 3	7052	76.8	8.1	62.2	2929	74.0	8.9	58.6
WB1	Overall	28698	72.4	6.3	73.5	7891	66.7	5.8	59.0
	Control	10247	72.8	6.2	71.0	2184	67.0	6.1	46.0
	Treatment 1	4391	73.5	7.2	61.1	1724	68.1	6.0	41.5
	Treatment 2	7837	71.5	6.0	65.7	2187	66.2	5.7	51.5
	Treatment 3	6222	71.8	6.2	56.7	1796	65.7	5.3	58.4
WB2	Overall	25753	69.2	7.8	69.6	7898	64.4	7.7	52.2
	Control	9207	70.4	7.7	69.6	2398	65.7	7.9	52.2
	Treatment 1	4569	69.1	7.2	61.9	1754	64.0	7.6	48.1
	Treatment 2	7781	67.1	7.6	67.3	2333	63.0	7.1	49.7
	Treatment 3	4196	70.8	8.0	63.2	1413	66.0	8.1	48.8
WB3	Overall	23320	71.6	7.9	69.3	6049	67.8	7.1	60.1
	Control	4392	73.6	7.4	66.9	1361	69.9	6.4	57.1
	Treatment 1	4949	72.6	7.6	59.8	1150	68.4	7.1	42.1
	Treatment 2	6075	70.5	7.6	63.0	1473	67.0	6.8	41.1
	Treatment 3	7901	70.5	8.3	68.6	2065	66.8	7.4	53.4

Table 5. ANOVA model results for eastbound passenger vehicles and trucks.

<table>
<tr><th rowspan="2">Counter</th><th rowspan="2" colspan="2">Variables</th><th colspan="2">Passenger vehicles</th><th colspan="2">Trucks</th></tr>
<tr><th>Coefficient*</th><th>R²</th><th>Coefficient*</th><th>R²</th></tr>
<tr><td rowspan="10">EB1</td><td></td><td>Constant</td><td>74.0</td><td rowspan="10">3.48%</td><td>69.7</td><td rowspan="10">4.02%</td></tr>
<tr><td rowspan="4">Permanent DMS messages</td><td>Control</td><td>0.5</td><td>1.2</td></tr>
<tr><td>Treatment 1</td><td>1.6</td><td>1.5</td></tr>
<tr><td>Treatment 2</td><td>-0.5</td><td>-1.4</td></tr>
<tr><td>Treatment 3</td><td>-1.6</td><td>-1.2</td></tr>
<tr><td rowspan="3">Light Condition</td><td>Light</td><td>0.9</td><td>0.8</td></tr>
<tr><td>Dark</td><td>-1.5</td><td>-1.1</td></tr>
<tr><td>Dusk/Dawn</td><td>0.5</td><td>0.3</td></tr>
<tr><td rowspan="2">Time of week</td><td>Weekday</td><td>1.1</td><td>0.7</td></tr>
<tr><td>Weekend</td><td>-1.1</td><td>-0.7</td></tr>
<tr><td rowspan="10">EB2</td><td></td><td>Constant</td><td>78.4</td><td rowspan="10">6.16%</td><td>75.2</td><td rowspan="10">9.53%</td></tr>
<tr><td rowspan="4">Permanent DMS messages</td><td>Control</td><td>-0.1**</td><td>-0.4</td></tr>
<tr><td>Treatment 1</td><td>3.0</td><td>3.9</td></tr>
<tr><td>Treatment 2</td><td>-1.2</td><td>-1.8</td></tr>
<tr><td>Treatment 3</td><td>-1.7</td><td>-1.7</td></tr>
<tr><td rowspan="3">Light Condition</td><td>Light</td><td>1.4</td><td>1.7</td></tr>
<tr><td>Dark</td><td>-1.7</td><td>-1.9</td></tr>
<tr><td>Dusk/Dawn</td><td>0.3</td><td>0.1</td></tr>
<tr><td rowspan="2">Time of week</td><td>Weekday</td><td>-0.2</td><td>-0.4</td></tr>
<tr><td>Weekend</td><td>0.2</td><td>0.4</td></tr>
</table>

*The positive or negative co-efficient indicates the direction of the change in speed compared to the constant, with a negative coefficient indicating speeds were slower than the constant.

**P-value = 0.074; p-values for all other variables at both counters were <0.000.

Table 6. ANOVA model results for westbound passenger vehicles and trucks.

Counter	Variables		Passenger vehicles		Trucks	
			*Coefficient**	*R^2*	*Coefficient**	*R^2*
WB1		Constant	72.3	3.85%	67.0	4.52%
	Permanent DMS messages	Control	0.4		0.2‡	
		Treatment 1	1.2		1.4	
		Treatment 2	-0.7		-0.6	
		Treatment 3	-0.8		-1.0	
	Light Condition	Light	1.0		0.8	
		Dark	-1.2		-1.1	
		Dusk/Dawn	0.2		0.3	
	Time of week	Weekday	0.3		0.1	
		Weekend	-0.3		-0.1	
WB2		Constant	69.3	7.44%	64.8	8.38%
	Permanent DMS messages	Control	1.0		1.3	
		Treatment 1	-0.2†		-0.7	
		Treatment 2	-2.1		-1.7	
		Treatment 3	1.3		1.1	
	Light Condition	Light	1.2		1.3	
		Dark	-2.0		-2.2	
		Dusk/Dawn	0.9		0.9	
	Time of week	Weekday	0.0§		0.4	
		Weekend	0.0§		-0.4	
WB3		Constant	71.6	7.59%	68.1	9.94%
	Portable DMS messages	Control	1.2		1.1	
		Treatment 1	1.3		1.0	
		Treatment 2	-1.2		-0.6	
		Treatment 3	-1.4		-1.5	
	Light Condition	Light	1.6		1.6	
		Dark	-2.1		-2.1	
		Dusk/Dawn	0.6		0.5	
	Time of week	Weekday	0.7		0.9	
		Weekend	-0.7		-0.9	

*The positive or negative co-efficient indicates the direction of the change in speed compared to the constant, with a negative coefficient indicating speeds were slower than the constant.

†P-value 0.048; §P-value 0.416; ‡P-value 0.065; all other p-values (unless footnoted) were <0.000.

The maximum change in safe stopping sight distances (SSD) observed in this study occurred during dark conditions. Table 7 shows these SSD for passenger vehicle and trucks at all counter locations during dark conditions, comparing the SSD observed when the control was posted compared to the treatment messages. The SSD decreased at all counter locations when the animal advisory treatment messages were posted on DMSs compared to when the control message (blank) was posted. When the "CALL 511 BEFORE YOU DRIVE" treatment message was displayed, speeds were higher at both eastbound counters (EB1 and EB2) and at the first westbound counter (WB1), while a 2.03% to 4.93% (17.8 – 35.6 feet; 5.42 m – 10.8 m) range of reduction in SSD at the other two westbound counters (WB2 and WB3) was observed when this treatment was posted. Reductions in safe stopping sight distances observed when the two animal advisory messages were posted ranged from 0.84% – 9.75% (7.5 – 85.5 feet; 2.3 m – 26.1 m) with passenger vehicles at WB3 showing the largest reduction. Reductions were similar for passenger vehicles and trucks, with the largest decreases in stopping sight distance being observed at WB3, after the portable DMS.

2.3.3. Field Study Driver Survey

A total of 2,473 surveys were handed out over the course of the study. Of these, 1,074 surveys were returned for a total response rate of 43%. However respondents didn't always answer every question, and therefore the sample size of responses varies from question to question. It is possible some individuals responded to the survey on more than one occasion. This was a result of distributing surveys during the morning and evening "rush hour" times when a large proportion of drivers exiting I-90 were local commuters going to or coming home from work; given that our survey distribution points and times did not vary, the survey distributors noted the same drivers accepting surveys on multiple survey days. Because the treatment messages changed daily, survey questions 2 and 3 (see Figure 3) refer to the particular DMS messages posted on a given day (question 2 included a date and question 3 refers to question 2; see Figure 3). As the message changed day to day, presumably driver's responses to questions 2 and 3 would change accordingly; hence, drivers were allowed to take the survey on multiple occasions to provide feedback on the different treatment messages posted on different days. However, if a driver provided survey responses for multiple days, their answers to questions 1 and 4 through 8 (see Figure 3) would have likely been duplicated from one survey to the next. Therefore, results for question 1 and 4 through 8 may contain duplicate data that we were unable to distinguish from original, unique responses.

The driver survey results are broken down into two sections. The first section summarizes responses to the five general questions characterizing the survey population's familiarity with the Bozeman Pass area and animal-vehicle collisions. The second section encapsulates drivers' responses to the public outreach campaign and the different DMS treatments. Additional written responses are presented in Appendix B: Field Driver Survey Comments, Table 13.

Table 7. Stopping sight distances (SSD) calculated for average speeds observed during dark conditions for each treatment type at each speed counter, compared to the SSD calculated with average observed speed at each speed counter when the control (a blank dynamic message sign) was applied.

Counter	Variable	Passenger Vehicles				Trucks			
		Mean Speed (mph)	SSD (ft)	Reduction		Mean Speed (mph)	SSD (ft)	Reduction	
				feet	%			feet	%
EB1	Control	73	771	-	-	70	719	-	-
	Treatment 1	75	822	none	none	71	746	none	none
	Treatment 2	72	765	6	1%	68	684	34	5%
	Treatment 3	71	749	22	3%	68	684	34	5%
EB2	Control	77	853	-	-	73	780	-	-
	Treatment 1	80	898	none	none	77	850	none	none
	Treatment 2	75	820	33	4%	72	756	25	3%
	Treatment 3	75	807	46	5%	71	742	38	5%
WB1	Control	72	757	-	-	66	661	-	-
	Treatment 1	72	763	none	none	67	680	none	none
	Treatment 2	70	733	24	3%	65	650	11	2%
	Treatment 3	70	730	27	4%	65	640	20	3%
WB2	Control	69	702	-	-	64	627	-	-
	Treatment 1	68	688	15	2%	62	597	30	5%
	Treatment 2	65	642	61	9%	61	585	42	7%
	Treatment 3	68	693	10	1%	63	615	12	2%
WB3	Control	72	758	-	-	68	696	-	-
	Treatment 1	71	743	15	2%	67	673	23	3%
	Treatment 2	68	696	62	8%	65	650	46	7%
	Treatment 3	68	686	72	9%	64	632	64	9%

2.3.3.1. General Survey Responses

These questions were included to generally characterize the respondents' familiarity with the Bozeman Pass area and animal-vehicle collisions. This information may provide insight into why drivers may or may not understand or respond to the treatment messages. For example, drivers familiar with the region and the experience of hitting an animal may respond differently to the treatment messages than drivers that may be more "naïve" to the area and potential animal encounters.

Question 1: ***On average, how many trips per month do you make between Bozeman and Livingston on I-90?***

Question 1 was an open-ended question that asked respondents how many trips, on average, they made between Bozeman and Livingston per month. Responses were categorized for display in Figure 4. Of the 1,048 responses, 51% cross Bozeman Pass only 0-5 times per month, while the other 49% made the trip 6 to more than 25 times per month.

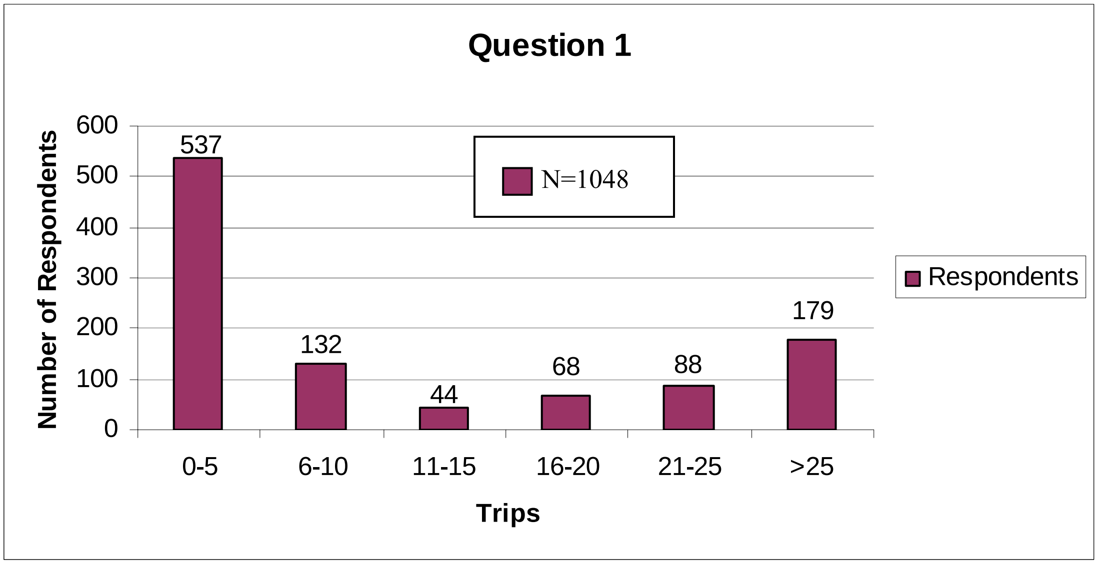

Figure 4. Reported number of trips made between Bozeman and Livingston per month by survey respondents.

Question 5: ***How often do you see animals (dead or alive) on or near I-90 between Bozeman and Livingston?***

Respondents were asked if they never, rarely, sometimes, frequently, or very frequently observe animals, dead or alive, on Bozeman Pass. Figure 5 shows that the most common response was *frequently* (34%), followed by *very frequently* and *sometimes* of the responses (30% and 24%), respectively. Nine percent reported *rarely* seeing animals while only 3% of the respondents stated that they *never* see animals on Bozeman Pass.

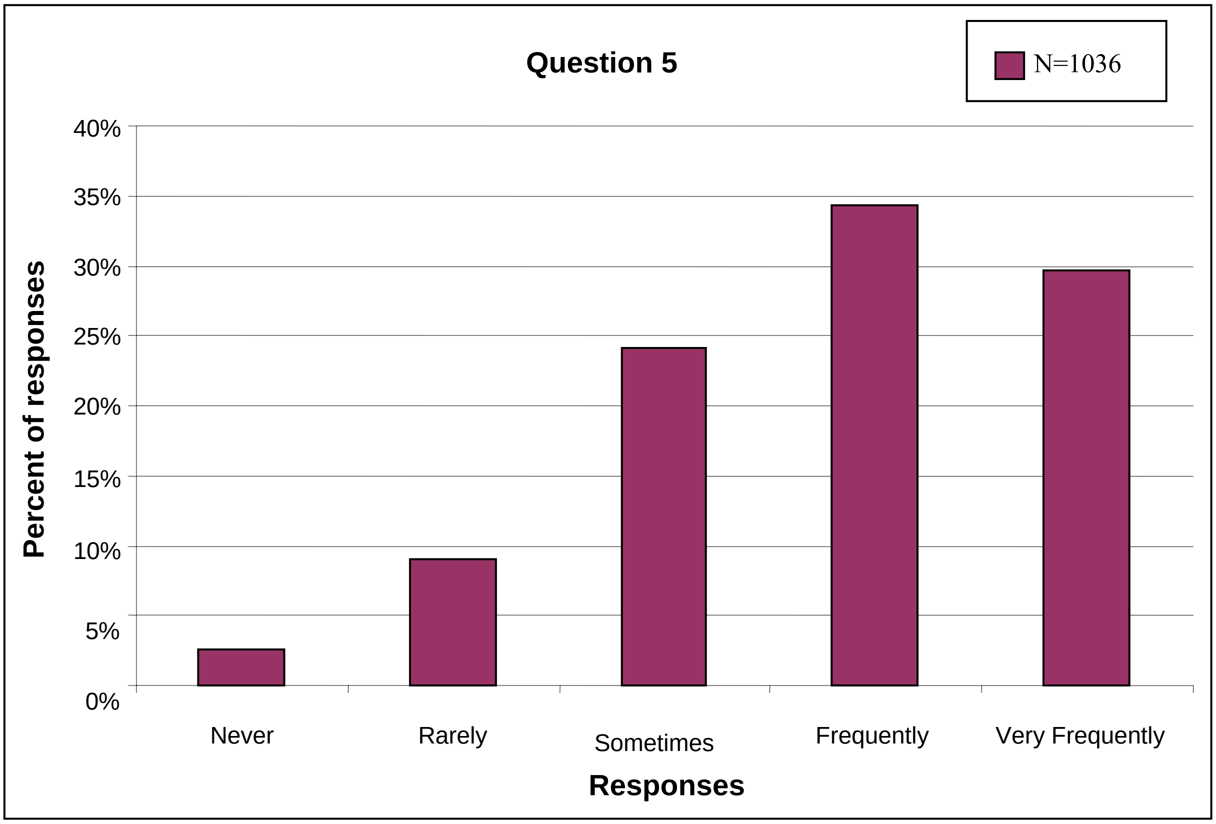

Figure 5. Percentage of respondents whom have seen animals (dead or alive) on I-90 between Bozeman and Livingston.

Question 6: ***Have you ever been involved in an animal-vehicle collision?***

This general question was asked to assess the respondents' experience with animal-vehicle collision events. Half of those surveyed had been in an animal-vehicle collision (Figure 6).

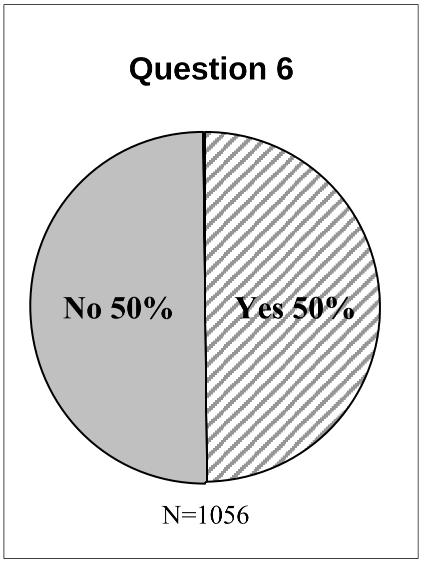

Figure 6. Percentage of respondents who have been in an animal-vehicle collision.

Question 7: ***Have you ever been involved in an animal-vehicle collision between Bozeman and Livingston?***

This question was asked of all respondents regardless of their response to the previous question. Only 6% of the 1,053 respondents that answered this question have been in an animal-vehicle collision between Bozeman and Livingston (Figure 7). All respondents who had been involved in an animal-vehicle collision on the Pass resided between Billings and Belgrade. Most of these individuals (84%) are from Bozeman or Livingston.

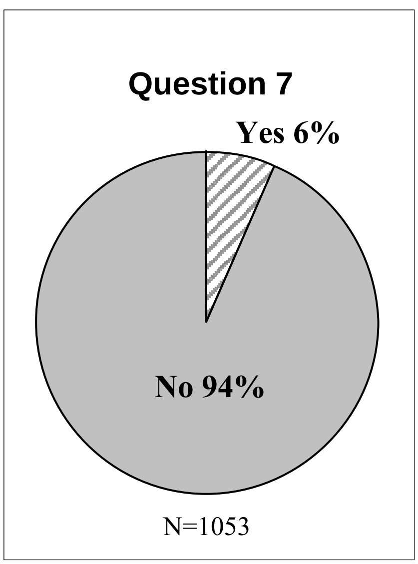

Figure 7. Percentage of respondents who have been in an animal-vehicle collision between Bozeman and Livingston.

Question 8: ***Where do you live?***

Respondents were asked to write in the city and state in which they reside. Responses were grouped together into the following regions: Bozeman, Livingston, Billings, Helena (the 4 most commonly reported cities); other responses were lumped into larger areas including northwestern Montana, southwestern Montana, central Montana, eastern Montana, and out of state (Figure 8). Over 80% of the 1,042 respondents were from the Bozeman and Livingston area. Only 6% of the respondents were from outside of Montana. The remaining respondents are from areas of Montana other than the Bozeman and Livingston areas.

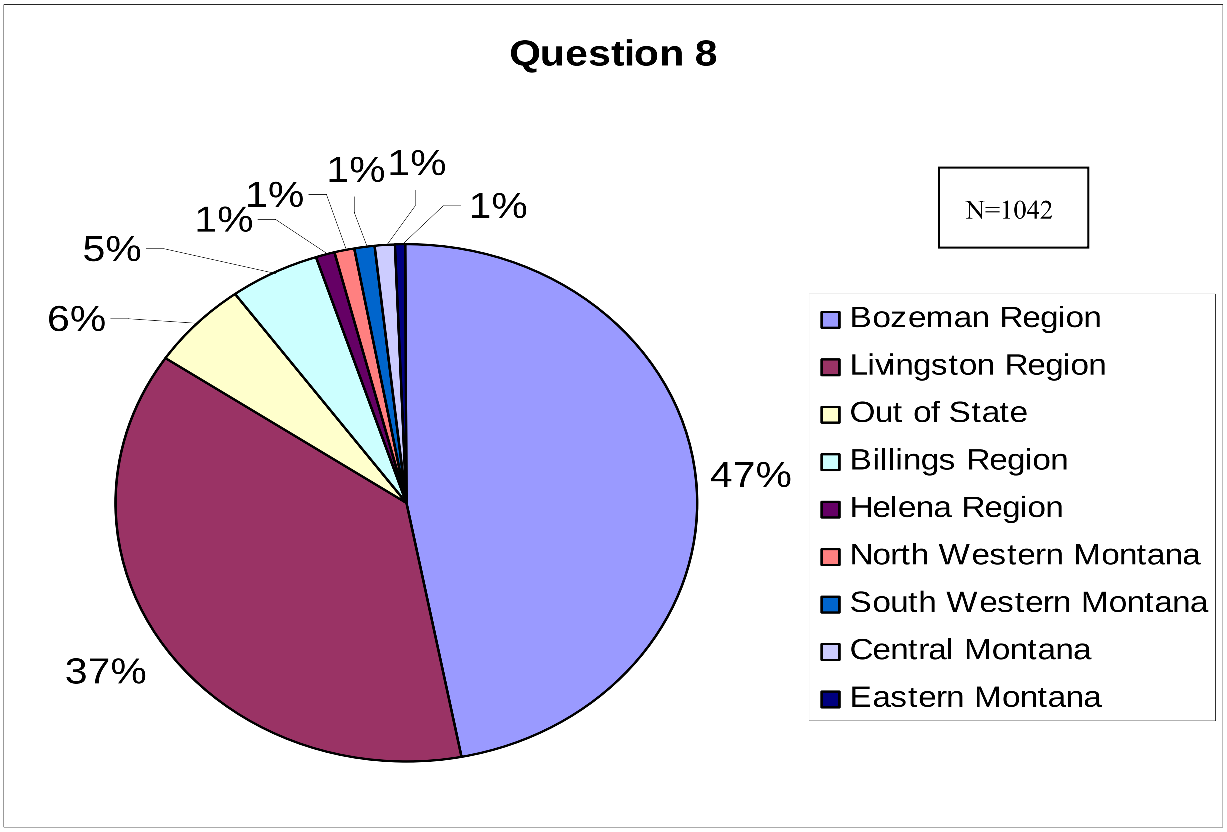

Figure 8. Survey respondents home by region.

2.3.3.2. Survey Responses Regarding Treatments

Three of the eight survey questions asked respondents specifically about the experimental treatments. Responses to survey question 4, regarding the public outreach campaign, were compiled and presented in two batches: survey responses prior to and after local newspapers had published features based on the outreach campaign's press release. Survey questions 2 and 3 referred specifically to the DMS messages and for each individual treatment day that surveys were distributed, as indicated by the stamped date and time on the survey (see Figure 3).

Question 4: ***Have you seen or heard newspaper or radio publicity about avoiding animal-vehicle collisions?***

Prior to the outreach campaign's press release of September 29, 2004, 180 of the 896 respondents (21%) reported that they had seen or heard newspaper or radio publicity about avoiding animal-vehicle collisions (Figure 9). After the press release's information was first printed in local papers on September 30, 2004, 47 of 142 respondents (33%) heard or saw the animal-vehicle collision publicity (Figure 10).

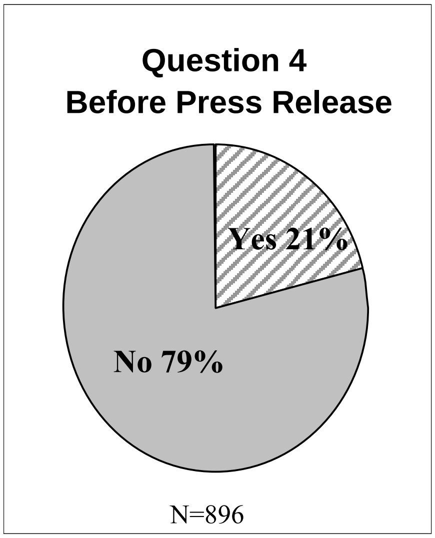

Figure 9. Percentage of respondents that had seen or heard publicity about animal-vehicle collisions before September 30, 2004.

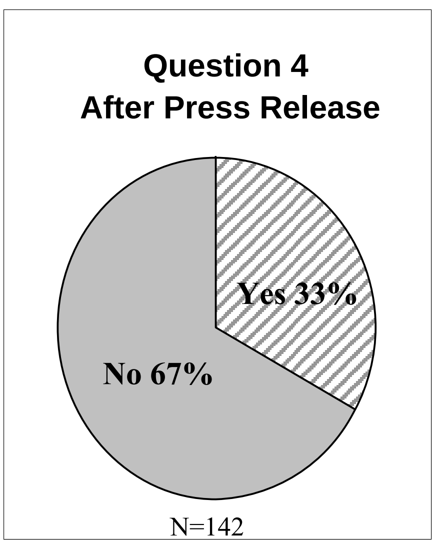

Figure 10. Percentage of respondents that had seen or heard publicity about animal-vehicle collisions on or after September 30, 2004.

Question 2: ***Did you see a message on the electronic message sign(s) on I-90 between Bozeman and Livingston [today] and what did the message relate to?*** **(choose only one)**

This questions requested respondents to select *one* of the following options:

- did not travel between Bozeman and Livingston today;
- do not remember;
- high winds;
- animal crossings;
- oversize loads;
- no message;
- road construction;
- 511 travel information; or
- “Buckle up, it’s the law”.

Question 3: ***Describe if or how you modified your driving behavior based on the message?*** **(check all that apply)**

Question 3 asked drivers to check all behavior modifications exercised in response to the message. The following options for this question included:

- did not modify behavior;
- slowed down;
- increased alertness for unexpected events;
- turned off “cruise control”; and
- other: ___________________

Responses to these two questions are presented for each treatment day surveyed (a single treatment day covered two calendar days because a set of treatment messages were posted on DMS from 5:00 PM until 9:00 AM the following day). Results reported for a given treatment day include the messages posted on the east- and westbound permanent DMS and westbound portable DMS (see also Table 1). Figure 11 depicts an example of the messages were posted on the which signs on the first treatment day, indicating which messages respondents would have passed prior to exiting and accepting the survey, depending on their direction of travel (east- and westbound permanent DMS messages were the same on a given treatment day while the westbound portable DMS message could have been different from the permanent DMS messages).

Survey responses for questions 2 and 3 (excluding respondents that selected "*did not travel between Bozeman and Livingston today"* in question 2) are presented in two graphs per survey day that distinguish between eastbound and westbound driver responses. The first graph includes arrows indicating the treatment message that was actually displayed on the message signs for both east- and westbound drivers, thus illustrating the relative accuracy of the drivers’ responses. Westbound drivers were exposed to both the permanent DMS message and the portable DMS message, hence responses from these drivers may be diluted between the two potential correct choices. Not all graphs contain eastbound survey data; due to staffing limitations, surveys were not distributed at the Livingston exit on the following dates: September 18, 22, 28, 29 and 30. The corresponding graphs for each of these dates only contains data collected from westbound drivers.

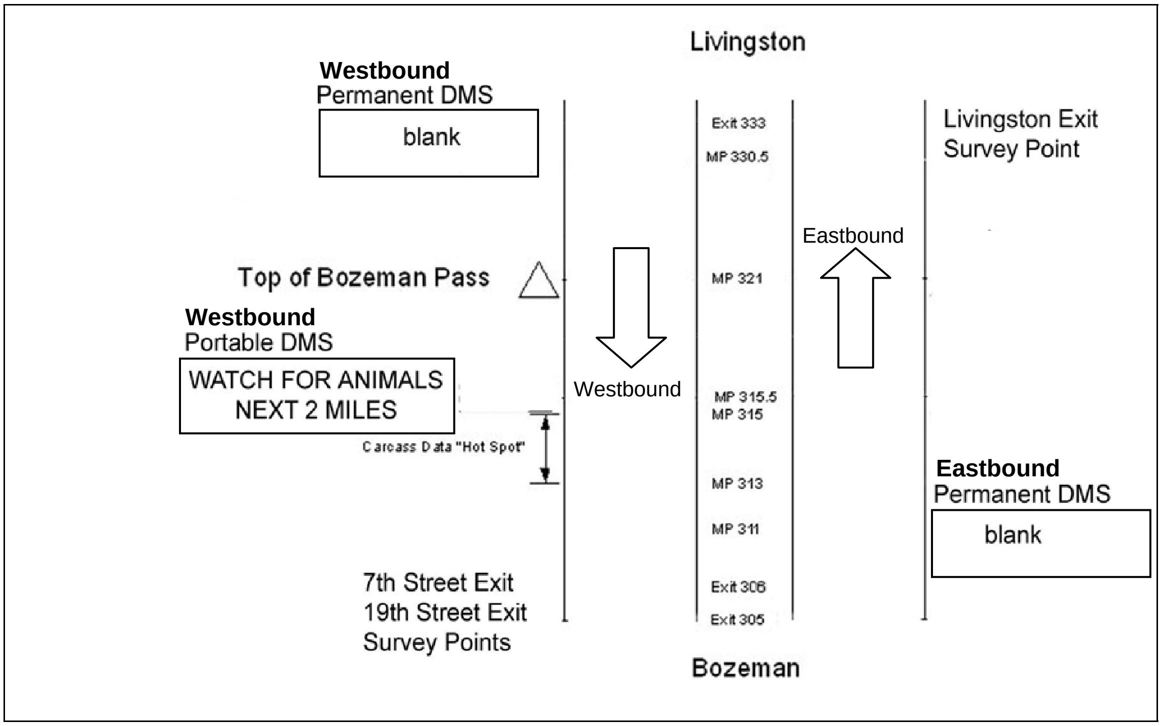

Figure 11. Example of messages displayed on the east- and westbound permanent DMS (same message on both permanent DMS) and eastbound portable DMS on treatment day 1, September 17, 2004.

<u>Treatment Day 1 (treatment "on" at 5:00 PM September 17, 2004 and "off" at 9:00 AM September 18, 2004)</u>

On treatment day 1 (September 17-18, 2004), the west-and eastbound permanent DMS were blank (no message) while the westbound portable DMS displayed the two-frame message of "WATCH FOR ANIMALS – NEXT 2 MILES" (Table 1; Figure 11). Figure 12 shows that of the 119 respondents that reported having traveled the pass, 27% of the eastbound drivers correctly identified the message as blank. The westbound traffic had two possible correct answers: *"no message"* (for the permanent DMS) and *"animal crossings"* (for the portable DMS). Of the westbound respondents, 61% correctly identified *"animal crossing"* and 15% selected *"no message"*. Most of the eastbound (61%) and 38% of the westbound respondents reported that they did not modify their driving behavior, while a larger percentage (38%) of the westbound respondents selected *"increased alertness"* in response to the observed messages (Figure 13).

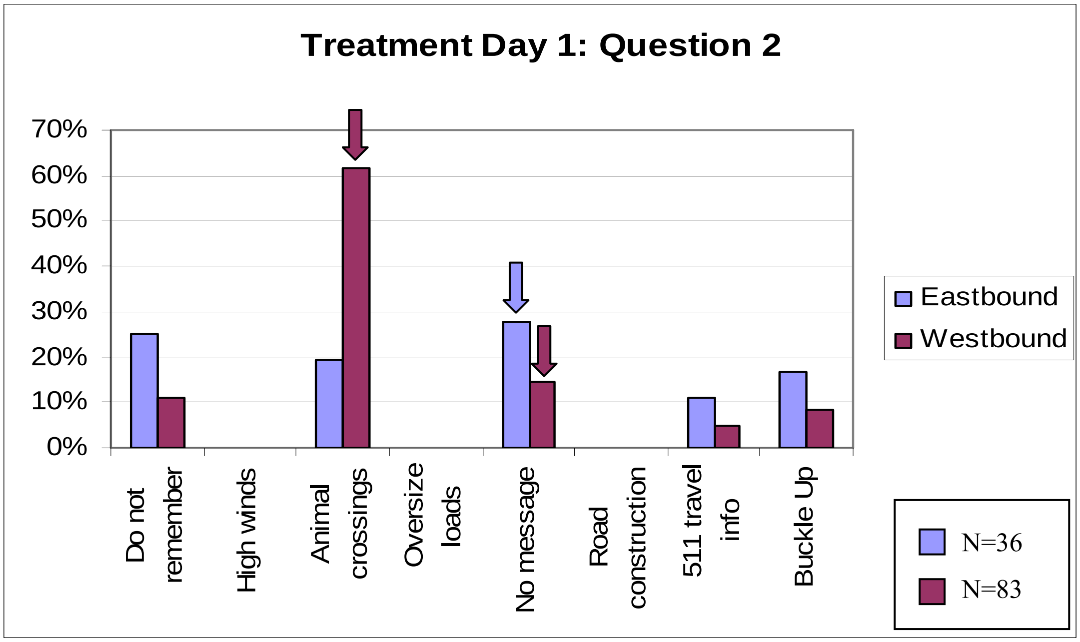

Figure 12. Messages recalled by survey respondents traveling eastbound and westbound on treatment day 1. Arrows indicate the appropriate answers for the messages that were posted.

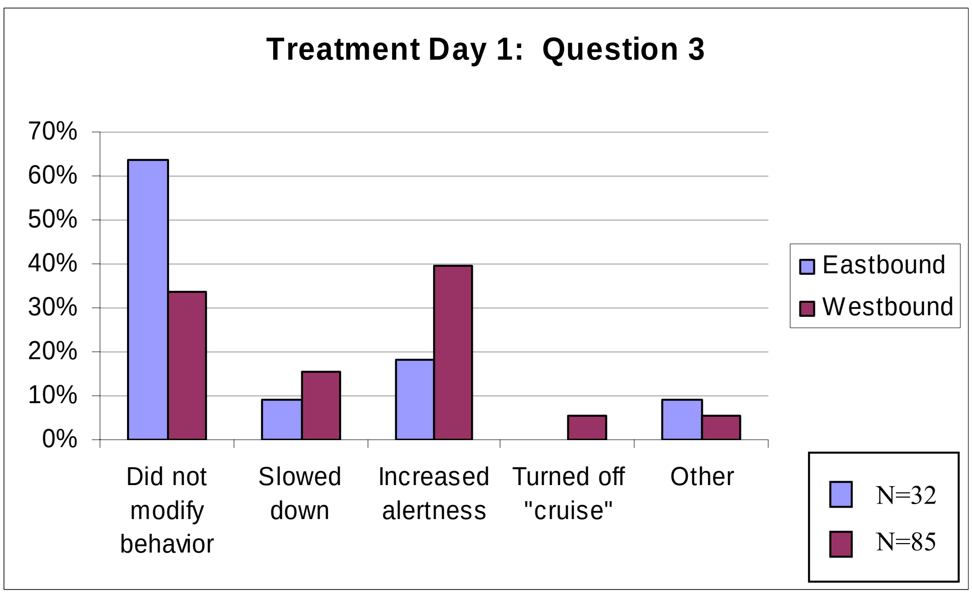

Figure 13. Survey respondents' reported driver behavior modifications to a blank sign (posted on the east- and westbound permanent DMS) and an animal advisory message (posted on the westbound portable DMS) on treatment day 1.

<u>Treatment Day 5 (treatment "on" at 5:00 PM September 21, 2004, and "off" at 9:00 AM September 22, 2004)</u>

On the fifth treatment day of the study (September 21-22, 2004), the east- and westbound permanent DMS displayed "TRAVEL INFO CALL 511 BEFORE YOU DRIVE" and the westbound portable DMS was blank (no message) (Table 1; see Figure 11 for example). Almost half (46%) of the 67 eastbound respondents correctly identified the message referring to *"511 travel information"* while more than a third of this group (38%) incorrectly reported seeing a message referring to *"animal crossings"* (Figure 14). The 109 respondents traveling west first passed the travel information message on the permanent DMS, and later passed the portable DMS with no message. Westbound respondents identified *"travel information"* and *"no message"* 47% and 18% of the time, respectively (Figure 14). In response to these messages, 43% of the eastbound drivers reported that they did not modify their driving behavior, while 37% increased alertness. Of the westbound respondents, 61% did not modify their behavior and 25% increased alertness (Figure 15).

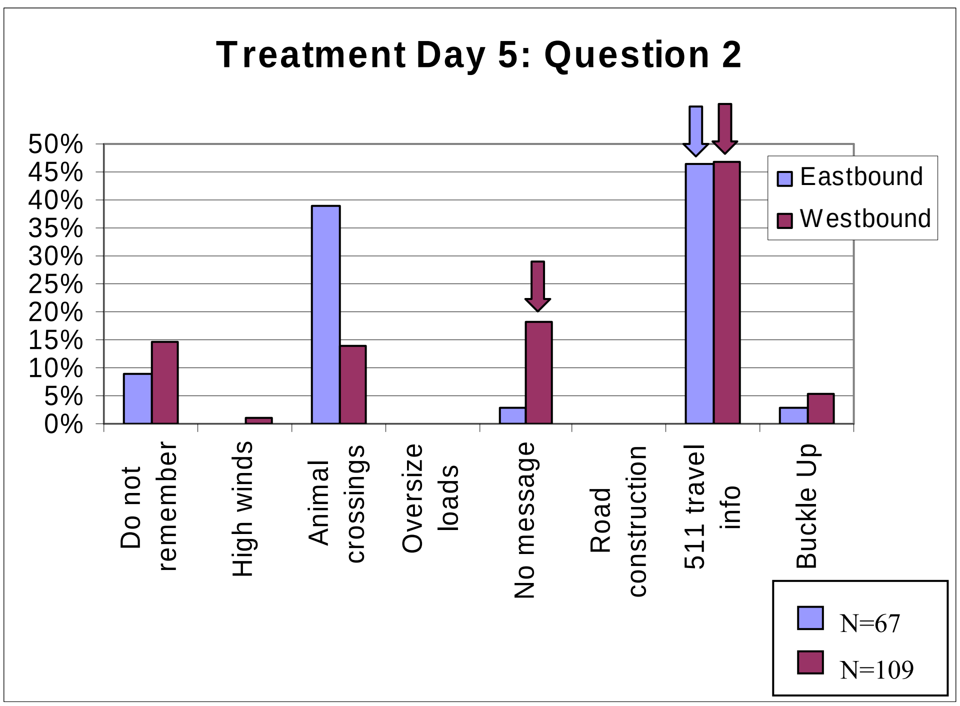

Figure 14. Messages recalled by survey respondents traveling eastbound and westbound on treatment day 5. Arrows indicate appropriate answers for the messages that were posted.

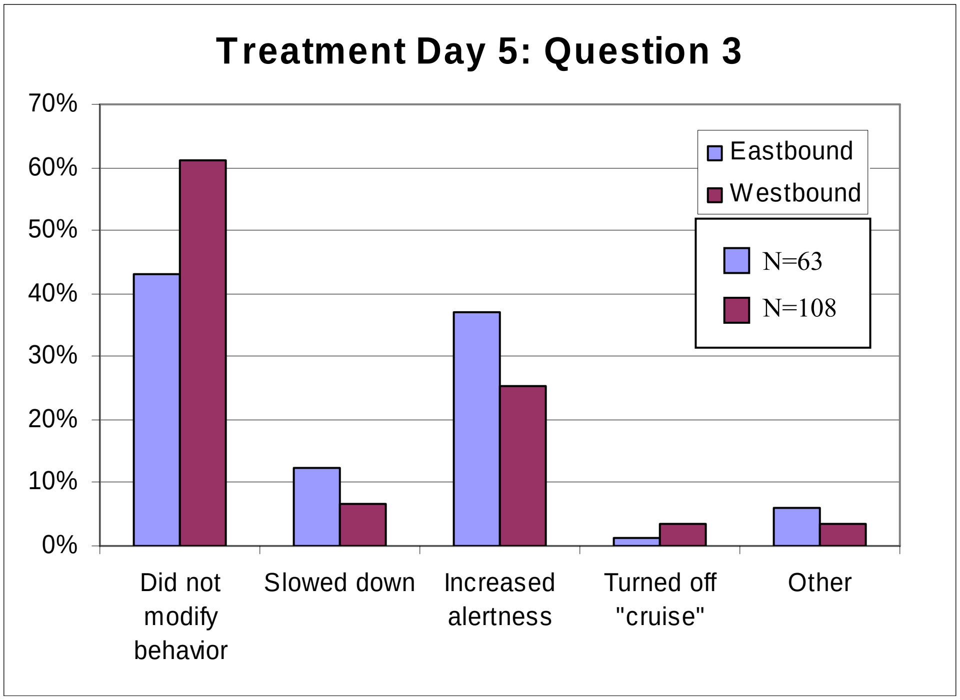

Figure 15. Survey respondents' reported driver behavior modifications in response to a blank sign (posted on the westbound portable DMS) and a travel information message (posted on the east- and westbound permanent DMS) on treatment day 5.

<u>Treatment Day 8 (treatment "on" at 5:00 PM September 24, 2004 , and "off" at 9:00 AM September 25, 2004)</u>

The set of messages displayed on the eighth treatment day of the study (September 24-25, 2004) were similar to those displayed on September 17, 2004. The west- and eastbound permanent DMS were blank (no message) and the portable DMS seen by westbound drivers displayed the two-frame message, "29 ANIMALS HIT – NEXT 2 MI THIS YEAR" (Table 1; see Figure 11 for example). Only 17% of the 59 eastbound respondents correctly reported seeing no message while most (53%) recalled seeing a message regarding animal crossings (Figure 16). The westbound traffic had two possible correct answers, *"no message"* and *"animal crossings"*. Seventy-eight percent of the 81 westbound respondents identified *"animal crossing"* and 11% selected *"no message"* (Figure 16). In response to the treatment messages, 41% of the westbound respondents increased alertness and 39% did not modify their driving behavior (Figure 22, Figure 17). The majority of the eastbound respondents were divided among the same categories, with 51% selecting, *"Did not modify behavior"* and 40% reporting *"Increased alertness"* (Figure 17).

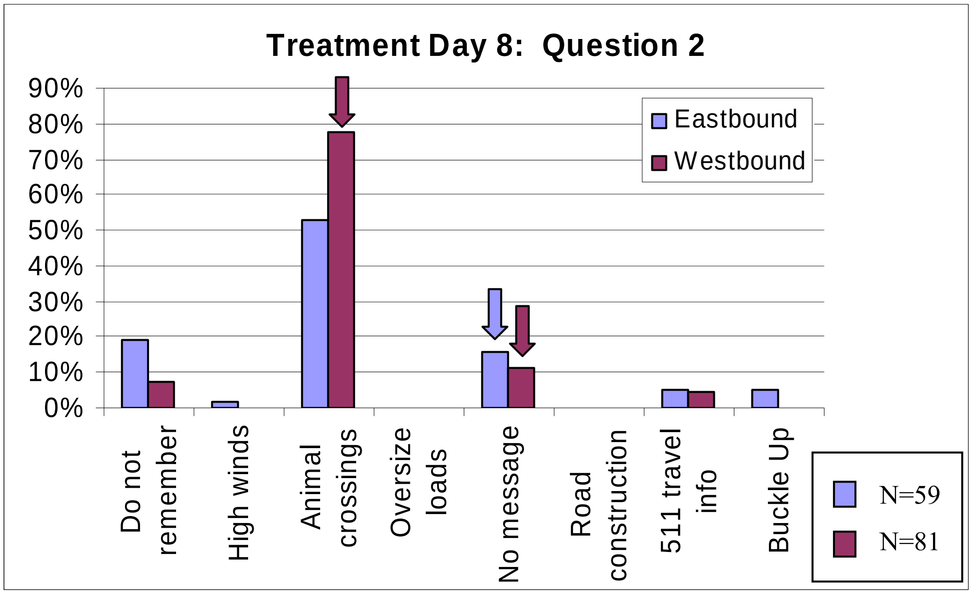

Figure 16. Messages recalled by eastbound and westbound survey respondents on treatment day 8. Arrows indicate appropriate answers for the messages that were posted.

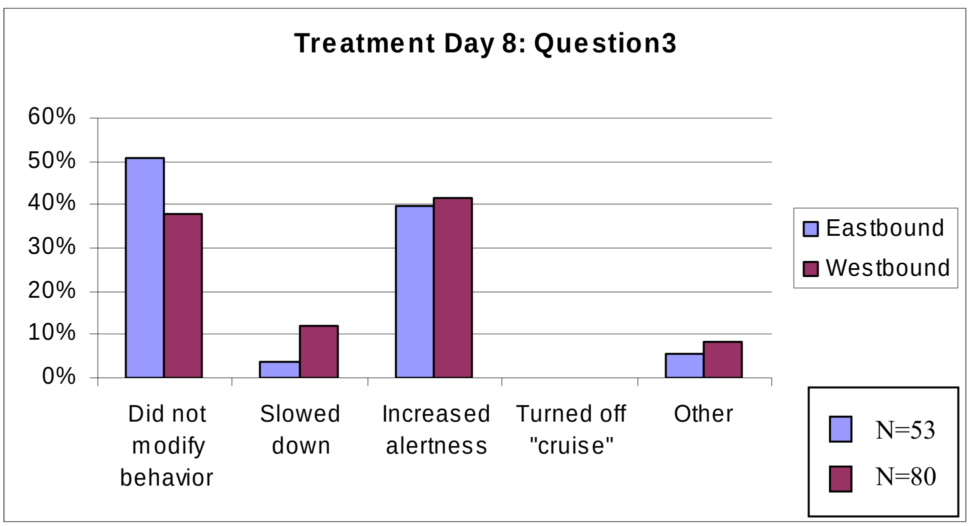

Figure 17. Survey respondents' reported driver behavior modifications in response to a blank sign (posted on the east- and westbound permanent DMS) and an animal advisory message (posted on the westbound portable DMS) on treatment day 8.

Treatment Day 11 (treatment "on" at 5:00 PM September 27, 2004, and "off" at 9:00 AM September 28, 2004)

On treatment day 11 (September 27-28, 2004), the permanent DMS displayed "185 ANIMALS HIT THIS YEAR NEXT 20 MILES" and the portable DMS displayed "34 ANIMALS HIT THIS YEAR – NEXT 2 MILES (Table 1; see Figure 11 for example). The majority of 36 eastbound and 82 westbound respondents (68% and 87%, respectively) selected the correct answer, *"animal crossings"* (Figure 18). In response to the message, 44% and 55% of the eastbound and westbound respondents, respectively, reportedly *"increased alertness"* (Figure 19). Most of the remaining eastbound and westbound respondents were divided between *"slowed down"* and *"did not modify behavior"*.

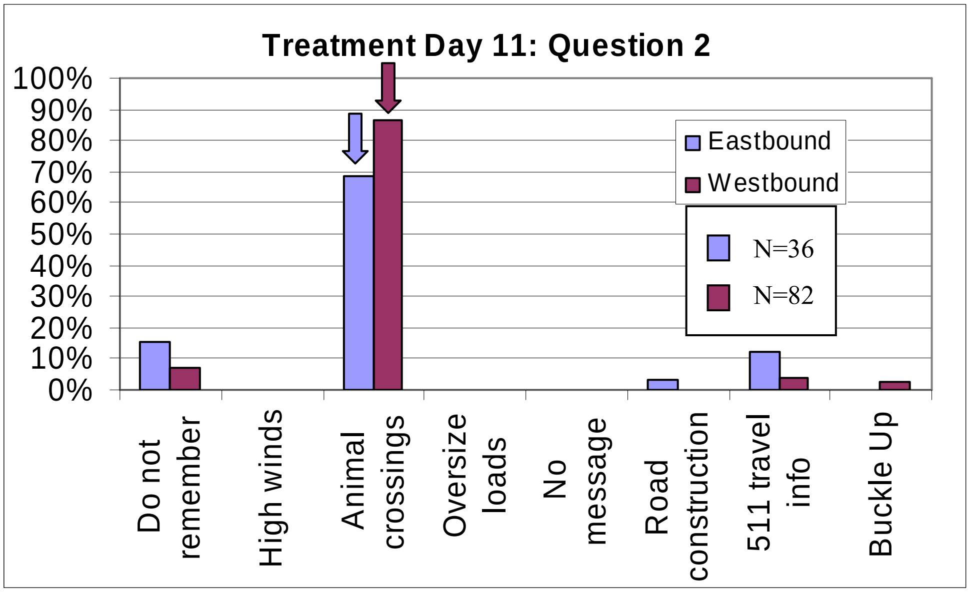

Figure 18. Messages recalled by survey respondents traveling eastbound and westbound on treatment day 11. Arrows indicate appropriate answers for the messages that were posted.

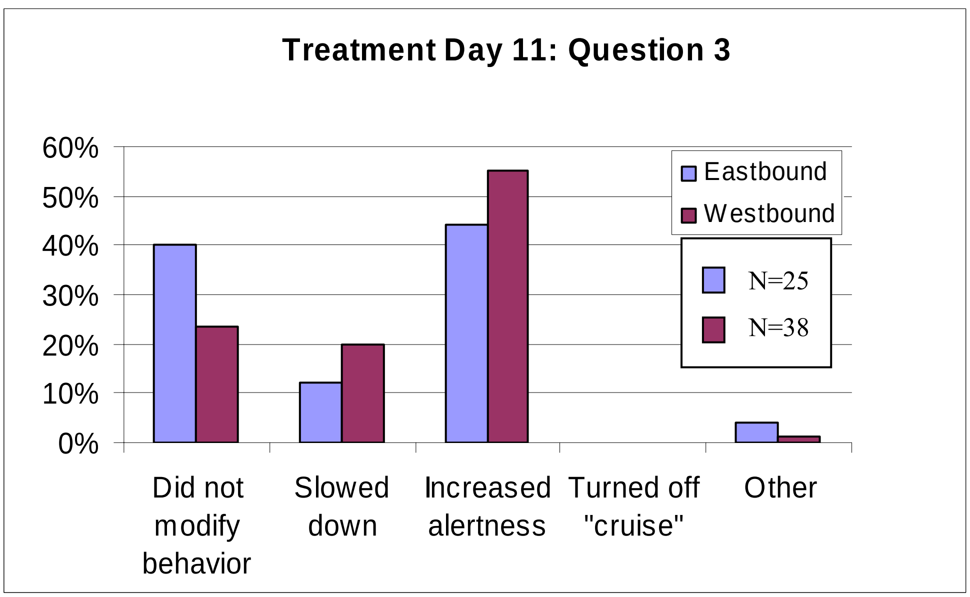

Figure 19. Survey respondents' reported driver behavior modifications in response to animal advisory messages on treatment day 11.

Treatment Day 12 (treatment "on" at 5:00 PM September 28, 2004, and "off" at 9:00 AM September 29, 2004)

On September 28-29, 2004, treatment day 12, the permanent DMS displayed "ANIMAL CROSSING NEXT 20 MI BE ALERT" and the portable DMS was blank (Table 1; see Figure 11 for example). Due to staffing limitations, surveys were only distributed at the Bozeman exits so only westbound data is shown in Figure 20 and Figure 21. Driver responses were split among *"animal crossings"*, *"no message"*, and *"511 travel info"*, 26%, 23% and 31% respectively (Figure 20), therefore 49% of respondents chose correctly. Figure 21 shows 26% of the westbound respondents increased alertness in response to the message and 66% reportedly did not modify driving behavior.

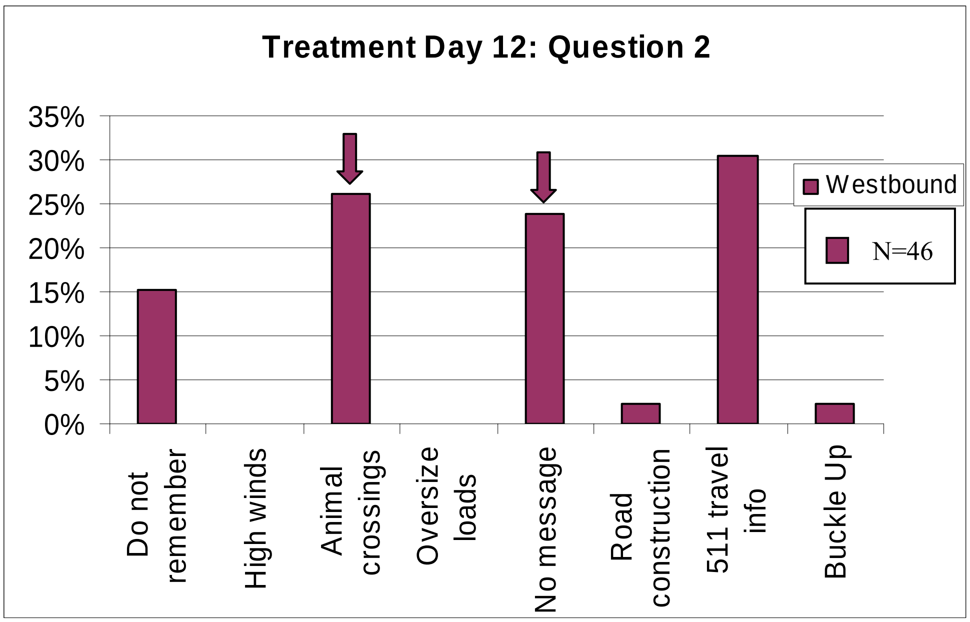

Figure 20. Messages recalled by survey respondents traveling westbound on September 28, 2004. Arrows indicate appropriate answers for the messages that were posted.

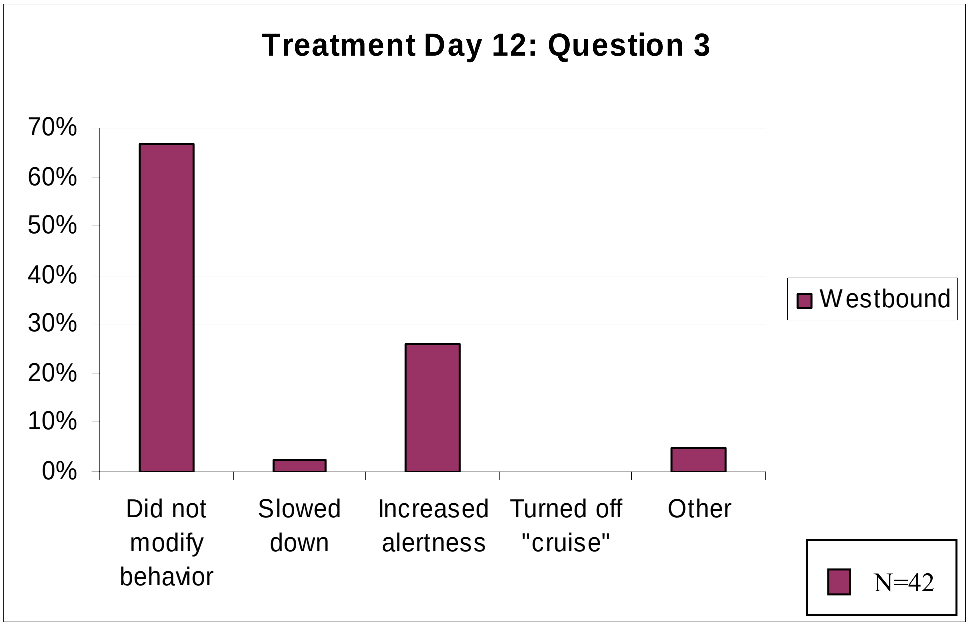

Figure 21. Survey respondents' reported driver behavior modifications in response to a blank DMS and an animal advisory message on September 28, 2004.

<u>Treatment Day 13 (treatment "on" at 5:00 PM September 29, 2004, and "off" at 9:00 AM September 30, 2004)</u>

Messages displayed on September 29-30, 2004, treatment day 13, were similar to those displayed on September 28, 2004 (Table 1); the permanent signs displayed "192 ANIMALS HIT NEXT 20 MILES THIS YEAR" while the portable sign remained blank (see Figure 11 for example). Surveys were only distributed at the westbound exits. Seventy percent of the westbound respondents chose *"animal crossings"* while 15% selected the other correct option, *"no message"* (Figure 22). In response to the messages, 47% of the respondents reportedly *"increased alertness"* (Figure 23) and *"did not modify behavior"* was selected by 41% of the westbound respondents.

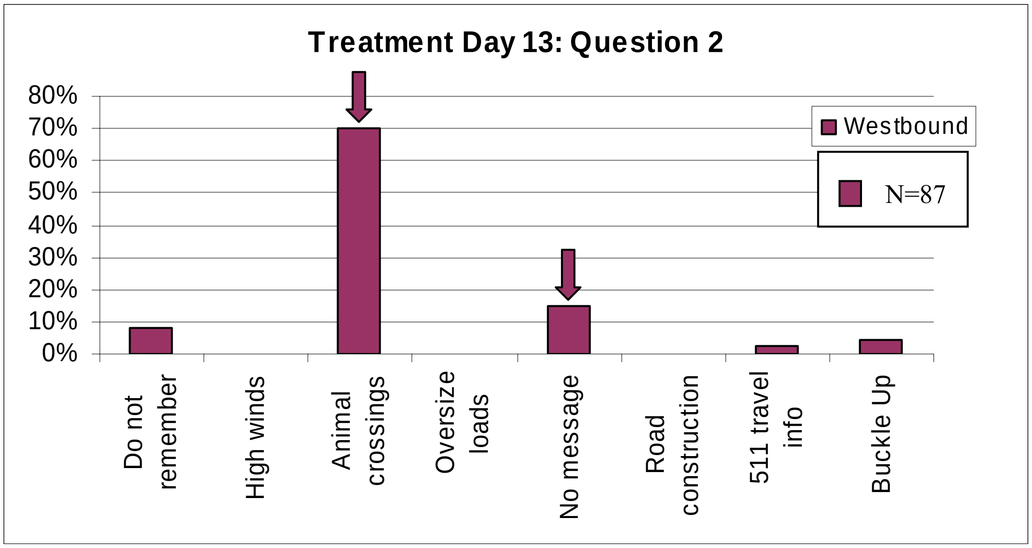

Figure 22. Messages recalled by survey respondents traveling westbound on September 29, 2004. Arrows indicate appropriate answers for the messages that were posted.

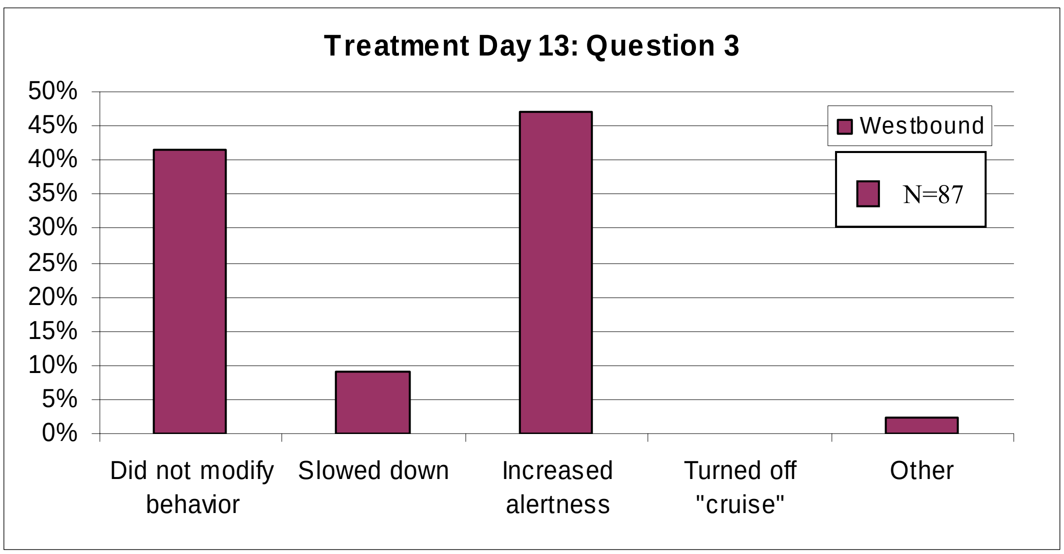

Figure 23. Survey respondents' reported driver behavior modifications in response to a blank sign and an animal advisory message on September 29, 2004.

Treatment Day 16 (treatment "on" at 5:00 PM October 2, 2004, and "off" at 9:00 AM October 3, 2004)

On October 2-3, 2004, the 16th treatment day, all signs displayed messages regarding animal crossings (Table 1). The permanent DMS displayed, "ANIMAL CROSSING NEXT 20 MILES" and the portable DMS read, "WATCH FOR ANIMALS – NEXT 2 MILES" (see Figure 11). Over half of the westbound traffic correctly identified the message regarding Animal Crossings (56%) while only 16% of the eastbound traffic accomplished the same (Figure 24). Fifty-five percent and 61% of west- and eastbound survey respondents, respectively, did not modify their driving behavior, while more than 40% and 32% of the west- and eastbound respondents claimed these messages increased their awareness (Figure 25).

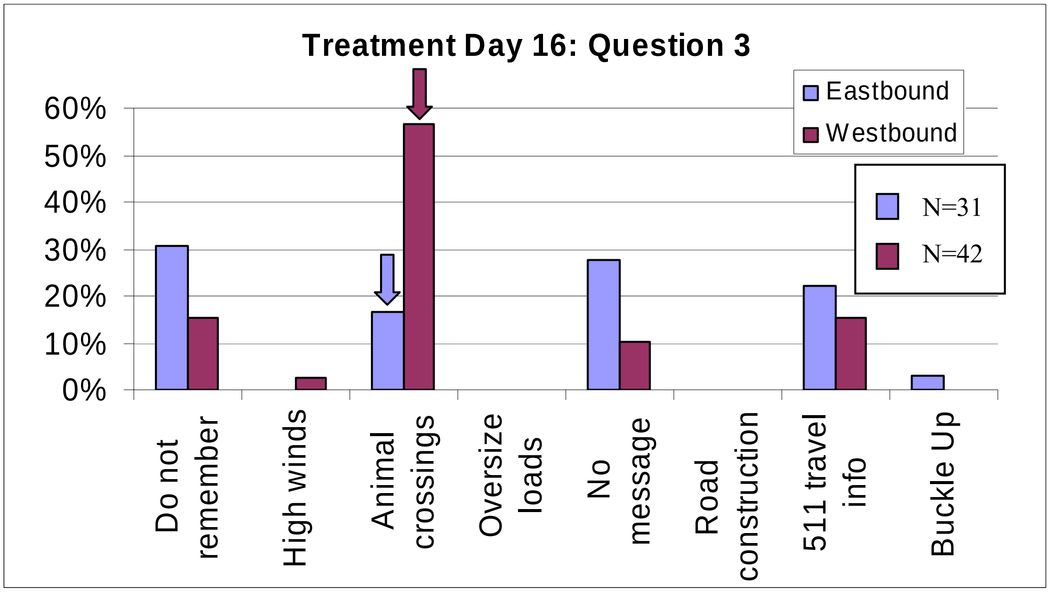

Figure 24. Messages recalled by survey respondents traveling eastbound and westbound on October 3, 2004.

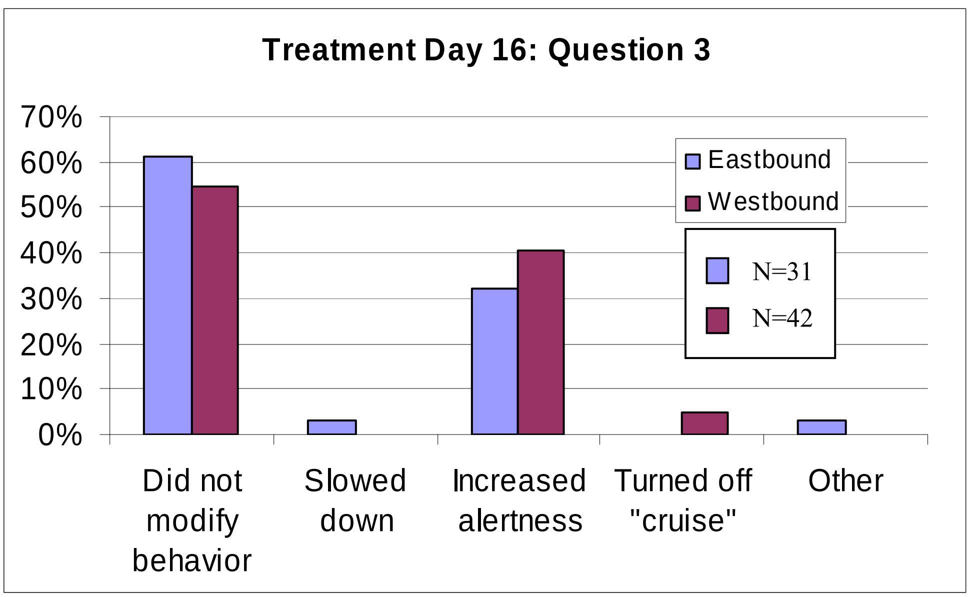

Figure 25. Survey respondents' reported driving behavior modification in response to the animal crossing message displayed on October 3, 2004.

Open Response

Comments regarding the I-90 transportation corridor between Bozeman and Livingston and animal-vehicle collisions.

This section summarizes the comments made in the open response question. A complete list of all comments may be found in Appendix B: Field Driver Survey Comments. Overall, many respondents felt the signs were a good idea. Some respondents said the signs were useful and were taken seriously; some specifically liked the message that kept a count of animals hit throughout the year. Others stated an appreciation for the effort put into reducing animal-vehicle collisions. On the contrary, several comments expressed a dislike for the signs. These respondents felt that the signs were a waste of taxpayers' money. A large number of comments were made in regards to other means of animal crossing safety measures. Several respondents suggested that the speed limit be lowered and enforced to reduce animal-vehicle collisions. Others suggested installing high fences, underpasses or land bridges to reduce the number of animals crossing the interstate and to provide passages where animals may cross safely.

2.4. Field Study Discussion

Results were synthesized for discussed below. Inferences were qualified taking into account limitations of the data and other relevant information that should be considered when interpreting these results.

2.4.1. Field Speed Study

In this field speed study, the use of permanent and portable DMS to deliver seasonal animal advisory messages over a 16-day study period resulted in statistically significant decreases in mean speeds compared to a blank DMS. Neither animal advisory treatment messages appeared to consistently induce lower speeds than the other. The greatest decrease in mean speeds was observed in "dark" conditions and at the speed counter located after the portable DMS treatment messages. "Light" conditions showed little to no reduction in speed for all messages displayed throughout the study.

Researchers originally deployed more traffic counters, including counters located just prior to the DMSs that would have served as a "control" for more certain understanding of observed changes in speeds, but due to complications with the traffic counters (requiring the manufacturer of the counters to extract needed individual speed observations from binned speeds, which were not valid for the analysis, at an unbudgeted expense), data from a number of counters from the dataset had to be dropped. Hence, researchers were unable to determine whether or not observed speed reductions were mainly influenced by the advisory messages rather than some other unrelated event occurring in the region (e.g., disabled vehicles, law enforcement presence, spilled loads, and/or blocked lanes). Although researchers were not aware of any such events occurring during the study, it is possible that such events could have occurred and affected our data.

Westbound drivers exposed to a message on the permanent DMS decreased mean speeds initially but then increased speeds some distance past that sign, as observed at the westbound speed counter 13 miles after the permanent DMS, suggesting, not unpredictably, that responses to the message were temporary. Although this study did not quantify the specific attrition rate of speed reductions over distance and time, these results indicated drivers' tended to speed up after traveling some distance beyond where they observed the advisory messages and, depending on the circumstances, may require multiple advisory messages over longer distances (e.g., more than a few miles) to sustain the desired response(s) where drivers may be at risk.

The greatest speed reductions were generally observed at the counter following the portable DMS, suggesting that multiple messages may be more effective in slowing drivers when they are “reminded” of the risks at hand (this reduction in speed after the portable DMS could also be due to drivers automatically slowing down in order to read the alternating two-frame messages). The idea that drivers’ recollection of and responses to advisory messages wane over time and space was further supported qualitatively by the driver survey results showing that westbound drivers were more likely to recall the correct message compared to eastbound drivers; westbound drivers were exposed to two signs, first the permanent DMS sign, then the portable DMS relatively close to where the surveys were distributed, while eastbound drivers would have seen a single DMS message some 20 miles before exiting and obtaining the survey.

Interestingly, the “CALL 511” general transportation message resulted in increased speeds observed at the counters just beyond the permanent DMS compared to the observed speeds when the DMS was blank. This observed increase in speed near the permanent DMS may be a response from local drivers that had become aware that this message was typically posted on the permanent DMS when no other priority or advisory messages were posted, who may then assume that the road is “clear ahead” and proceed to accelerate past the permanent DMS. It is also possible that drivers did call 511 and if there were no advisories, they may have also made the same assumption and increased their speed.

2.4.2. Field Study Driver Survey

Driver surveys were distributed to travelers that happened to exit at the Livingston and Bozeman interchanges during peak traffic periods (in order to optimize distribution efforts and sample size) when local commuters constituted a large proportion of the exiting traffic. This resulted in an emphasis on local drivers’ responses. While this particular population of Bozeman Pass travelers is of great interest, it should be noted that the survey is likely not representative of all Bozeman Pass traffic and may be biased toward local viewpoints.

Local commuters may have been offered and responded to the survey on multiple days. This is not problematic regarding questions related to the specific treatment messages posted on the various DMSs, which were unique from one day to the next; however, this may have resulted in some pseudoreplication of responses to the general questions about where respondents reside, how often they travel the pass, whether they’ve been involved in AVCs, and whether they’ve seen any publicity regarding AVCs. Therefore, it should be noted that the responses to these general questions could be skewed, potentially resulting in replicated emphasis on local responses.

Over 60% of the respondents frequently or very frequently saw wildlife (dead or alive) along I-90 as they traveled Bozeman Pass. Six percent of all respondents reported being involved in an AVC in the study area, and of that group, two-thirds indicated that they traveled across Bozeman Pass more than 10 times per month. These results emphasized the public’s awareness of wildlife on Bozeman Pass, and indicated that local drivers may be more aware of the potential for AVCs in this area.

The public outreach campaign appeared to reach local drivers, which constituted 90% of the survey respondents answering the question regarding exposure to publicity related to AVCs. Prior to the press release, 21% of the respondents recalled seeing or hearing publicity on this topic (presumably from other locales at other times, given that the survey didn't frame the question to any particular location or timeframe) while 33% recalled hearing or seeing such publicity after the press release. Although the times that the surveys were distributed and the timing of the release of the public information campaign did not overlap in time in order to better quantify this relationship in the survey responses, these results do indicate that outreach did reach drivers, and that drivers did recall the publicity.

Survey respondents were asked to recall the messages posted on the permanent and portable DMS and report changes in driving behavior in response to the messages. These questions were intended to indicate how well drivers remembered the messages and whether or not drivers responded to the animal warnings posted on the DMS. Overall, the majority of eastbound and westbound respondents selected animal crossing messages regardless of what was actually displayed on the DMS, particularly on the latter days of the study, hinting at the idea that local travelers that took the survey more than once may have answered in anticipation of the survey's focus. Many survey questions pertained to animal-vehicle collisions and wildlife, which may have influenced these responses, even for one-time respondents. It is possible the surveys were not filled out on same day they were distributed, increasing the likelihood that the correct message was forgotten, or perhaps respondents traveled the pass one or multiple times after receiving but before filling out the survey, resulting in responses related to what they could recall from the most recent trip rather than what was observed on the specific date that was stamped on the survey. It is also possible that some eastbound surveys were filled out with the westbound DMS in mind; e.g., some locals may have observed one set of messages upon traveling to Bozeman in the morning, then, upon their afternoon return commute, were given a survey at the Livingston exit and then reported the morning's messages rather than what was posted in the afternoon when they were handed the survey with a particular time and date stamped on the survey.

In general, westbound respondents correctly identified the actual messages displayed more often than the eastbound respondents. Westbound traffic was exposed to two DMS, one of which was relatively close to the exits where surveys were distributed to westbound drivers. Conversely, eastbound traffic traveled further between the DMS and when they received a survey compared to westbound respondents.

Responses to the survey question asking how drivers may have responded to the DMS were generally divided among *"did not modify behavior"* and *"increased alertness"* on any given day. Although *"increased alertness"* may have been the most popular response; many respondents both eastbound and westbound indicated that they did not modify their behavior, possibly attributed to local familiarity with the region; e.g., locals who travel across Bozeman Pass frequently are more familiar with the area and may be less likely to modify driving behavior (alternatively, it could be argued that this same population of locals may be more likely to modify behaviors if they see particular advisory messages given that they are more aware of the risks due to personal observations and experiences). However, results show some relationship between the message and behavior modification. When travel information was displayed, *"did not modify behavior"* was a slightly more popular choice than *"increased alertness"* for both eastbound and westbound traffic. However, when an animal crossing message was displayed *"increased alertness"* was selected more often than *"did not modify behavior"*. This holds particularly true for the westbound respondents.

3. DRIVING SIMULATION STUDY

Complementary to the field study (see previous chapter or Hardy et al. 2006), the intent of the driver simulation study was to further explore the potential for drivers exposed to enhanced wildlife advisory messages to slow down and increase braking distance, as an indicator of increased awareness and the potential for drivers to avoid AVCs. Researchers at WTI quantified driver responses to standard wildlife advisory signs and enhanced wildlife advisory signs, including the use of DMS to display wildlife advisory messages in a simulated environment. Based on our literature review, no published studies have examined the use of DMS specifically for wildlife advisories in the field or in a simulated setting.

3.1. Driver Simulator Methods

The methods used for the driver simulator study follow. Information on the driving simulator equipment, test subjects, simulated driving environment, experimental treatments, testing procedures and analyses of the data is detailed in the following subsections.

3.1.1. Laboratory Equipment

Data were collected using the Western Transportation Institute's Driving Simulation Laboratory. This laboratory is a 36 square meter light and sound controlled room containing a DriveSafety 500C simulator running HyperDrive™ Simulation Authoring Suite software and Vection™ simulation software version 1.9.8. The simulator is comprised of a modified 1996 Saturn SL sedan cab with fully functional controls, five rear-projection plasma displays arranged in a semicircle around the front of the cab (providing a 150-degree field of view and rear-view mirrors), five audio speakers, a simulator operator station, and associated computers.

The simulator, pictured in Figure 26, provides physics-based vehicle dynamics. The graphics systems render realistic driving scenarios including geometrically correct urban and rural roadways, traffic control devices, cultural features, ambient traffic, pedestrians, animals and other features. Realistic auditory effects of traffic, engine noise, and wind noise are generated by the 3-D audio system. The simulator program records data related to driver performance including speeds, lane position, and braking behaviors.

Figure 26. The DriveSafety 500C Vection Driving Simulator.

3.1.2. Subjects

Licensed drivers were recruited by announcements on the university campus and in the surrounding community. Potential subjects completed a screening questionnaire to identify and disqualify those who had medical conditions or histories that might indicate increased levels of risk (e.g., headaches and motion sickness) in the simulation environment. Qualified subjects were placed in one of four treatment groups balanced upon age and gender. All subjects were familiar with the Bozeman Pass corridor and were compensated $20.00 for their participation in the research.

3.1.3. Driving Environment

The twenty-six mile eastbound segment of I-90 between Bozeman and Livingston, Montana, (i.e. Bozeman Pass) was simulated. The simulation of the Bozeman Pass was made as realistic as possible given the standard roadway tiles available in the HyperDrive™ Simulation Authoring Suite software. Simulated features such as billboards, foliage (forested areas and open grass land), terrain (rural mountainous pass through a canyon), roadway geometry (several curves and straight sections), traffic density (low density), and posted speed limit (75 mph/120km/hr) were qualitatively similar to the real road segment, but the scenario was not an exact representation of the Bozeman Pass. For example, on/off ramps were not included in the simulated scenario.

The simulated driving scenario emulated the time of day that most animal-vehicle collisions occur (i.e., light conditions were set for "half-light" to mimic dusk/dawn lighting conditions). A carcass was placed on the side of the road at the beginning of the scenario to indicate that wildlife interactions might exist. Deer were not present on or off the roadway segment until the end of the scenario where subjects encountered a group of deer crossing the road. This was done to increase the likelihood that driver responses were related to the treatments rather than the presence of wildlife. All drivers in all treatment groups drove the exact same scenario with the exception, of course, of the different treatment signs.

3.1.4. Sign Treatments

Treatment signs were placed on straight roadway segments at the same location in each of the scenarios. Non-wildlife related signs were placed intermittently throughout the scenario to reduce the potential for subjects to capture the intent of the study. The four sign treatments consisted of:

1. Standard sign with text "Next 20 Miles" (Figure 27);
2. Standard sign with active flashing beacon with text "Next 20 Miles" (Figure 28);
3. Dynamic Message Sign (DMS) with text "Animal Crossing Next 20 Miles Be Alert" (Figure 29); and
4. Combination of sign treatment 3, the DMS with text "Animal Crossing Next 20 Miles Be Alert" and a second treatment standard sign with flashing beacon with text "Next 20 Miles" (Figure 30) located approximately 6 miles (9.7 km) after the DMS sign.

Figure 27. Sign Treatment 1 – Standard Sign.

Figure 28. Sign Treatment 2 – Standard Sign with Flashing Beacon.

Figure 29. Sign Treatment 3 – Dynamic Message Sign.

Figure 30. Sign Treatment 4 – Combination Group with Dynamic Message Sign followed by the Standard Sign with Flashing Beacon.

Other non-treatment signs were also included in all treatment group scenarios. For example, signs with the mileage to towns, billboards (with the Western Transportation Institute logo), and speed limit signs were included so that the treatment signs did not stand out as the only signs in the scenario.

To measure the effects of sign type on situational awareness, five pieces of construction equipment were placed within the driver's field of view, but beyond the immediate driving field of view. At the end of the simulation, subjects were asked to report how many pieces of construction equipment they remembered seeing during the testing session. The objective of seeing the construction equipment beyond the immediate field of view was to capture whether subjects were scanning for the presence of wildlife, thus having an elevated sense of awareness. A layout of the scenario, demonstrating the start/end point, sign treatment(s) location, and heavy equipment locations is illustrated in Figure 31.

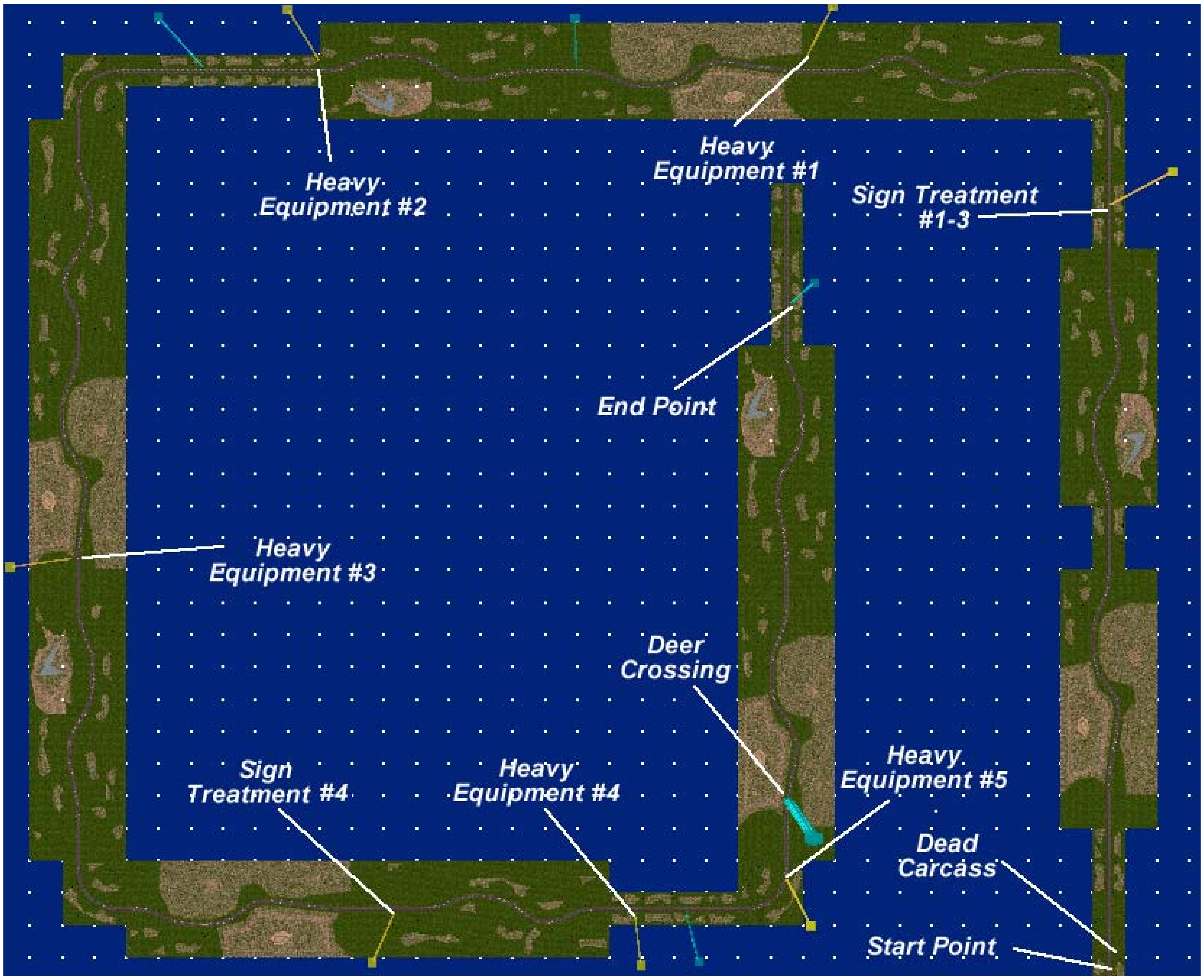

Figure 31. Layout of the Hyperdrive™ Simulation Scenario Environment.

3.1.5. Simulation Testing Procedures

Simulator Induced Discomfort (SID), including nausea, headaches, and dizziness, can be a significant issue during driving simulation research which frequently results in the attrition of subjects. Prior to testing sessions, subjects completed screening questionnaires directed primarily at identifying their potential susceptibility to SID. Subjects were then acclimated to the driving simulator by completing three training scenarios in the simulator, each lasting between three and five minutes. The first of the training scenarios involved gentle turning and braking, light traffic, and scenes designed to minimize the sensation of motion in the peripheral visual fields. As subjects proceeded through the training, the scenarios became increasingly longer, more challenging, and more visually complex. At the completion of training, subjects completed a follow-up questionnaire on any SID symptoms they experienced.

For data collection, subjects were divided into four groups balanced in terms of gender and mean age. Subjects drove one 15-minute scenario simulating the eastbound section of the Bozeman Pass (I-90 between Bozeman and Livingston, MT). All subjects were given the following instructions prior to testing:

> Your task is to drive for approximately 15 minutes along the road obeying all traffic signs and signals. Drive as you normally would. This scenario simulates the Bozeman Pass Eastbound from Bozeman to Livingston at dusk. You will drive until I tell you to stop; you will not be required to exit at any point.

Upon completion of the testing session, subjects were given a four-part questionnaire to determine (1) the types of signs and messages they remembered seeing; (2) if, and how, the signs altered their behavior; (3) the number of pieces of construction equipment in the scenario; and (4) a personal history of wildlife/vehicle collisions. Each subject also completed a questionnaire related to their experience with simulator discomfort.

3.1.6. Data Analyses

Two types of analyses were conducted on the data collected from the simulator: driver performance assessment and situational awareness. Dependent variables relating to driver performance included velocity, the onset of braking from the encroachment of deer, and number of collisions. *Velocity* was the speed of the subject vehicle (mph/km/hr). *Onset of braking* (i.e., *stopping distance*) was the point at which the subject began to decelerate in order to apply the brake as a means to avoid collision (i.e., when the subject removed his/her foot from the accelerator pedal). The onset of braking suggests that subjects saw the deer and had begun to physically react by removing their foot from the accelerator pedal and applying pressure to the brake pedal. *Collisions* included whether the subjects collided with the deer crossing the roadway near the end of the scenario.

For the driving performance data, excluding the number of collisions, mean differences of velocity and stopping distance from deer encroachment as a function of the experimental condition was conducted using an analysis of variance (ANOVA) on sign treatment (standard sign, standard sign with flashing beacon, DMS, standard sign with flashing beacon and DMS). A chi-square test was performed on the collision counts among the groups.

In assessing situational awareness between the groups, a chi-square test was conducted based on two categories: (1) less aware - those who saw two or less pieces of construction equipment were deemed to be less aware of their environment (i.e. not scanning beyond the roadway for deer), and (2) those seeing three or more pieces of construction equipment (a total of five were in the scenario) were categorized as being more aware of the environment.

Data management was performed using SAS 9.00. MiniTAB 14.1 was used for statistical analysis. Velocity data was filtered 500 ft./152.4 m before and after the sign treatment (for a total of 1000 ft/304.8 m). An average velocity was computed for these 1000 ft/304.8 m

3.2. Driver Simulator Study Results

Results from the driver simulator study are outlined below. Details regarding the population of test subjects, their performance under the different experimental treatments, and their responses to the surveys are detailed here.

3.2.1. Subjects

Eighty-one licensed drivers between the ages of 18 and 63 years (mean age = 34) participated in this study; these subjects were divided into four treatment groups of 20 and one group of 21. Subjects who reported severe motion sickness (5%) were removed from the data analysis, due either to their excessively slow speeds, or to the fact that some could not complete the testing session. In cases when subjects drove excessively fast or slow, residuals (i.e. outliers) of ± 4.5 mph (7.2 km/hr) were removed from data as were stopping distance residuals of ±145 ft/44.2 m.

3.2.2. Driver Performance

When the data set was evaluated in its entirety (n = 81) without removing residual data (i.e. simulator sickness induced discomfort affected data as mentioned above), there were no significant main effects of sign treatment on velocity, number of collisions, onset of braking, or situational awareness. However, when outliers in the data were removed (n = 77), significant main effects were found among the sign treatments, with the DMS sign treatment resulting in significantly slower speeds than the standard sign treatment ($F_{3,7} = 2.87$, $P<0.05$). Significant main effects were found in the onset of braking with the treatment that combined the DMS sign and the standard sign with flashing beacon showing significantly greater stopping distances than the standard sign treatment ($F_{3,59} = 2.85$, $P<0.05$). No main effects were found between sign treatments for the situational awareness test.

Figure 32 illustrates driver speed in response to the sign treatments. The DMS sign treatment (treatment 3) scenario recorded the lowest average speed (72.0 mph/115.9 km/hr) while the standard sign treatment (treatment 1) had the highest average speed (76.6 mph/123.3 km/hr). The DMS sign resulted in a 4.6 mph/7.4 km/hr significant (P <0.05) reduction in speed compared to the standard signs. The standard sign with flashing beacon (treatment 2) induced a speed reduction, relative to the speeds observed with the standard sign, of 3.3 mph/5.3 km/hr, while the combination of DMS and flashing beacon (treatment 4) resulted in a of 2 mph/3.2 km/hr slower than the conventional standard wildlife advisory sign. No significant differences were found among the other sign treatments, but all enhanced sign treatments did result in speeds below the posted speed limit.

Figure 33 illustrates the four treatment group braking distance responses: the distance from where subjects began decelerating and applying the brake, to the deer crossing the road. The standard sign with flashing beacon and DMS sign combination (treatment 4) group maintained the greatest distance from the deer (542.60 ft/165.4 m) while the standard sign (treatment 1) group had the shortest distance (465.99 ft/142.0 m). A statistically significant difference (P <0.05) was observed between subjects in the combination DMS and flashing beacon treatment group and subjects in the standard sign treatment group. A 76.61 ft/23.35 m reduction in distance was recorded in the combination DMS and flashing beacon treatment group as opposed to the standard sign treatment group. No main effects were found between the other sign treatments, but all enhanced sign treatments did increase stopping distance.

With regards to collision counts, no significant differences were found between sign treatments. The percentage of subjects colliding with deer at the end of the scenario included: 15% in the standard sign (treatment 1) group, 10% in the standard sign with flashing beacon (treatment 2) group, 18% in the DMS (treatment 3) group, and 5% in the combination DMS and flashing beacon (treatment 4) group.

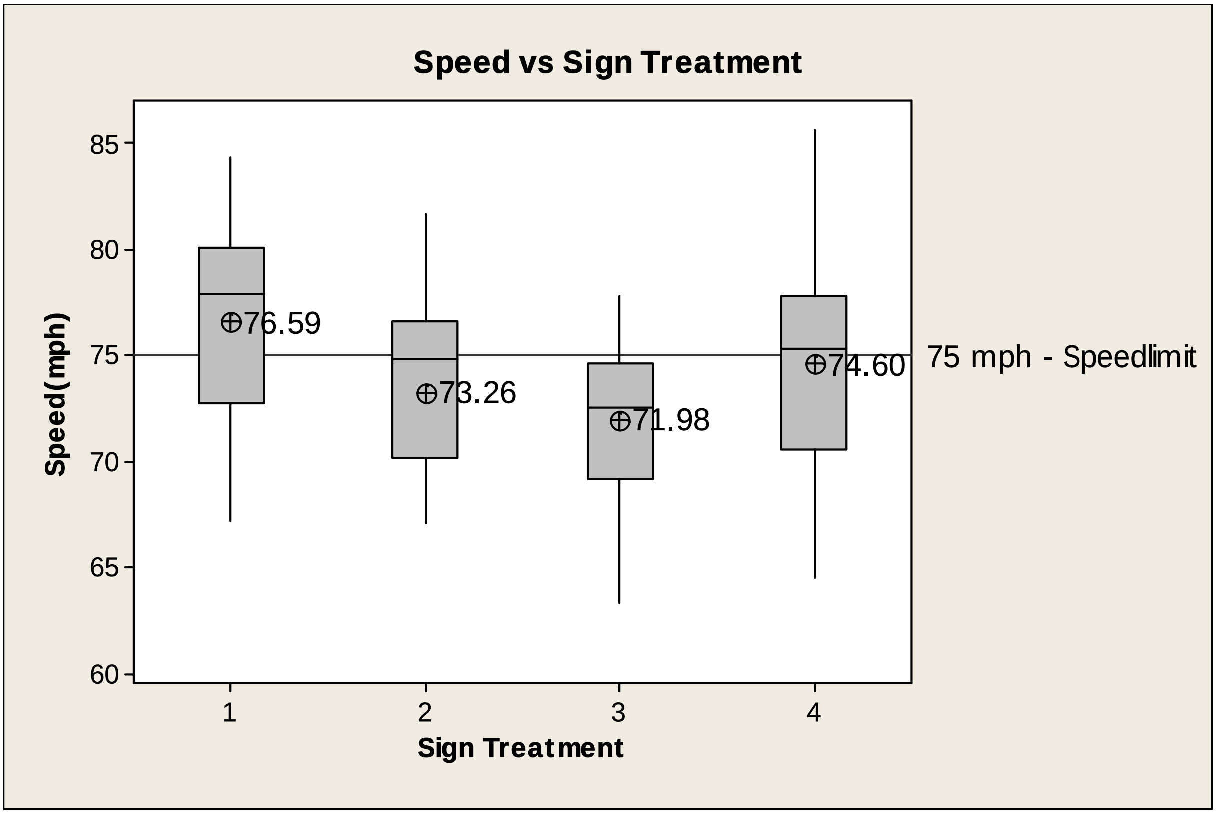

Figure 32. Observed speeds for treatment 1 (standard sign), 2 (standard sign with flashing beacon), 3 (dynamic message sign), and 4 (Standard Sign with Flashing Beacon & Variable Message Sign). The box shows the 25th percentile and 75th percentile at the bottom and top of each box, respectively. Data points represent mean speed (with standard deviations quantified as shown), horizontal lines within boxes indicate median speed, and lines extending vertically from each box represent standard deviation.

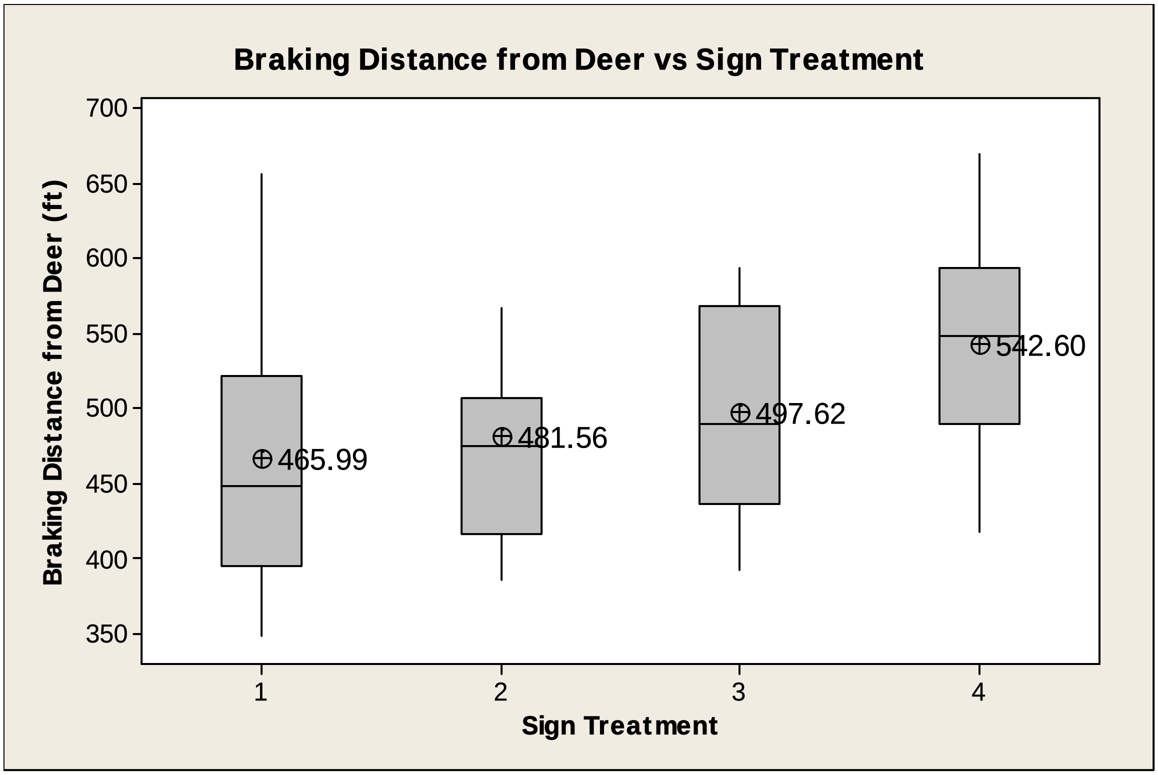

Figure 33. Initial braking distance from deer versus sign treatment 1 (standard sign), 2 (standard sign with flashing beacon), 3 (dynamic message sign), and 4 (standard sign with flashing beacon & dynamic message sign). The box shows the 25th percentile and 75th percentile at the bottom and top of each box, respectively. Data points represent mean speed (with standard deviations quantified as shown), horizontal lines within boxes indicate median speed, and lines extending vertically from each box represent standard deviation.

3.2.3. Survey Data

A summary of the responses to each survey question is provided below. The original written responses or comments from the survey have been included in Appendix C: Driver Simulator Subject Survey Comments. It should be noted that some subjects did not respond to all of the survey questions.

Question 1

While driving in the last scenario, did you see any of the following signs (check all that apply)?

The drivers were to select any of the following: do not remember any signs, billboards, animal crossing advisories, oversized loads advisories, speed limit signs, stop signs, high wind advisories, road construction advisories, 511 travel information, “Buckle up, it’s the law”, exits, and miles to towns/cities. Each of the four groups was generally divided amongst the same four sign types: billboards, animal crossing advisories, speed limit signs and mileage signs all of which were in all scenarios (Figure 34). The percentages of subjects per treatment group who reported that they did not see any wildlife crossing advisories during the simulated drive were 30% for the standard sign group (treatment 1), 5% for the standard sign with flashing beacon (treatment 2), 18% in the DMS sign group (treatment 3), and 0% in the combination DMS and flashing beacon group (treatment 4).

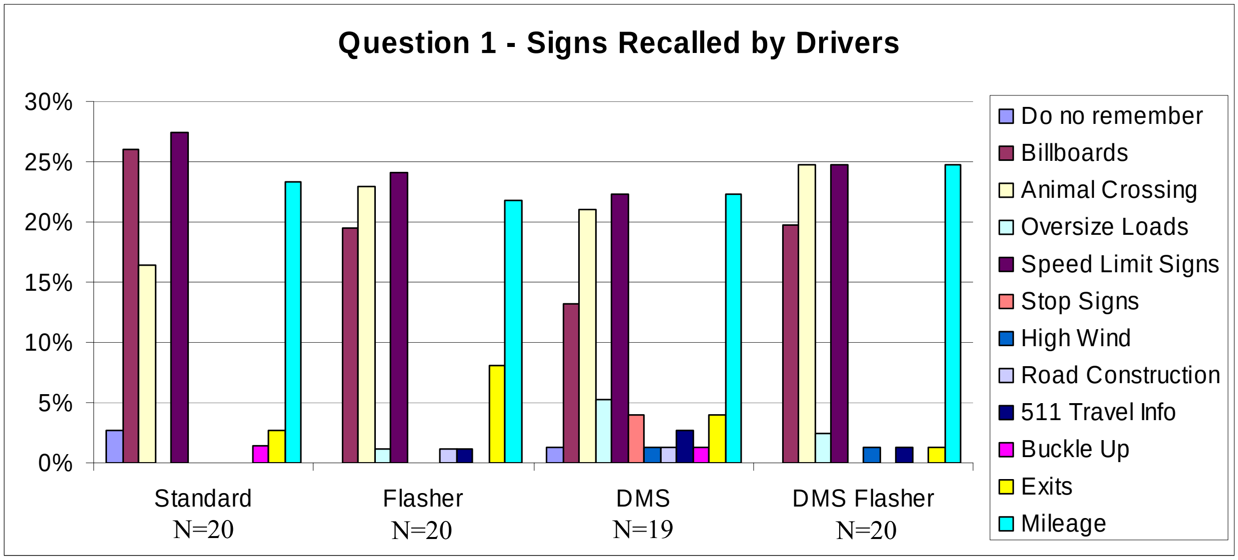

Figure 34. Sign types reportedly seen by driver simulator subjects in each of the four treatment groups.

<u>Question 2</u>

Was there anything different or unusual about any of the traffic signs you saw in the last scenario?

The majority of respondents in each group did not notice anything unusual about the signs (Figure 35). However, those who did notice unusual signs commented on the animal advisories and the DMS signs. Some respondents mentioned that the presence of the DMS sign was unusual while those who commented on the animal advisories found the standard sign with the flashing light and animal advisories on the DMS were unusual. All responses to this question are presented in Appendix C: Driver Simulator Subject Survey Comments, Table 14.

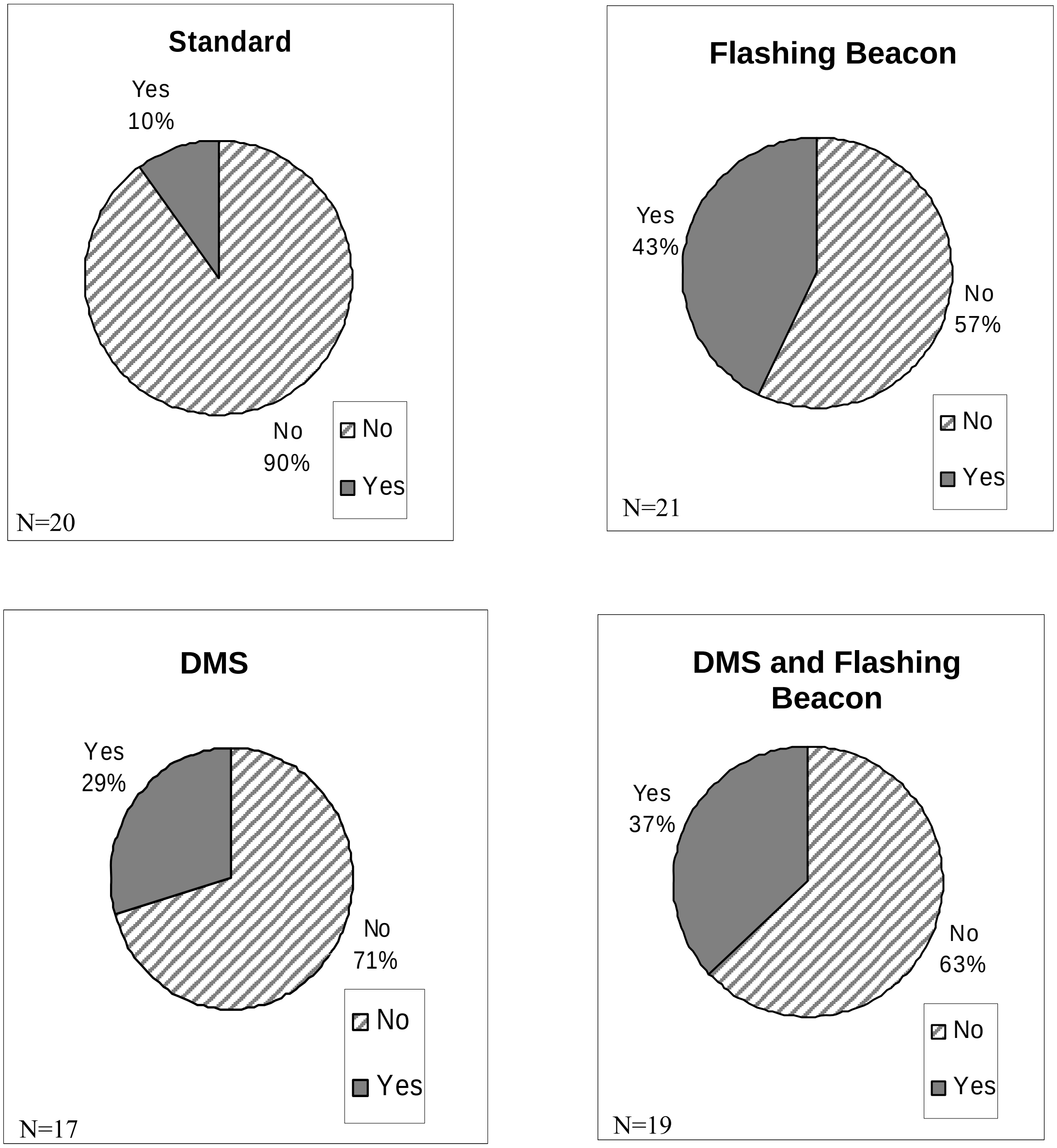

Figure 35. Percentage of subjects in each treatment group that reportedly noticed unique traffic signs.

Question 3

While driving in that last scenario, did any signs that you saw influence your driving behavior in any way?

This question presented the same list of sign types that were included in question 1 and asked respondents to report, generally, if any signs influenced their behavior, and how their behavior changed in response to the different signs. The majority of subjects in each treatment group selected 'yes' for this question (Figure 36). Only 10% of the flashing beacon (treatment 2) group and the combination DMS and flashing beacon treatment (treatment 4) group reported that they did not change their driving behaviors, while 15% of the group exposed to the DMS alone (treatment 3) and 41% of drivers in the standard sign (treatment 1) group reported no change in driving behaviors due to the signs. Figure 37 shows reported changes in driving behavior in response to the animal crossing advisories. Most subjects in each group increased alertness after observing an animal crossing advisory.

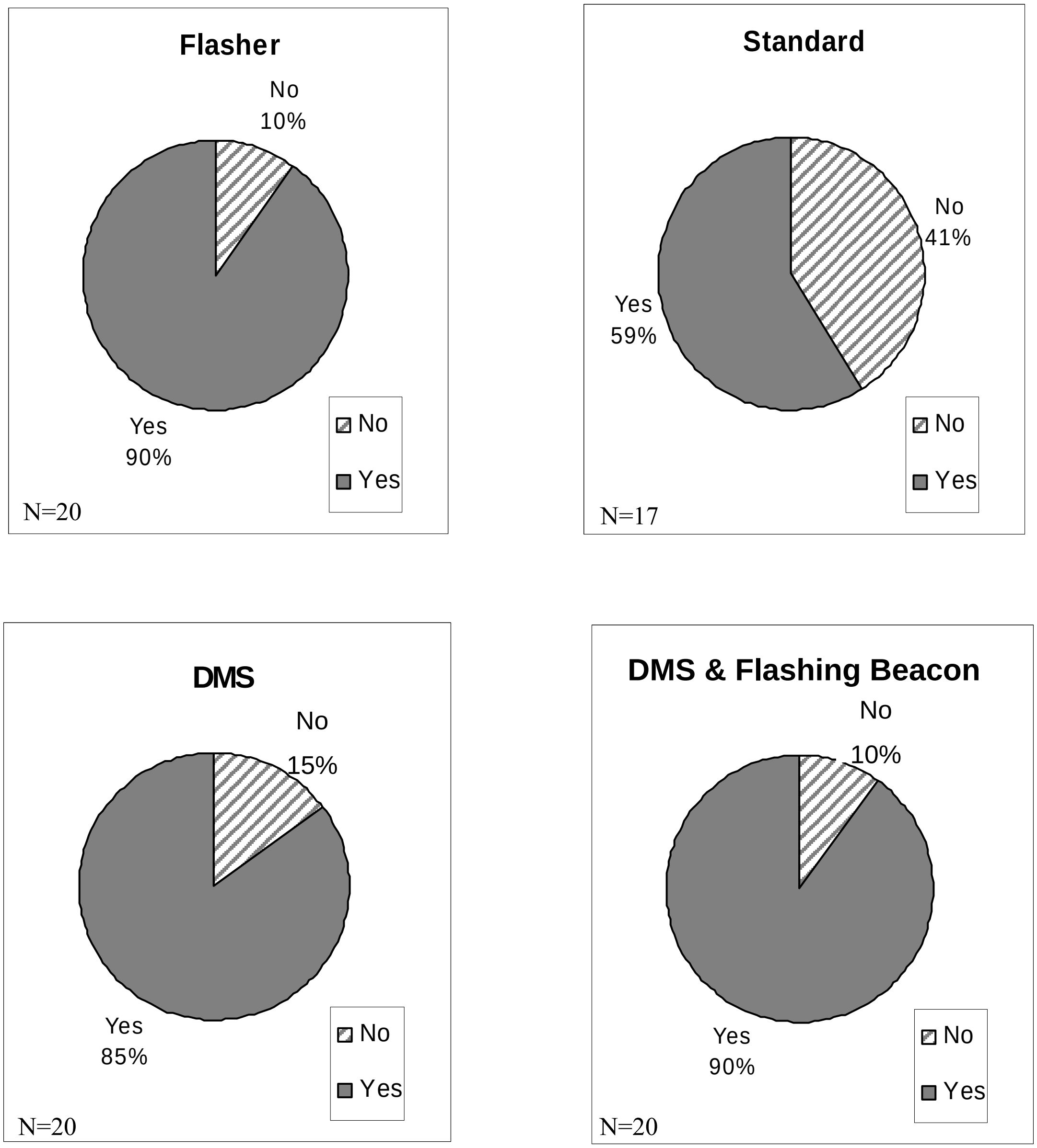

Figure 36. Percentage of subjects in each treatment group that reportedly adapted their driving behavior due to the signs included in the driving scenario.

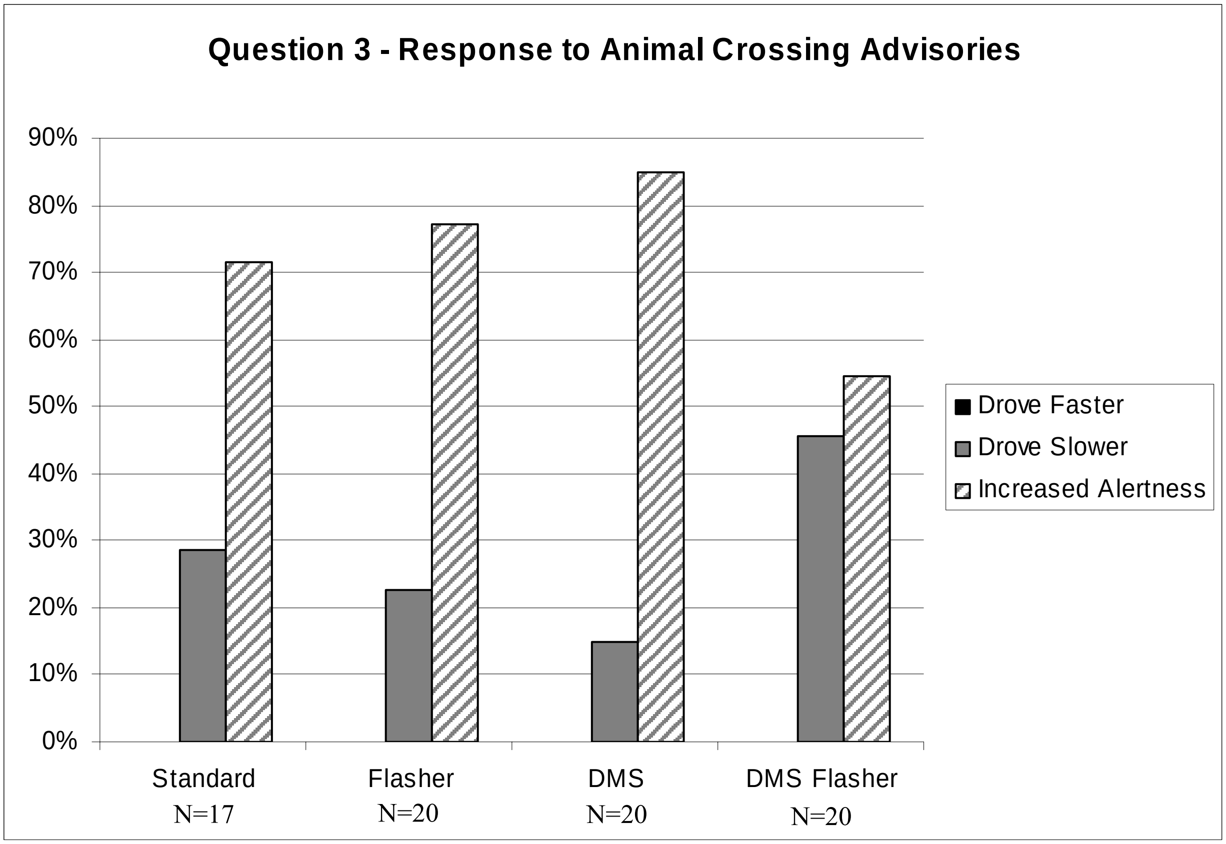

Figure 37. Percentage of subjects that drove faster, slower and/or increased awareness in response to animal crossing advisories.

Question 4

How many pieces of construction equipment did you notice in the last scenario?

To assess situational awareness, subjects were asked to circle a number between zero and ten to represent the number of construction pieces observed in the scenario. These responses were then categorized as "less aware" and "more aware" based on whether subjects reported seeing two or less or three or more pieces of construction equipment, respectively (Figure 38). More than half the subjects in treatment groups 2 (flashing beacon sign) and 4 (flashing beacon and DMS combination) reported seeing 3 or more pieces of equipment, while less than half of the subjects in the other two treatment groups (1, standard sign and 3, the DMS) reported seeing 3 or more pieces of equipment.

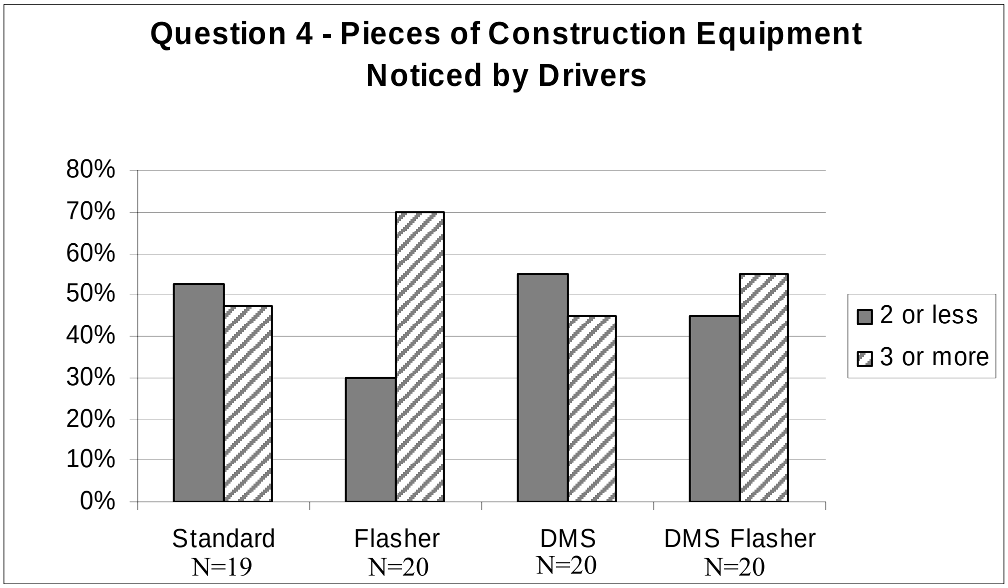

Figure 38. Percentage of subjects in each treatment group that reported seeing 2 or less or 3 or more pieces of construction equipment during their driving scenario.

Question 5

Do you drive differently during the day compared to how you drive at night? If so, how and why do you drive differently at night versus during the day?

Figure 39 shows that at least 90% of subjects in each treatment group claimed to drive differently during the day compared to nighttime driving. Most subjects (98.8%) reported driving at slower speeds at night than during the daytime under real-world driving conditions. All comments for this question may be found in Appendix C: Driver Simulator Subject Survey Comments, Table 15.

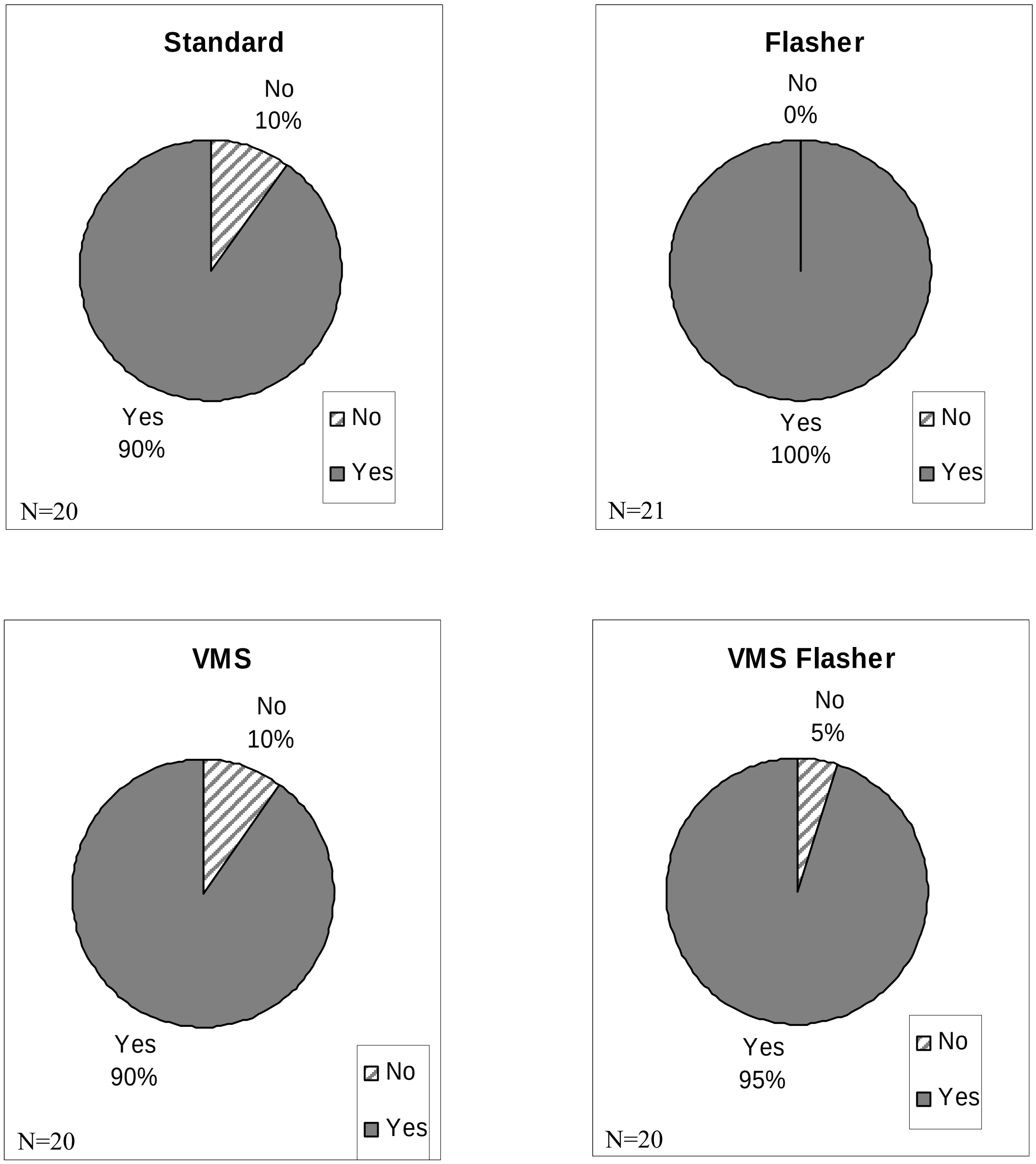

Figure 39. Percentage of subjects that reported driving differently during the day compared to driving at night.

<u>Question 6</u>

Have you ever hit any medium or large animals (wild or domestic; e.g. coyote, deer, bear, horse, sheep, etc.). If so, was the animal killed? Were there any human injuries? Was there damage to the vehicle? Did you report the incident to your insurance company?

Most of the subjects reported that they had not hit an animal while driving (Figure 40). Twenty-eight percent of all the subjects had previously hit an animal while driving in the "real world". Of those who reported hitting an animal, nearly 60% claimed the animal was killed in the incident, however, no one reported any human injuries (Figure 41). While nearly 80% reported vehicle damage only 35% reported the incident to their insurance company. Seventeen subjects reported a damage estimate for an average or $1,073 per incident. For a list of reported damage estimates see Appendix C: Driver Simulator Subject Survey Comments, Table 14.

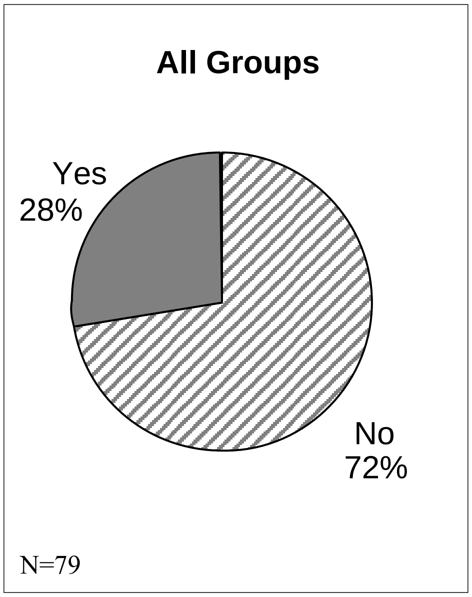

Figure 40. Percentage of subjects that reported having hit an animal while driving (in the "real world").

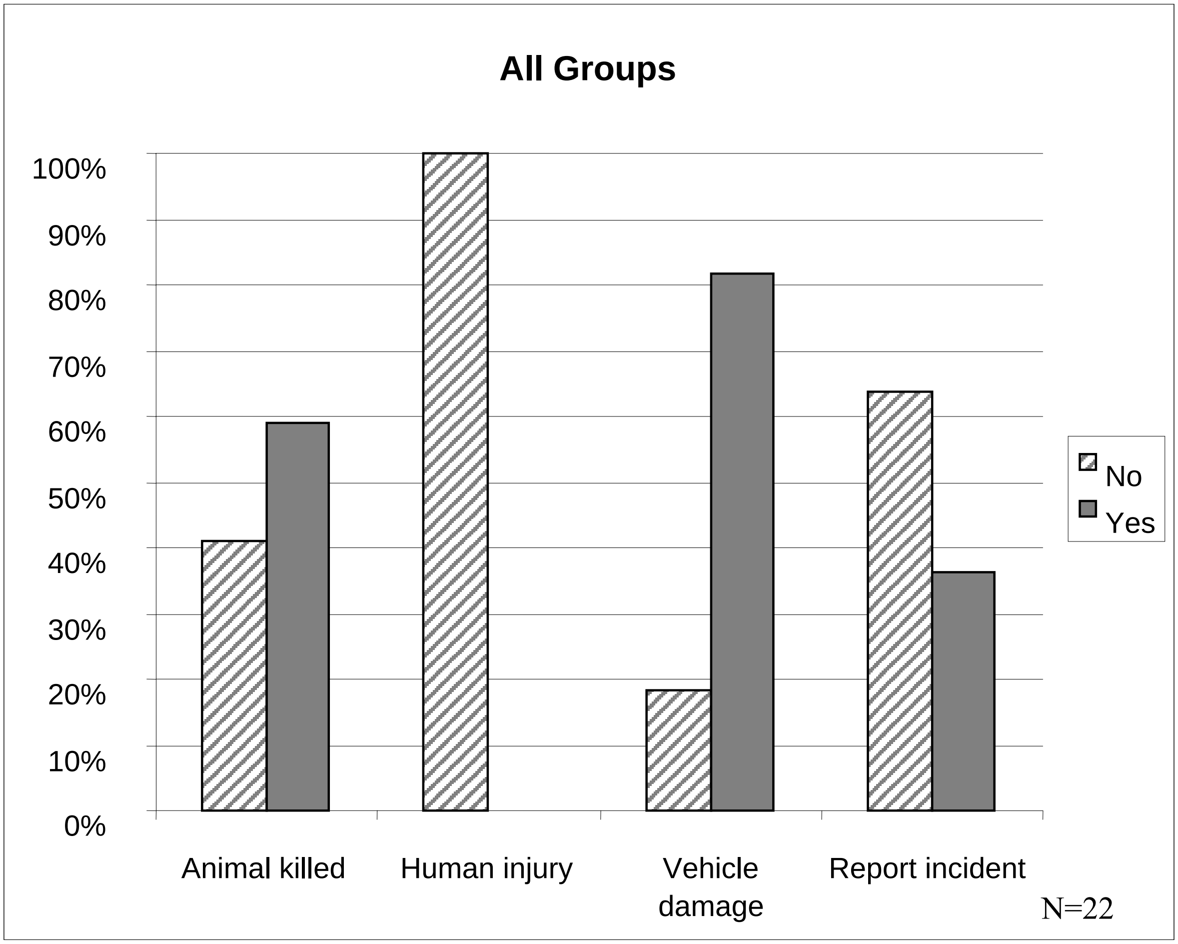

Figure 41. Percentage of subjects that had been involved in an animal-vehicle collision (in the "real world") that reported animals killed, human injuries, vehicle damage or the incident to authorities.

3.3. Driver Simulator Study Discussion

All enhanced sign treatments (treatments 2-4) resulted in average speeds below the posted speed limit of 75 mph (120.7 km/hr) while the average speed observed for the standard sign treatment exceeded the posted speed limit (76.6 mph; 123.3 km/hr). All enhanced signs increased braking distance compared to the standard signs. Drivers exposed to the DMS sign treatment initiated braking 31.63 ft (9.64 m) before the group that had seen the standard signs. Similarly, but to a lesser degree, the group of subjects that encountered the flashing beacon on the standard sign initiated braking 15.57 ft (4.73 m) before the drivers in the standard sign group.

Interestingly, the observed mean speed of the combination DMS and flashing beacon treatment group was the least different (2.0 mph; 3.2 km/hr lower) from the mean speed of the standard sign treatment group when compared to the lower mean speeds of the other enhanced sign treatments. However, this group did have the greatest onset of braking distance from the deer (542.60 ft; 165.4 m) while the standard sign treatment group had the least amount of braking distance (465.99 ft; 142.1 m). No subjects in the combination DMS and flashing beacon sign group collided with the deer while subjects in the standard sign group collided with the deer more often than drivers in the other treatment groups.

The treatment with two signs increased driver awareness and response times, as seen in the braking and collision data, despite observed mean speeds faster than what was observed with the other enhanced sign treatments. In this case, increased awareness may simply be because two signs are more likely to be seen than one. The second sign may reinforce the advisory where memory of and responses to the first sign would have dissipated, effectively elevating awareness over more distance and time than the single sign. Proximity of the second sign to the deer crossing event compared to the location of the first sign may be a contributing factor to these results as well.

The speed and collision data from the simulator survey implied that drivers may be “habituated” to the standard sign and that they may be more apt to notice and respond to the enhanced signs. The driver simulator survey results indicated that subjects in the standard sign treatment group were more likely to “miss” wildlife crossing advisories than subjects that were exposed to the enhanced advisory signs.

4. WILDLIFE MONITORING

While previous chapters in this report assessed driver responses to wildlife advisory messages on Bozeman Pass and in a simulated environment, this chapter summarizes field data characterizing wildlife-vehicle conflicts and wildlife movements on and near Interstate 90 (I-90) on Bozeman Pass. These data are not statistically appropriate for analyses related to the relatively short-term speed study assessing driver responses to animal advisories on DMS on the pass; however, this project allowed the continuation of a smaller scale monitoring effort that began in 2003 to assess the effect of wildlife mitigation measures that have been planned for installation in the fall of 2006 near the Bear Canyon interchange on I-90.

Several years prior to the driver-focused field speed study and simulation study, which started in 2004, a working group of interested agencies and local organizations initiated discussions regarding motorist safety and wildlife connectivity issues on I-90 over Bozeman Pass. Those discussions and consideration of road kill documented by the Craighead Environmental Research Institute (CERI), led the working group to propose to MDT the addition of wildlife mitigation measures into the planned Montana Rail Link (MRL) bridge overpass reconstruction project on the stretch of interstate that has seen the highest amounts and greatest species diversity of road kills between Livingston and Bozeman. These recommendations were incorporated into the construction project and MDT provided a contract to continue and expand the wildlife monitoring activities to evaluate the effect of the proposed fencing on animal-vehicle collision (AVC) rates and wildlife movements in the area where the mitigation will be installed.

Specifically, the mitigation includes the installation of wildlife exclusion fencing (i.e., 1.2 meter [8 feet] high) along both sides of 1.44 km (0.9 mile) of I-90, extending east and west from the bridge that crosses over the MRL railroad (The MRL overpass is located at approximately milepost 314.1; the wildlife fencing will extend from milepost 313.5 to milepost 314.4). To limit the chance of animals getting trapped on the right-of-way between the two fences if they breach the fence (potentially causing conflicts between the trapped animal and drivers), features called “jump outs” were included in the fencing plans as well. “Jump outs” are small mounds of earth abutting the inside of the wildlife fence allowing trapped animals to run up and jump over the top of the fence to exit the right-of-way, without allowing animals to jump in. The western termini of the fencing are located at the top of the access ramps of the Bear Canyon interchange, where double “Texas gates” or cattle guards will be installed to deter animals from walking around the end of the fence on to the access ramps. The eastern termini include “wings” of fencing angled away from the road to discourage animals from “end runs” around the fence. The objective of these measures is to limit wildlife access to the road while encouraging wildlife movements under I-90 via the MRL overpass, ultimately increasing driver safety by reducing AVCs and providing habitat connectivity under the road.

Although wildlife exclusion fencing has been shown to reduce ungulate-vehicle collisions by as much as 96% and all AVCs by 80% (Clevenger et al. 2001), each mitigation site is unique, with numerous variables that can affect wildlife movements and AVC occurrences. It is possible, depending on the situation, for wildlife fencing to displace AVCs, potentially creating AVC clusters at the edges of the fenced area where animals may cross the road. It is also possible that fencing may impose a barrier that limits wildlife movements across the landscape. Another potential negative outcome may occur if animals breach the fence, become trapped on the right-of-way and entangled in conflicts with vehicles. Thus, continued monitoring is essential to assess if the objectives were achieved. The pre-fencing wildlife monitoring data collection and results are presented here.

4.1. Wildlife Fencing Evaluation Study Objectives

In 2003, MDT contracted WTI to oversee the "Bozeman Pass Wildlife Connectivity and Driver Safety Pilot Study". WTI subcontracted the Craighead Environmental Research Institute (CERI) to conduct the wildlife monitoring efforts given that CERI had been funded by another entity to record base-line road kill data on Bozeman Pass for two years (2001-2002) prior to this project. Data collected during these years demonstrated the need to consider mitigation measures in the vicinity of the MRL bridge, which led to MDT incorporating the wildlife fencing into the bridge replacement reconstruction plans.

The goal of the MDT pilot study was to obtain pre- and post-mitigation data that would be used to comparatively assess the effect of the mitigation on AVCs and wildlife movements from one side of the highway to the other. Additionally, the road kill monitoring extended across the entire Bozeman Pass to identify other areas where wildlife-vehicle conflicts might be mitigated in the future. The tasks outlined for the pilot study included the following:

- Road kill data collection and data management.
- Monitoring of wildlife behaviors in the MRL overpass area including the following subtasks:
    - Recording animal movements under the MRL overpass via tracking observations; and
    - Remote photo-monitoring of animals passing under I-90 via existing culverts near the MRL overpass.
- Data analysis of road kill and crossing data.

The remainder of this chapter details the monitoring methods employed to accomplish the above tasks and summarizes the pre-mitigation field data collected through December 31, 2005. With the anticipated completion of the MRL overpass bridge reconstruction and wildlife mitigation installation in the fall of 2006, post-mitigation monitoring efforts will occur for two or three years (depending on available funding) after the mitigation is installed (Note: WTI and CERI recommend a longer period of post-mitigation monitoring to increase the sample size of the post-mitigation dataset and, hence, increase statistical confidence in the results). Analysis of the pre- and post-mitigation data will occur during late fall of 2007 and results are expected to be reported by December 31, 2007. Those results will be integrated into another version of this report to provide a comprehensive overview of the 4+ years of animal-vehicle collision and habitat connectivity mitigation efforts on Bozeman Pass.

4.2. Animal-Vehicle Collision Monitoring

There were four main objectives for monitoring animal-vehicle collisions across Bozeman Pass:

- Identify species involved in AVCs;
- Identify areas of high ungulate-vehicle collision (UVC) risk;

- Determine average yearly UVCs across Bozeman Pass for sections that will and will not receive mitigation; and
- Identify whether mitigation reduces UVCs in high-risk areas, while continuing to monitor areas outside mitigation to evaluate whether high-risk collision areas were simply displaced rather than truly mitigated.

We used ungulates (deer, elk, and moose) as focal species of interest for several reasons. First, ungulates are large-bodied animals that can cause significant damage to vehicles and personal injury in collisions. Second, ungulates are common across Bozeman Pass, comprising one-half of all AVCs recorded. Finally, ungulates are game species, and Montana Fish, Wildlife and Parks Agency (FWP) is interested in the highway as a source of mortality to ungulates, and as a barrier to ungulate movement across the landscape. Methods to achieve these objectives are described below. Results from the preconstruction data collection efforts are summarized thereafter.

4.2.1. Animal-Vehicle Collision Data Collection and Analysis

Animal-vehicle collision data were derived mainly from observations of carcasses along the road (presumably killed in an AVC; herein referred to as "road kill") in the study area. During 2001 and 2002, many of the road kill observations were recorded opportunistically by two wildlife biologist volunteers as they commuted together from Livingston to Bozeman on weekday mornings and returned from Bozeman to Livingston at the end of the work day (i.e., the westbound leg of a survey occurred in the mornings while the eastbound leg occurred in early evenings). More standardized survey efforts were used from 2003-2005. These survey methods involved driving I-90 from Bozeman to Livingston (mileposts 309 to 331) and back to Bozeman during daylight hours at approximately 88 km/hr (55 mph), stopping to record information on each new carcass observed on or near the road. For each observed carcass, CERI sources recorded the species, sex and age class (if determinable), and the location of the carcass. Locations of each observed carcass were determined by using the vehicle odometer to estimate the tenths of a mile from the nearest milepost.

In addition to the road kill data reported by CERI and their volunteers, supplemental carcass data collected over the same period of time was obtained from MDT Maintenance reports of animal carcass removals and disposals. In general, MDT removes dead animals from the road or right-of-way only if the carcass creates unsafe driving conditions; MDT counts have recorded additional elk, moose, and other large animals that were picked up before CERI personnel could observe them during their survey efforts. MDT's Safety Bureau also provided additional data from Montana Highway Patrol (MHP) accident reports of collisions with wildlife on Bozeman Pass. Furthermore, in 2001, FWP provided records of less common species of wildlife that were sometimes collected for necropsies. Typically, FWP reports not accounted for by CERI sources or MDT included rarer species such as mountain lions, black bear, moose, and a wolf. At a minimum, data from these supplemental sources included the species and location, to the nearest tenth of a mile relative to existing mileposts, of the observed carcass. Road kill observation data collected by CERI personnel were reconciled with data acquired from MDT (both carcass removal reports and MHP collision reports) and FWP and screened to avoid duplicate records in the dataset.

This pre-fencing road kill dataset was summarized in general terms for all species, years, and area sampled (mile markers 309-330). A subset of only ungulate-vehicle collisions (UVCs) was analyzed to identify areas where higher-than-average UVCs were reported for the entire Bozeman Pass area (mile markers 309-330) and UVCs reported between mile markers 309-319 (from Bozeman to Jackson Creek) were used specifically in reference to the fencing evaluation because this is the area where post-fencing monitoring will be focused.

Power analyses were applied to the pre-fencing road kill UVC dataset to determine what degree of change in UVC rates would be statistically detectable when comparing UVC rates before and after the mitigation is installed. This statistical test determines the probability of detecting differences, or effects, between two groups of data, if an effect actually occurs (Zar 1999). This information is useful when determining appropriate sample sizes (e.g., number of years of post-construction UVC data) that will allow for useful quantitative inferences. The larger the sample size, the more likely one will be able to detect smaller differences with greater precision, but the expense and effort of obtaining such larger samples may be prohibitive; alternatively, with small sample sizes, relevant differences in may not be detected and inferences may be limited if not inaccurate.

Power analyses were conducted within a hypothesis testing framework where failing to reject the null hypothesis indicated that differences between two estimates were not detected. If the null hypothesis was rejected, indicating that there were differences between the two samples, then the test supported alternative hypotheses of anticipated differences that were likely to be observed in the data. Alternative *a priori* hypotheses may be one-sided or two-sided: a one-sided (i.e., one-tailed) hypothesis tests for an expected change (e.g., a reduction in reported UVCs); a two-sided (i.e., two-tailed) hypothesis tests for an uncertain outcome (e.g., a reduction or an increase in reported UVCs). Power (i.e., the probability of correctly rejecting a false null hypothesis) and significance level or α (i.e., the probability with which one is willing to reject the null when it is in fact correct) can be controlled in these analyses.

Using these pre-fencing UVC data, researchers ran 3 power analyses (power level = 0.8; α = 0.05) to determine the minimum detectable difference in UVCs in 1-10 years of post-mitigation study for stretches inside and outside the proposed mitigation area from mile markers 309 to 319. The first power analysis looked at the area that will receive wildlife fencing (mile markers 313.5-314.4), a one-sided test with the hypothesis that the presence of the fence will result in a decrease in UVCs. The second power analysis examined UVCs reported in areas outside the fence only (mile markers 309 to 313.4 and mile markers 314.5 to 319.0), a two-sided test to determine whether UVCs increase outside the fence, due to animals moving around fence edges, or decrease due to effective mitigation by the fence and animals safely crossing elsewhere. The third power analysis was another one-sided test to determine statistically detectable reductions in UVCs within the area to be fenced plus a 0.2 mile buffer on either side (313.3 – 314.6).

4.2.2. Pre-Fencing Animal-Vehicle Collision Data Summary

A total of 526 road kill surveys covering 11,572 miles between mile markers 309 and 331 were conducted by CERI and their volunteers from January 2001 through December 2005. The dataset obtained via opportunistic observations by wildlife biologists on their daily commute between Bozeman and Livingston was not statistically different than data collected by CERI; therefore the two datasets were combined over 2001-2005 for analysis. MDT, MHP and FWP data were also included after eliminating duplicate observations from the dataset.

The 2001 through 2005 dataset of road kill observations in the study area included 1,336 reports involving 37 different species (Table 8). It should be noted, however, that the 2005 data were likely affected by the initiation of construction at the MRL overpass. While CERI monitored the entire Bozeman Pass in 2005, reconstruction of the MRL overpass began April 12, 2005 and the construction work zone rerouted traffic from 4 lanes (2 lanes in each direction separated by a median) to 2 lanes traveling in opposite directions on one side of the median from mile marker 313.5 to 314.4. This change in the configuration of traffic appeared to have an effect on the numbers of road kill observed and reported in this area (see below).

The total number of UVCs reported annually from 2001-2005 appears in Figure 42. Reported UVCs from 2001-2005 are presented by month in Figure 43. Figure 44 plots locations of UVCs to the nearest 1/10 mile using data from 2001 through 2005; however, due to the apparent influence of the construction zone traffic configuration, only data from 2001 to 2004 were used to determine establish the average used as a "benchmark" to define where "hotspots" of UVC occurred. A hotspot was defined as a 1/10 mile stretch where the number of kills was 3 standard deviations higher than the pass-wide average determined with the UVC data from 2001-2004. Using these criteria, the area between mile markers 309.7 and 310.3 was defined as a hotspot. Also, high numbers of UVCs occurred from mile markers 312.7 to 313.3 and 313.8 to 313.9. This latter section partially overlaps the area that is planned to have wildlife fencing installed in the fall of 2006 (mileposts 313.5 to 314.4).

Table 8. Number and species of AVCs reported from 2001-2005 on Interstate 90 across Bozeman Pass (mile marker 309-330.9), between Bozeman and Livingston, in southwestern Montana.

SPECIES	2001	2002	2003	2004	2005	TOTALS
Badger	-	-	-	5	2	7
Beaver	-	-	2	2	-	4
Bird (Other)[1]	-	2	3	7	11	23
Bird (Owl)[2]	1	10	3	8	9	31
Bird (Raptor)	1	8	1	-	1	11
Black Bear	1	8	5	1	3	18
Bobcat	-	-	-	1	1	2
Cat (Domestic)	-	-	4	4	4	12
Coyote	7	7	12	14	8	48
Deer (Mule)	33	63	40	31	43	210
Deer (Unk)	36	72	44	38	37	227
Deer (Whitetail)	34	56	53	42	36	221
Dog (Domestic)	-	-	-	5	0	5
Elk	6	4	13	4	7	34
Fox	5	7	3	3	-	18
Marmot	-	4	6	1	1	12
Mink	-	-	2	-	-	2
Moose	-	-	2	-	2	4
Mountain Lion	2	4	1	-	1	8
Pine Marten	-	2	-	-	-	2
Porcupine	3	4	13	12	2	34
Raccoon	12	23	37	20	14	106
Skunk	13	51	50	33	23	170
Small Mammal[3]	1	12	41	17	17	88
Unidentifiable	3	7	4	18	6	38
Wolf	1	-	-	-	-	1
TOTALS	159	344	339	266	228	1336

1. Includes pheasants, grouse, Hungarian partridge, ravens, magpies, ducks and turkeys.
2. Includes great horned owls and unknown owl species.
3. Includes rabbits, ground squirrels, and gophers.

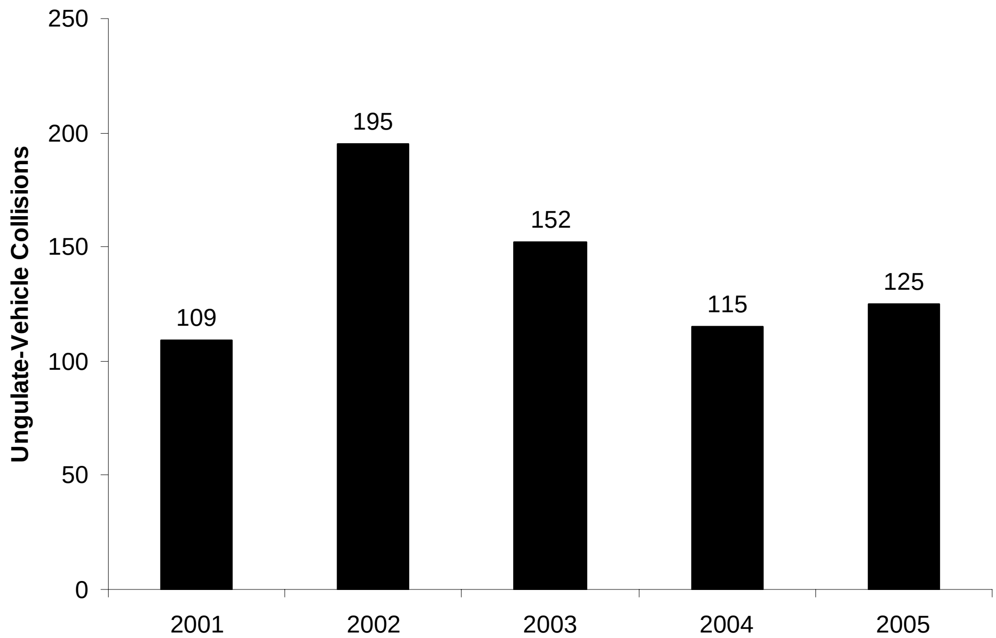

Figure 42. Annual number of ungulate-vehicle collisions observed on Interstate 90 across Bozeman Pass (mile marker 309-330.9), between Bozeman and Livingston, in southwestern Montana.

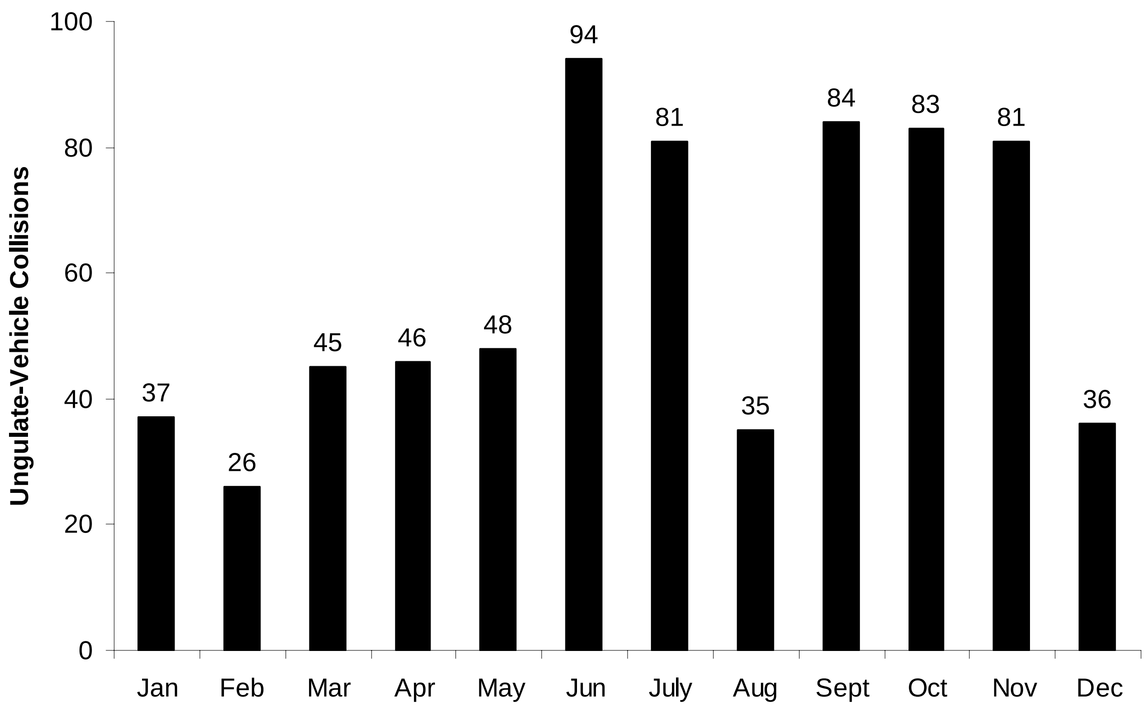

Figure 43. Total accumulated monthly observations of ungulate-vehicle collisions reported from 2001-2005 on Interstate 90 across Bozeman Pass (mile marker 309-330.9), between Bozeman and Livingston, in southwestern Montana.

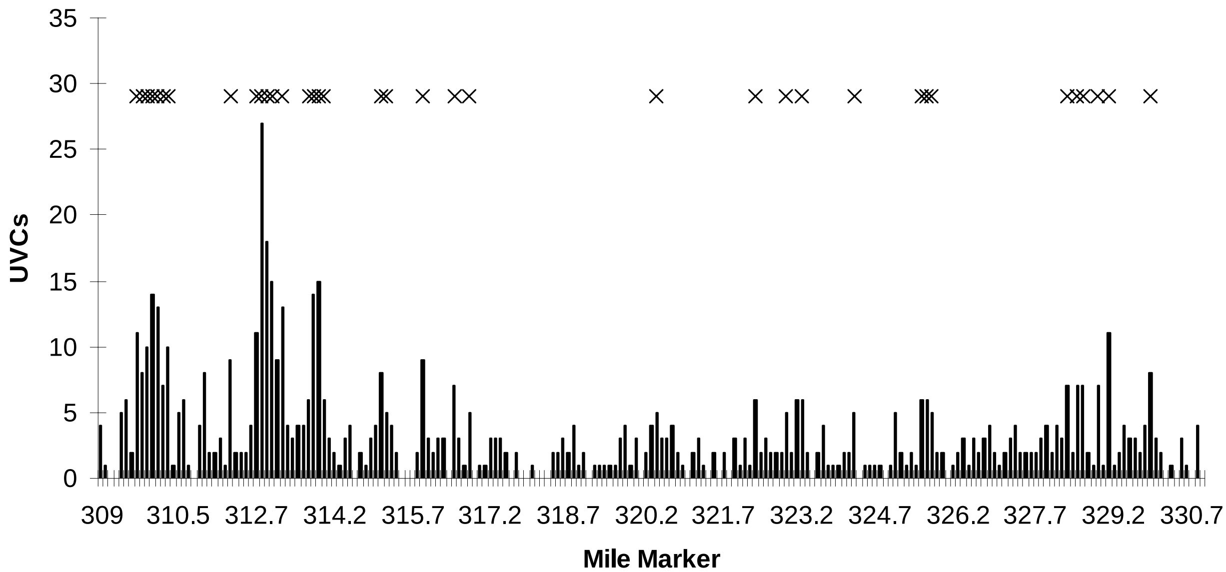

Figure 44. Ungulate road kill locations by 1/10 mile increments recorded between 2001 and 2005. Note that the actual distance between mile marker 311 and 312 is only 0.4 miles; the x-axis reflects this anomaly. "X" indicates areas where the number of reported UVCs was at least 3 standard deviations above the average number of UVCs across the entire pass (this average excluded the 2005 data due to the influence of the construction zone on reported road kill rates on the west side of the pass).

Researchers compared the UVC rates observed within the 0.9 mile (1.5 km) stretch of I-90 (mile markers 313.5 to 314.4) that will have wildlife fencing installed in the fall of 2006 to the UVC rates observed from areas that will not receive fencing between mile markers 309.0 and 319.0 (8.4 miles; 13.5 km). The analysis standardized the number of UVCs within the given area of interest by the length of that section to use UVCs per mile as the unit of interest, in order to compare rates in the fenced and unfenced areas after the construction of the fence (Table 9).

Table 9. The yearly number of ungulate-vehicle collisions per mile in the area where the wildlife fence will be built (mile markers 313.5-314.4) and in the areas outside the planned wildlife fencing installation (mile markers 309-313.5 and 314.4 to 319).

	Area to be Fenced	Area with no Planned Fencing
2001	15	5.71
2002	11	11.1
2003	14	9.0
2004	14	6.5
2005	4	8.8

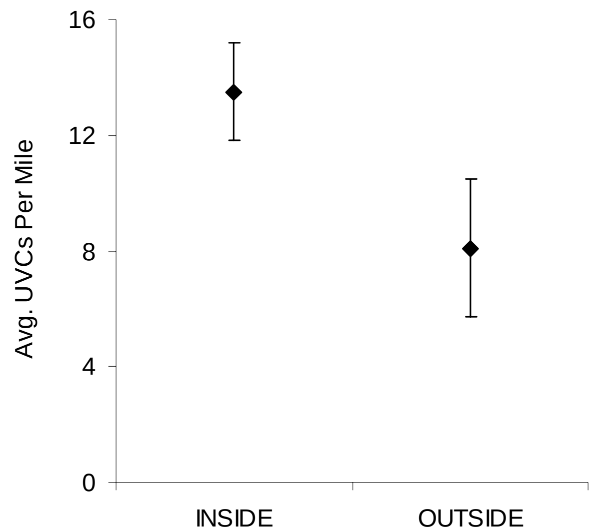

Figure 45. Mean number of ungulate-vehicle collisions per mile inside and outside the area to be fenced, assessed over 2001-2004. Bars represent 95% confidence intervals around the mean.

From 2001-2004, the number of reported UVCs per mile inside the area to be fenced were significantly higher than the UVCs/mile outside the area to be fenced ($P<0.05$; Figure 45). The estimated average UVCs/mile inside the area to be fenced was 13.5 (1 SD = 1.73) and the estimated average yearly UVCs per mile outside the fence was 8.10 (1 SD = 2.44). Because the number of road-killed ungulates reported in 2005 was much lower in the area planned for fencing than in previous years (Table 9), presumably due to the reconfiguration of traffic patterns in the construction zone through this area, the power analyses excluded the year 2005 from power analyses of the pre-fencing UVC data.

Power analyses (power = 0.8; $\alpha = 0.05$) indicated three to five years of post-fencing study would be an optimal investment of energy in order to make reasonable quantitative comparisons between the pre- and post-fencing UVC data (Figure 46). The minimum detectable difference in the areas to be fenced ranged from 36-27% ($\alpha = 0.05$) given three to five years of post-fencing monitoring, compared to a minimum detectable difference of 50% if post-fencing monitoring were to be carried out for only two years (note that calculating a power analysis involves the harmonic mean of the pre- and post- sample sizes, so there is not sufficient time to gauge how much change that could be detected given 1 year of post-construction study because the degrees of freedom for the test would be less than 1; Zar 1999).

Variance in UVCs reported outside the areas to be fenced and between mile markers 309 and 319 was high between years relative to the mean. Therefore, there was little power to detect a difference in yearly UVCs across the unfenced portions of Bozeman Pass. The estimated minimum detectable difference with three to five years of post-fencing data was estimated at approximately 84-69% change based on pre-fencing reported UVCs at $\alpha = 0.05$.

The power analysis for the area to be fenced plus 0.2 mile (0.3 km) adjacent to the ends of the fences was a 1-sided power analysis because researchers expected a decline in UVCs in this area. However, if animals move around the ends of the fence and are killed on the highway then no difference would be detected. Including the 0.2 mile buffer area on both sides of the fence reduced variation between years of pre-fencing UVC data, resulting in high power to detect smaller decreases in UVCs in this area. One year of study could not be tested for reasons described above; three to five years of post-construction study would allow detection of a 31-19% decline in UVCs across this area.

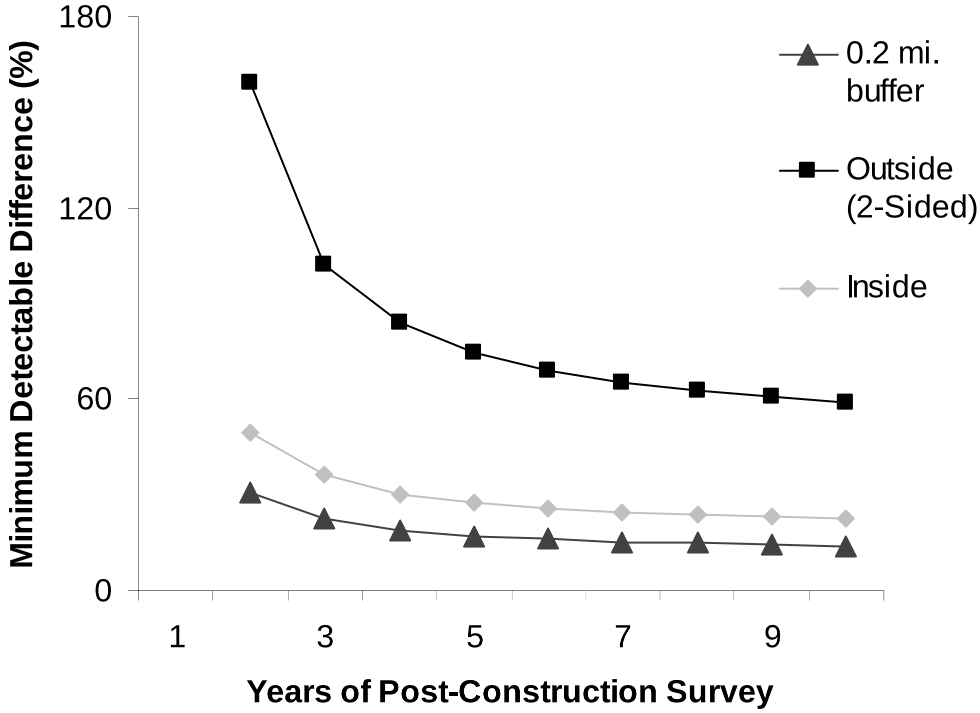

Figure 46. Power analyses for minimum detectable differences in UVCs per mile inside the area to be fenced (one-sided test), outside the area to be fenced (mm 309-319, excluding area to be fenced; two-sided test) and inside the area to be fenced plus a 0.2 mile buffer. Tests used data collected from 2001-2004. Power = 0.8, α = 0.05.

4.3. Animal Movement Monitoring in the MRL Overpass Area

In addition to monitoring animal-vehicle collision occurrences, it is equally important to monitor how wildlife fencing affects animal movements. The installation of wildlife fencing can result in three responses when an animal approaches the mitigated road segment: 1) the animal follows the fencing to one of its ends to cross the road at-grade; 2) the animal turns away from the fencing and road, not completing the movement across the road; or 3) the animal follows the fencing to a passage that allows movement under or over the road. The first response listed above is undesirable, for the obvious reason that animals crossing the road at-grade at the end of the fence will likely conflict with passing motorists, possibly shifting and/or amplifying the problem that the fencing was employed to address. The second potential response listed is also undesirable, resulting in the isolation of animals (or populations of animals) on either side of the road, reducing the amount of available habitat and possibly inducing a barrier to genetic exchange, both important factors for sustaining healthy wildlife populations (Saunders et al.

1991, Mills and Yale 2003). The desired outcome is to guide animals to passages allowing movement under (or over, depending on the infrastructure) the road.

To assess how wildlife mitigation measures affect wildlife movements in the vicinity of the MRL overpass, CERI employed three methods prior to construction, as follows: sand track beds under the MRL overpass, behavioral observation sessions, and photo-monitoring of the larger culverts in the vicinity of the MRL overpass. These data establish base-line data of animal activity prior to mitigation that will be compared to data collected using the same methods after the mitigation is installed.

This section addresses methods and results for tracking animal crossings at the MRL overpass and methods and results for monitoring additional culverts found near the MRL overpass. The objectives for monitoring animal crossing information in the MRL overpass area, which lies within the area that will be mitigated with wildlife fencing, include:

- Determine which species regularly use the current wildlife passageway;
- Estimate the daily crossing rate for deer before mitigation;
- Determine whether there are seasonal influences on deer daily crossing rates; and
- Determine whether deer crossing rates change after mitigation.

Evaluating this information will help determine how effective mitigation is in shifting deer movements away towards these preferred safer passageways.

4.3.1. Methods for Measuring Animal Crossing Events at the MRL Overpass

If wildlife fencing is successful in guiding animals away from I-90 and towards this underpass, researchers would expect to see an increase in deer crossings after mitigation. But, in order to determine the success of the mitigation, the influences of seasonal movement patterns on crossing rates needed to be determined. To estimate crossings of I-90 via the MRL overpass, CERI built a sand track bed on the north side of the railroad tracks under the MRL overpass (the track bed was constructed under MDT Encroachment Permit ID # is FAP I-1G90-6(2), maintenance number 2201 for route I-90: with an approved Right Of Entry Permit obtained from MRL on September 23, 2003). Paralleling the trajectory of the interstate, the track bed spanned roughly two-thirds of width of the passage under I-90 due to the angle of the railway as it crosses under the interstate; because of this configuration, it was not possible to completely "census" animal movements through this area, but rather, track bed observations provided an index of crossing activity.

The track bed was visited by CERI staff several times a month throughout the period of monitoring tracks. Tracks were identified to species or suite of species (e.g., "deer" tracks were generally recorded since it is not possible to distinguish white-tailed and mule deer tracks from one another) and the surface was raked clean after all tracks were documented.

4.3.2. Track Bed Data Analyses

While it would seem intuitive to divide the number of crossings (C_i) by the number of days in the interval (D_i), add up this figure across all intervals (I_i) and divide by the number of intervals that were recorded (Equation 1), this method presents two problems.

$$\frac{\sum \frac{C_i}{D_i}}{\sum I_i} \qquad \textbf{Equation 1}$$

First, persistence of tracks on the landscape is indeterminate. Although tracks are expected to accumulate steadily over the interval, it is also conceivable that older tracks would be obscured by newer tracks, rain, wind, freezes, thaws, snows, and snow plowing from the highway above. The second problem with differing interval lengths involves statistical methodology and ratio estimators. The method described above (Equation 1) consists of averaging ratios, which is a less-preferred and less-accurate method than creating a ratio of sums (Equation 2). The latter method consists of adding the total number of tracks observed and dividing by the total number of days over which the tracks accumulated.

$$\frac{\sum C_i}{\sum D_i} \qquad \textbf{Equation 2}$$

Note that there is no error around the estimate derived from equation 2, because the sum of crossings and sum of days are the total that was measured over the period of interest, be it yearly or seasonally. Because the objective was to compare how post-construction deer crossing rates may differ from the pre-construction crossing rates, researchers desired to establish a mean and variance around crossing rates.

Therefore, two approaches were attempted. The first approach involved truncating the data set to include only the data collected over 1-day units of measurement. This method was desirable because each day of sampling represented a measurement of the deer crossing rate for that day. Researchers had 86 of these samples of the true population parameter. Compiled over a time period of interest, the analysis can determine an average and associated variation in these daily crossing rates.

The objective of the second approach was to include more of the collected data. Researchers created a moving window, 31 calendar days in length, which used equation 2 to estimate daily deer crossing rates for the central record. For this method, both 1-day and 2-day long intervals were included. This approach also allowed the interpretation of the mean and variance in deer crossing rates for periods of interest, and it allowed the incorporation of more data. Upon preliminary analysis to determine if the dataset was appropriate for this approach, the moving window approach was disregarded for two reasons. First, the data set contained several gaps of 15-55 days in length. These gaps resulted in the over-representation of singular records, which made interpretation difficult. Secondly, this approach clouded seasonal differences because the window was one month long. Shorter intervals were inappropriate due to the size of gaps in the data.

If wildlife fencing is successful in guiding animals away from I-90 and towards this underpass, an increase in deer crossings after mitigation would be expected. But, in order to determine the success of the mitigation, the influences of seasonal movement patterns on crossing rates needs to be determined. To determine whether seasonal crossing rates differed, researchers divided the dataset of observations collected within 1 day of the previous tracking session by month and used Equation 2 to estimate crossing rates for each month. Based on these preliminary analyses, as well as *a priori* biological knowledge of the system, the data were divided into seasons and tested for differences using the negative binomial distribution because 1) the data were counts which could only be expressed in integer form, 2) Poisson goodness of fit tests indicated lack of fit because the variance in the counts was larger than the mean ($s2 > \bar{x}$) and 3) the negative binomial is a robust alternative to the Poisson for data sets with larger variance (i.e., over-dispersed Poisson; Zar 1999).

Researchers used the "glm.nb" function within data analysis software package R (2.2.1, R Core Development Team, 2005) to analyze two models, one including seasonal effects, and the other estimating a single, yearly crossing rate. The analysis used Aikaike's Information Criterion (AIC) as a model selection criterion (Burnham and Anderson 1998), and did not correct for small sample size because n = 86. Researchers could not perform a power analysis on these data because track data were distributed according to the negative binomial distribution, and there are no established methods for power analyses involving this distribution.

4.3.3. Pre-Mitigation Track Bed Data Summary

The track bed was visited on 234 days out of the 551-day sampling period between October 25, 2003 and April 12, 2005, when construction activities commenced at the site. An estimated 374 tracking-days were monitored through these 234 visits. Tracks of seventeen species were recorded during 234 observation sessions of the sand track bed under the MRL overpass (Table 10). The most frequently observed species using this underpass were deer, followed by rabbits (which inhabited the underpass), marmots and snakes.

Table 10. Number and types of species tracks observed crossing the track bed at the Montana Rail Link overpass between October, 29 2003 through April 12, 2005.

Species	Count	Species	Count
Bobcat	1	Marmot	24
Canid(unk)	5	Mouse	1
Cat	20	Rabbit	34
Deer	132	Raccoon	11
Dog	2	Skunk	5
Elk	2	Sm. Mammal	3
Felid (unk)	2	Snake	20
Fox	3	Weasel	4
Horse	1		

Visits occurred 1-11 days apart, with tracks presumably accumulating between visits. The bulk of the deer track data (86 records) were collected after roughly 24 hours of accumulation since the last visit. However, 27 records were collected after 2 days of accumulation, 19 records were collected after 3 days of accumulation, 6 records were collected after 4 days of accumulation, and 10 records were collected after 5-11 days of accumulation. The analysis found that the total number of track crossings counted decreased with the length of the interval (Figure 47).

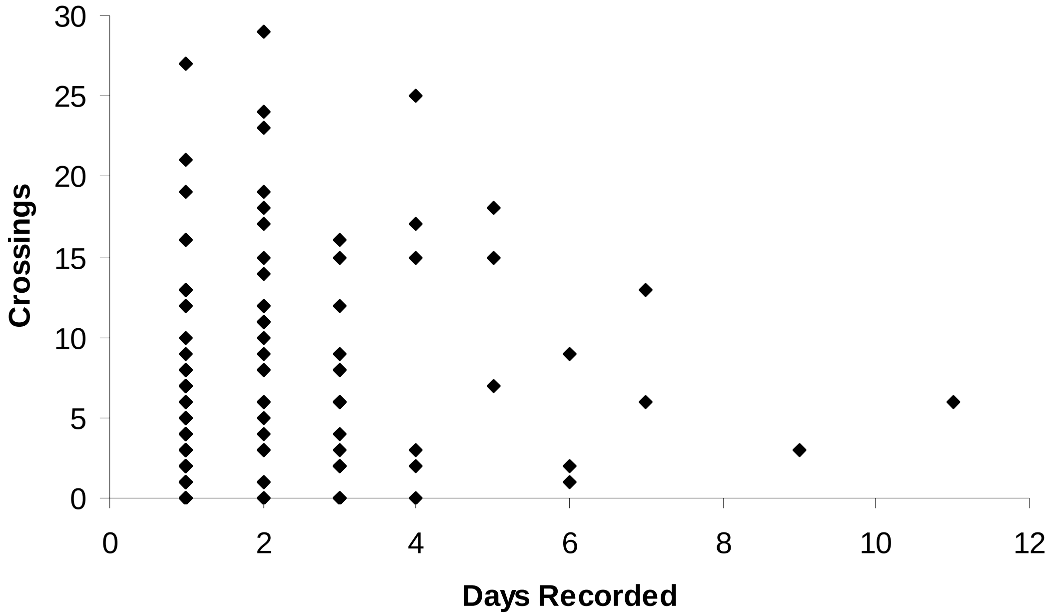

Figure 47. Number of deer tracks observed in the track bed observed under the Montana Rail Link overpass after a given number of days since the last track observation session.

Researchers chose to use only those raw data that were collected over an approximate 24 hour period to estimate an overall daily deer crossing rate. These 86 data records represent measurements of actual deer crossings that occurred in 1 day. Looking at the frequency distribution of these data, the cluster of observations at the low end of the scale (0-2 tracks per day) and the more sporadic and fewer observations on the right tail of the distribution of observations are indicative of a non-normal distribution (Figure 48). Poisson goodness of fit tests indicated lack of fit because the variance in the counts was larger than the mean ($s^2 > \bar{x}$), confirming that the negative binomial distribution was the appropriate distribution to use for analyses.

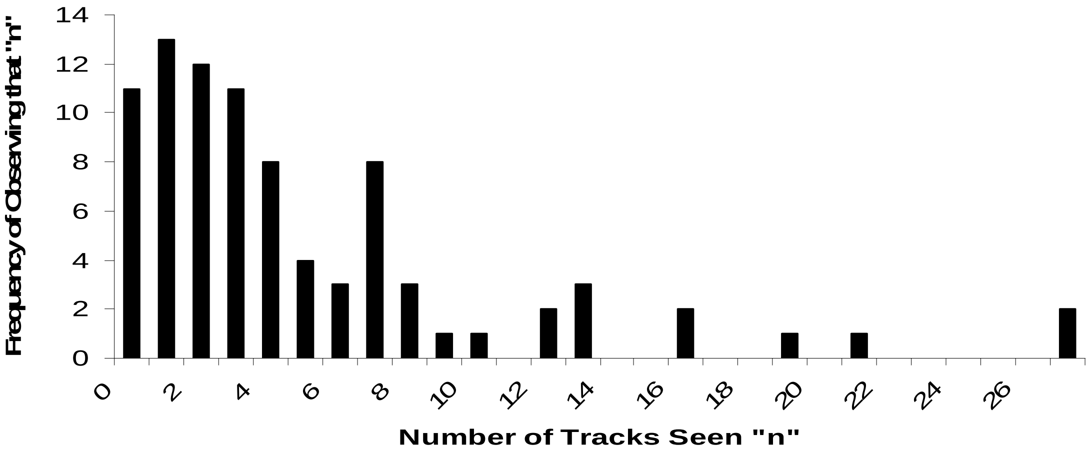

Figure 48. The frequency distribution of number of deer tracks (crossings) observed in the track bed below the Montana Rail Link Bridge in 86 observations of length = 24 hours.

There were three relatively clear changes in crossing rates (Figure 49), dividing the year into three seasons of 4 months apiece. Based on this histogram, as well as biological knowledge of the system, the deer track data were divided as follows ("n" representing the numbers of visits):

1) Winter = December through March (n = 21)
2) Summer = April through July (n = 25)
3) Fall = August through November (n = 40)

Note that the fall season completely overlaps all archery and rifle hunting seasons, as well as rut. These are factors that may alter deer movement behavior. The expected lull in winter season movements are well-represented by the relatively few track observations reported in December through March, and movements associated with spring thaw and "green-up" jumped beginning in late April.

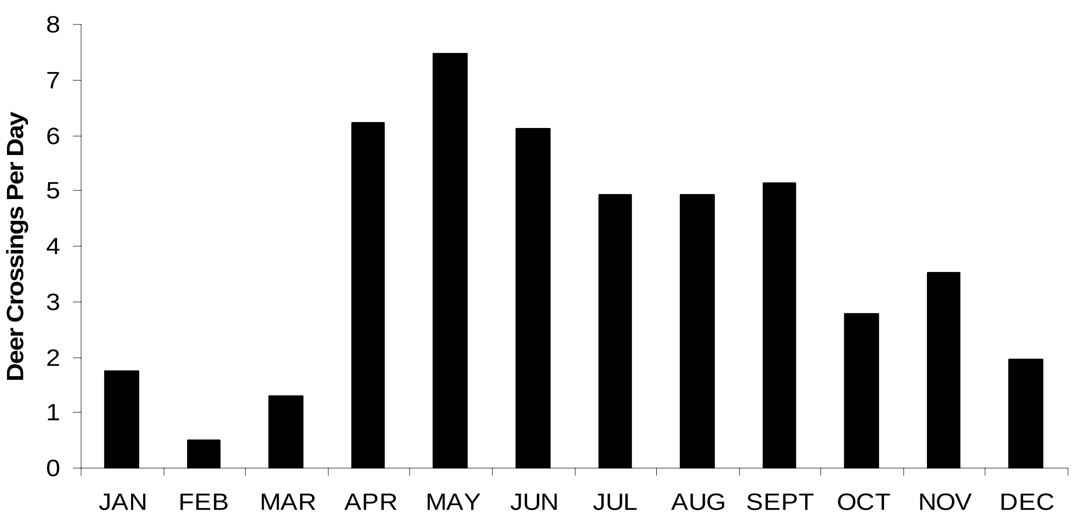

Figure 49. Seasonal distribution of deer crossings based on track bed observations at the MRL bridge.

Researchers tested whether there were significantly different crossing rates between these three seasons. First, they modeled the fit of a single negative binomial curve to the overall number of crossings. Second, a "season" covariate with three values (winter, summer, fall, as designated above) was used to model the effect of season on crossing rate. The AIC output for these two models indicated much higher support for interpreting seasons separately, with the one-season model 17.6 AIC units higher than the three-season model (note: relative to other AIC scores produced from the same dataset, lower AIC scores indicate better model performance and predictive abilities; Burnham and Anderson 1998). The coefficients on the season parameter were all significant at $P < 0.05$, with winter = 1.95 crossings per day (95% C.I. = 0.37, 3.53; n = 21), summer = 8.28 crossings per day (95% C.I. = 5.15, 11.41; n = 25), and fall (4.5 crossings per day; 95% C.I. = 3.19, 5.80; n = 40). Thus, crossings were more frequent in summer, less frequent in fall, and least frequent in winter (Figure 50).

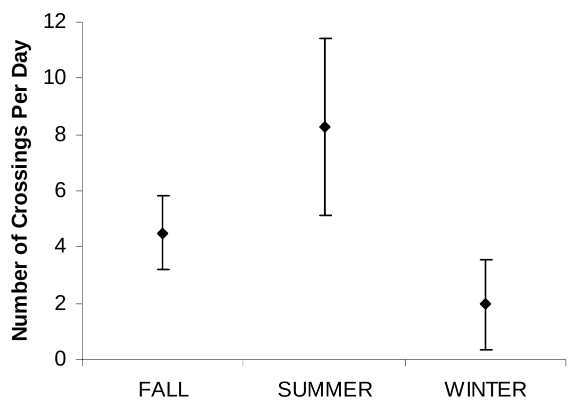

Figure 50. **The average and 95% confidence interval around the number of deer crossings that were observed in 1 day in winter, summer, and fall.**

4.3.4. Methods for Monitoring of Animal Culvert Crossings

Track bed information under the MRL overpass provided quantifiable estimates of crossing rates. CERI complemented these data with behavioral observation sessions, and photo-monitoring of the larger culverts in the vicinity of the MRL overpass. These data established baseline data of animal activity prior to mitigation that will be qualitatively compared to data collected using the similar methods after the mitigation is installed.

Remote motion- and heat-sensing cameras were installed at 5 locations in the MRL overpass area. Four cameras were positioned in or adjacent to 3 double-culverts along Rocky Creek that passed under I-90 at mile markers 314.6, 314.8, and 315 (a camera inside the culvert at mile marker 315 was stolen in July 2004 and subsequently replaced in a less conspicuous location outside the culvert). A fifth camera was added below the Montana Rail Link Bridge to further verify activity through that area (in addition to the track bed).

4.3.5. Pre-Mitigation Animal Culvert Crossings Data Summary

Some photo-monitoring at culverts near the MRL overpass was initiated in 1998 by CERI prior to this study effort. The eastern culvert at mile marker 314.6 was monitored from February 19, 1998 until January 23, 2005. The western culvert at mile marker 314.6 was monitored from January 1, 1998 until July 22, 2004. The eastern culvert at mile marker 314.8 was monitored from January 14, 2002 until November 21, 2005, but the western culvert was not monitored because it was full of water. The western culvert at mile marker 315 was monitored over July 21, 2003 until July 17, 2005 because the eastern one was full of water. The 315 culvert had a camera stolen in July 2004, whereupon it was moved and hidden outside the culvert, after which it did not work as well. In August 17, 2004, a camera was added below the Montana Rail Link bridge, where it was maintained until May 4, 2005.

The total number of animals detected in photos is summarized in Table 11. These data account for each individual seen in each photograph. If one individual was seen in a photo, it contributed 1 to the encounter total. If 3 individuals were seen in one photo, this contributed 3 to the encounter total. Raccoons, mink, humans, ducks, deer and rabbits were the only species where photographs held more than 1 individual. These data are suitable only to assess species presence.

Table 11. Photo encounters of species moving under I-90 via 4 large culverts near the MRL overpass and the MRL underpass near and the track bed under the MRL underpass on Bozeman Pass between 1998 and 2005 (photo-monitoring periods varied for each camera and location).

SPECIES:	314.6 EAST	314.6 WEST	314.8 EAST	315 WEST	TRACK BED
Beaver	5		3		
Bird	9		2	9	
Black Bear		1	3	3	
Deer				0	13
Domestic Dog	4	2	3	1	
Duck		1	2	0	
Frog		1		0	
Great Blue Heron				1	
Human	8		19	32	16
Long-Tailed Weasel			5	0	
Marmot			17	0	
Medium Mammal (unknown species)	4			0	
Mink			87	0	
Mouse			3	0	
Muskrat			1	0	
Mustelid	7			0	
Nest	3			0	
No Data	161	60	253	172	315
Pigeons				0	14
Porcupine				1	
Rabbit			107	0	
Raccoon	82	1	112	5	
River Otter			1	2	
Train				0	28
Uncertain species	4			1	

4.4. Measures of Effectiveness

Effectiveness relates to a "desired outcome" based on values. When considering the effectiveness of investments to maintain habitat connectivity, for example, there may be multiple "effective" outcomes based on biological, social, economic, political or safety values (Table 12; Servheen 2006). Because individuals and agencies may have different values, presenting the results with no judgments of the outcomes allows assessments of effectiveness based on individual values. At the same time, setting reasonable, measurable, and defendable targets defining desirable outcomes will help guide management decisions.

Table 12: Possible "effective" outcomes of management actions to maintain wildlife linkage zones (i.e., habitat connectivity corridors) where wildlife move across landscapes between core areas of habitat (Servheen 2006).

Biological	• Wildlife movement across the landscape; • Gene flow; • Dispersal success; • Female movement; • Access to resources; • Reduction of wildlife mortality; • Reduction of wildlife-human conflicts in linkage areas
Economic	• Improved efficiency in project planning; • Road or bridge designs that don't have to be rebuilt for wildlife needs; • Minimal environmental review and court challenge; • Reduced safety liability risk due to highway design and planned wildlife crossing/fencing in likely wildlife crossing areas; • Property value increases due to perceived value of adjacency to wildlife linkage areas
Public Safety	• Reductions in AVCs
Social	• "Buy in" by local people to build support for concept of mitigation measures; • Acceptance of linkage by local public/political interest; • Involvement of local people in refinement of linkage area locations; • Involvement of local people in linkage area management design
Political	• Support for linkage planning by mgmt in budget and personnel decisions by DOT; • County planning board considerations of wildlife linkage in long-term planning and subdivision approval considerations; • Congressional support for linkage area identification, management, monitoring, and evaluation in federal agency budgets; • County commissioner support for linage planning and implementations

Assessing effectiveness involves determining if there is an *effect* that may be attributable to a specific change (e.g., the installation of wildlife fencing). *Effect* in this context refers to a change that may be measured statistically and/or biologically. A statistical *effect* (e.g., a detectable reduction of deer-vehicle collisions by 35%) may not be considered *effective* (e.g., by parties wanting to see a reduction by 50% or greater). A statistically detectable effect may or may not be biologically significant; i.e., just because a change was measured does not necessarily mean it will have biological impacts on the population or community of interest. Conversely, it is possible to have biologically significant effects or changes within the population of interest that are not statistically detectable, an unfortunate outcome for imperiled populations if managers do not recognize the potential for this outcome.

Many factors influence whether actual effects may be statistically detectable. With large sample sizes, applied statistics may detect significant effects to a fraction of a percent – an effect size that may be too small to be biologically significant. On the other hand, in cases with small sample sizes (i.e., rare or elusive species), a statistical effect may only be determined after very large changes, and a statistically insignificant change may be very biologically significant (Taylor and Gerodette 1993). As more data is amassed, variability in the dataset may decrease, which increases the ability to detect statistical differences in the response variable.

Additionally, time will likely affect the outcomes observed as animals adjust their navigation patterns to a landscape with wildlife fencing. Hence, determinations of effectiveness may change as time passes, animals adapt to their new setting, and more data is acquired. It is advisable to mention this caveat if presenting outcomes prior to the completion of an evaluation study.

Even if an effect is measured, it can not be considered "proof" of a simple "cause and effect" relationship (Neter et al. 1996). Other variables such as population fluxes, unusual weather events, increases in traffic volumes or changes in observed speeds may influence the response variable of interest. In the case of 2005 AVC data from Bozeman Pass, the number of reported AVCs appear to decrease dramatically on the west side of the Pass, indicating some change in the environment; further investigation reveals that I-90 traffic was slowed and rerouted to a two-lane configuration in the construction zone where the MRL bridge was being replaced. Presumably, the change in traffic patterns contributed to the observed decrease in reported AVCs. Additionally, the construction site itself may have displaced wildlife such that they are not crossing I-90 in that area, and therefore are not being hit, because of the disturbance. These variables and others need to be considered when analyzing data and drawing inferences regarding effectiveness of any management action.

In the context of the Bozeman Pass wildlife fencing evaluation, potential *effects* pertain to measurable changes in UVCs and wildlife movements across the highway. Statistically detectable effects for these parameters were estimated based on analyses of the pre-fencing dataset; those results were presented in detail in the previous sections of this chapter. In terms of potentially significant biological effects, there were no imperiled wildlife populations (that biologists were aware of) in the immediate vicinity of the area to be fenced (Craig Jourdonnais, FWP Wildlife Biologist, pers. comm.). Therefore there was no need to define specific targets for biological effectiveness.

MDT, FWP and American Wildlands agreed to meet with WTI and CERI annually to discuss the available data, analyses, and effectiveness of the fencing in reducing UVCs and allowing movements under I-90 via the MRL bridge. Limitations of the datasets and factors that may have influenced the outcomes will be considered. If the group feels there is adequate evidence to determine if the fencing is effective, the group will document their determination of effectiveness and recommended management changes, if necessary (see Adaptive Management Options, below). These discussions will be documented to track decisions and to illustrate if or how time and additional data may affect results and determinations of effectiveness. The following subsections describe the approach that will be used to define *effectiveness* for the parameters of interest.

4.4.1. Effectiveness Relative to Ungulate-Vehicle Collisions

All animal-vehicle collisions will be reported and summarized. However, determinations of effectiveness will be based on changes in ungulate-vehicle collisions. UVCs composed the majority of the pre-fencing reported road kill and because of their relatively large size, are likely to have the greatest impact on driver safety. Additionally, this subset of data has the highest statistical power to detect changes.

Post-fencing UVC data will be compared to pre-fencing UVC data annually to determine if there have been statistically-detectable changes in UVCs since the installation of the fencing. The cumulative UVC dataset (i.e., one year of data will be analyzed after the first year, the second year analyses will include both the first and second years of data, third year will include all three years of data) will be analyzed for the following subsets of data:

- within the fenced area;
- 0.2 miles immediately outside the fenced area;
- within the fenced area and 0.2 miles immediately outside the fence; and
- within the 10-mile post-fencing road kill monitoring study area (mile marker 309-319).

Any detectable reduction in UVCs in these areas may be considered an effective outcome (assuming a reduction in one area is not offset by an increase in UVCs of equal or greater magnitude in the other areas). If there is a detectable increase in UVCs, the group will consider adaptations to remedy the situation (see Adaptive Management Options, below). If there are no statistically detectable changes, the group will assess the available information qualitatively to arrive at a determination of effectiveness.

4.4.2. Effectiveness Relative to Animal Movements Across I-90

Estimated numbers of individual species moving under the MRL bridge and around the ends of the fences will be compared to pre-fencing movement data to determine effectiveness. Because the capability to statistically detect changes in wildlife movements is unknown, the group will consider the data quantitatively and qualitatively, in addition to limitations of the data, and other factors that may affect wildlife movements, to determine effectiveness. Movement or a potential increase in movements compared to the pre-fencing movements under the MRL bridge will be considered effective.

4.4.3. Adaptive Management Options

If the group determines at any point that there is an increase in UVCs or lack of wildlife movement under the MRL bridge, several options may be considered to address the problem. Depending on the situation and available resources, the following adaptations may be applied:

- <u>Signing</u>: per recommendations in Chapter 6, the permanent or a portable DMS, or permanent static signs with enhanced features may be used to broadcast wildlife advisory messages to drivers about wildlife moving across the road.
- <u>Landscaping</u>: Creating a natural path or planting native vegetation that provides cover and possibly attracts wildlife to encourage animal movements at the MRL bridge.
- <u>Fencing</u>: Removal, extension, scaling back, or moving fences.
- <u>Animal detection systems at fence ends</u>: systems to detect movements around the ends of the fences and then dynamically warn drivers precisely when such an event has occurred may be considered if the 0.2 mile stretch on either side of the fence ends appears to be incurring more UVCs after the fence is installed.

With any adaptive management action, it is recommended that monitoring continue for an appropriate period (minimum of one year) to assess whether the change produced the desired effect. Depending on the type of management change being assessed and the variability in the response variable, it may take several years to understand how the changes affected the system.

5. MAINTENANCE OPERATIONS IMPACTS

Highway maintenance operations typically remove and dispose of road killed carcasses. Additionally, maintenance operations often play a role, if not the lead role, in the installation and maintenance of AVC mitigation measures in the field. While this may not seem like an obvious or significant drain of resources on a day-to-day basis, the cumulative impact of AVCs on maintenance is likely an unacknowledged burden on budgets and diverts labor from the multitude of other issues that maintenance is tasked with addressing. Depending on the magnitude of the problem or the types of mitigation measures that they may have to service, maintenance operations may be putting significant resources toward this issue, possibly at the expense of other maintenance needs.

5.1. Maintenance Operations Survey

To better understand how and to what degree the Montana Department of Transportation's (MDT) Maintenance Operations are impacted by AVCs, WTI, with the assistance of the MDT Maintenance Division at Headquarters in Helena, developed and delivered a survey consisting of 16 open-ended questions to Maintenance Chiefs in all ten maintenance divisions in the state in August 2005 (see Appendix D: MDT Maintenance Survey Regarding Animal-Vehicle Collisions and Carcass Removal Practices). Survey questions sought to qualitatively characterize the approaches, issues, expenses, and challenges related to road killed carcass removal in the various divisions. Twelve surveys were completed by 14 individuals and returned by October 2005. We summarized the responses to assess trade-offs between the burden of carcass removal and disposal versus the time and effort put into the maintenance of mitigation measures, and whether mitigation investments alleviate some of the hardship of carcass removal and disposal.

5.2. Results of Survey

All respondents indicated that their staff opportunistically removed carcasses from the roads in their respective divisions during routine road inspections or when other entities (e.g., Highway Patrol; Fish, Wildlife and Park; citizens; state employees) informed MDT of road killed animals. Routine road inspections reportedly occurred at least once a week on Mondays, and in many cases, on several days or daily during the work week, depending on the roadway, traffic volumes, and other on-going efforts in the division. Each carcass removed was reported on an "animal incident report"; these reports are compiled at MDT Headquarters' in the Safety Management Section.

The animal incident report records basic information such as date of occurrence, route, location on route, species of animal, and, if discernable, sex and approximate age of animal. There were varied responses regarding species of carcasses reported from one division to another; given the range of eco-regions and habitat types found in Montana, this would be expected. Not surprisingly, deer was the most commonly reported response, followed by elk and bear, then antelope, moose, and domestic animal (e.g., horses and cows), and in one case, one respondent mentioned removing and reporting mountain goats and mountain lions. Smaller animals such as birds, porcupine, raccoons, coyote, and skunks were also mentioned, with some divisions reportedly documenting these on the animal incident report while other divisions did not report smaller animals.

When possible, carcasses were simply moved out of site on the highway right-of-way. Some divisions reported carcasses that were moved but not removed from the right-of-way and disposed of elsewhere, while other divisions did not report these carcasses. Ten of 12 respondents indicated that the location of the animal carcass was recorded to the nearest tenth of a mile. Two respondents said they reported the location to the nearest “milepost” or “mile marker”.

When asked, on average, how many carcasses were removed from the roads in their respective divisions annually, some respondents did not provide an estimate but referred to Safety Management Section. Of the respondents that did guess at an average annual number, guesses ranged from 100 to 2500 carcasses reported annually, on average. One chief declined to estimate an annual average, but instead mentioned, “…34 animals picked in a two-week period”. These estimates were not scaled to the miles of highway and interstate within each division.

Most respondents reported seeing seasonal peaks in the numbers of carcasses removed. Fall was the most common response, often identified in combination with another peak in spring. Only one reported the peak occurring in the spring alone in their division. It was suggested that Safety Management Section be consulted with regards to identifying seasonal peaks.

Most were generally aware of stretches of roads that had more carcasses than others. One person indicated that “all areas” have deer hits. A few respondents mentioned particular sections of highway, while others said to contact Safety Management Section for specific stretches with higher than average reported carcasses. Many associated interstates and higher traffic volume highways as having more carcasses compared to lower volume highway routes. Some anecdotally suggested that higher numbers of road kills occurred in association with “vegetated areas” or “areas of migration”. One relayed that the extended drought may be resulting in more AVCs because often the only green grass there may be is found along the roadsides which likely attracts animals and creates conflicts between drivers and animals.

Several different carcass disposal locations were reported. If it was necessary to remove a carcass from the road and right-of-way, most reported disposing the carcasses at local landfills or in dumpsters. One division mentioned dumping carcasses away from public residences on Forest Service or Plum Creek lands. In Missoula, the local rendering plant receives carcasses. A carcass composting site was recently created by MDT specifically for dumping carcasses as well.

While five respondents reportedly did not pay for carcass disposal, others reported costs associated with disposing of carcasses. Some dumpster services charged an annual fee (no value reported). Landfills charged by the ton ($51.35/ton) or by the carcass, ranging from “one to five dollars or more per carcass”, seven dollars a carcass, or a fee depending on the animal (e.g., $75 for a horse carcass). The rendering plant charged a flat fee of $125/month for carcass disposals.

Half the divisions reported no injuries as a result of carcass removal duties, and one of these divisions mentioned sending out two workers for carcass removals to help avoid injuries. The other half of the divisions mentioned back, shoulder or hip injuries, or muscle strains; fortunately, most injuries were reported as minor and typically little or no work time was lost due to injuries. It was suggested we contact Mike Buckley in the Organizational Development Bureau, Employee Safety Section for accurate data on such injuries.

It was difficult for most respondents to quantify their division’s total expenses associated with carcass issues (i.e., labor time, costs of injuries or worker’s compensation claims, disposal fees) because this activity is carried out as part of normal roadway inspections and is not distinguished from the multitude of other activities that occur during these inspections. Some mentioned that this activity was tracked in MDT's Maintenance Management System under cost code 1203, but this code covered other debris removals, not only animal carcass removals, making it challenging to put a figure on this activity. For those that ventured a guess, estimates were generalized as, "at least 2 hours per day per crew" were dedicated to carcass disposal. Some provided estimates such as, "$100,000-$150,000 per year," amounting to "2-3% of salaries and equipment expenses". Another guessed salaries, equipment and disposal costs totaling $100,000 or 1% of the division's total budget. One respondent provide specific figures, as follows:

> "In FY 2005 a total of 2437 hours ($61,537.83) and $16,472.12 in equipment was charged to MMS activity 1203 (Debris removal). If half of that were attributed to animal removal, a **guess** would be 1218.5 hours at $30,768.92 in manpower and $8,236.06 in equipment charges for a total of $39,000.98 for FY 2005. "

Respondents indicated that they do not budget specifically for this particular activity.

Regarding mitigation measures that may be deployed in the divisions, most mentioned using signs in higher-risk areas. The wildlife fencing and crossing mitigation efforts on US93 (both north and south of Missoula) were cited, and three respondents referred to other wildlife fencing efforts, either in place or planned, as well. The animal-detection/driver warning system on US 191 in Yellowstone National Park was also mentioned. When asked how much effort is required by their crews to maintain these measures, all divisions said that it required little time or effort to maintain signs, depending on what or how many signs needed replacing on an annual basis, but we did not get any feedback specific to maintaining fencing or the animal-detection system, likely due to the fact that these measures are relatively new or planned. No division was aware of any actual reductions in AVC rates as a result of signing or other mitigation measures.

5.3. Discussion of Maintenance Operations Impacts

Overall, responses from this survey qualitatively implied that carcass removal activities and expenses in the maintenance divisions are incorporated into the daily duties and, although there is no specific budget for this task, it did not appear to be imposing significant burden on operations. Mitigation investments appear to be minimal in most divisions, so it was not apparent if the expense and effort of installing and maintaining these features obligated significant resources. There were no indications of observed decreases in AVCs as a result of the measures that were deployed (signs, fencing); however there are efforts occurring at several of the mitigation sites (where fencing and crossing passages have been or are planned to be installed, and at the animal-detection/driver warning system site) to evaluate the effect that these investments may be having on the AVC rates, as well as animal movements across the landscapes.

More time and experience with mitigation deployments and on-going maintenance, plus time to evaluate the effectiveness of these measures, may be needed to adequately assess the "trade-offs" of carcass removal tasks versus the investment required for maintaining mitigation. Alternatively, further analyses of the carcass removal data, as well as Montana Highway Patrol reports of AVCs, compiled in the Safety Section may provide useful insights that could expand on the qualitative results from this survey.

6. CONCLUSIONS AND RECOMMENDATIONS

Results are summarized below including recommendations based on outcomes from the different components of this study. A final synthesis of the efforts to reduce wildlife-vehicle conflicts in the Bozeman Pass transportation and wildlife movement corridors is provided at the end of this end.

6.1. Field Study Conclusions and Recommendations

Warning signs are intended to call the attention of drivers to unexpected conditions and situations that may not be readily apparent to road users, usually with the intention of raising driver awareness and lowering speeds. The field study determined that wildlife advisory messages posted on permanent and portable DMSs can reduce motorist speeds and indicated that drivers likely had heightened awareness due to the wildlife advisories, thus reducing the safe stopping sight distance of motorists, with the most significant reductions observed during "dark" conditions when the likelihood of AVCs is highest. Given that the occurrence or avoidance of an animal-vehicle collision may be determined within a fraction of a second, the judicious use of DMS to warn drivers of animal-vehicle collision has the potential to reduce speeds and increase driver awareness, ultimately giving the driver that extra fraction of a second to respond in order to avoid a collision with an animal.

Based on these results, as well as the driver simulator study results (summarized in the following subsection; see also Chapter 3 and Stanley et al., 2006) and the literature, it can be inferred that enhanced animal advisory signs can affect driver behavior with the potential of reducing animal-vehicle collisions. However, overuse or inappropriate use of such signs may result in drivers becoming complacent to the importance of these signs. The following recommendation refore we recommend that enhanced animal advisory signs be used sparingly in the following conditions:

- If using DMS to deliver animal advisory messages, follow guidelines on message construction. See Dudek and Ullman (2001) and Dudek (2002);
- If using enhanced standard signs, use larger-than-typical formats and consider including flashing lights, bright flagging, and reflective backing;
- Apply signs only where there is documentation of concentrated animal movements or AVCs, understanding that driver responses will be greatest only a short distance (0.3-0.6 miles; 0.5 to 1.0 km) after passing the signs (Al-Ghamdi and AlGadhi, 2004). Enhanced signs may be used alone in high-risk areas or in conjunction with other mitigation measures, such as at the ends of animal fencing where clusters of animal movements and AVCs may occur;
- Apply or activate signs when animal movements and AVCs peak, typically at night during the fall months. Examine data on animal movements and AVCs to confirm when the risk of an AVC is highest at the site in question. Remove enhanced signs when this peak period of high-risk has passed;
- Consider the characteristics of the driving population, favoring areas where local motorists may be more aware of AVCs and animal movements; and
- Consider applying enhanced signs in conjunction with education outreach and/or public relations campaigns advising drivers of the risks of AVCs.

In addition to the above recommendations, we encourage agencies to employ monitoring programs to assess how well enhanced signs may be reducing speeds and/or AVCs. Driver surveys may also provide useful insight that may allow for adaptive management of the use of these signs.

6.2. Driver Simulator Study Conclusions and Recommendations

To summarize, all enhanced signs decreased speed, increased the onset of braking distance (i.e. increased reaction time), and reduced the number of collisions with deer compared to the standard wildlife warning sign. Subjects were also more likely to see the enhanced wildlife crossing advisory signs than the standard sign. Given that standard signs are ubiquitous, and presumably, it is rare for drivers to witness animals crossing the road shortly after seeing these signs, it is not surprising to see these results indicating that standard signs have little effect on driving behavior or awareness.

The group exposed to the combination treatment of the DMS and flashing beacon sign demonstrated the greatest increase in the onset of braking distance, the lowest number of collisions, and the highest instance of wildlife advisory sign observations. These results are similar to the speed study and field survey results which indicated that drivers responses waned over time but drivers exposed to two DMS were more apt to correctly recall the messages than drivers that only saw one DMS.

In conclusion, in conjunction with the speed study recommendations regarding seasonal use and placement of enhanced signs (see previous subsection), we recommend considering the use of multiple enhanced animal advisory signs to increase driver awareness and potentially decrease speeds in hopes of reducing animal-vehicle collisions. Additionally, further driver simulator studies would be useful in exploring what types, combinations of, and appropriate distances between enhanced signs maximize driver awareness and speed reductions.

6.3. Post-Mitigation Conclusions and Recommendations for Wildlife Monitoring

The monthly total UVCs across Bozeman Pass indicated that June-July and September-November had higher rates for UVCs than other months. June and July occur shortly after the spring birth pulse, and the inflated rates may be due to naïveté of new fawns as well as their slower movements. Note also that September through November correlates to the rut (breeding season) and bow and rifle hunting seasons in Montana, and hunting pressures could cause additional deer movements, resulting in higher kill rates. Continued AVC monitoring is recommended throughout the year to encompass seasonal variation in kill rates.

Power analyses indicated that three to five years of post-construction research would be the optimal level for increasing researchers' ability to statistically differentiate pre- and post-fencing UVC rates. The estimated minimum detectable difference in the areas to be fenced ranged from 36-27% ($\alpha = 0.05$) given three to five years of post-fencing monitoring, compared to a minimum detectable difference of 50% if post-fencing monitoring were to be carried out for only two years. Three to five years of post-construction study would allow detection of a 31-19% decline in UVCs across the area to be fenced plus a 0.2 mile buffer extending from the ends of the fence. More than 5 years of post-construction data would not result in significant gains in the ability to detect a difference in UVCs. Two-sample t-tests have maximum power and robustness when sample sizes are equal (Zar 1999), therefore four years of post-construction survey would be useful in evaluating pre- and post- mitigation differences in UVCs.

Attention must be given to the seasonal differences in crossing rates under the MRL bridge when future data are collected. It is suggested that the fall, summer and winter seasons be interpreted separately for because of the high variability observed in the pre-fencing data when pooling all seasons together; the differences the observations of animal movements between seasons allows for more precise assessment of changes in pre- and post-fencing movements within seasons.

Although researchers were unable to do a power analysis for these data (because the data were not normally distributed), a simple ANOVA for pre- and post-fencing data by season will elucidate the degree of changes that may have occurred. The number of days sampled pre- and post-construction be equal to provide better power to detect differences (Zar 1999), if there was a change in pre- and post-fencing movements under the MRL bridge.

Post-fencing monitoring of animal crossings at the MRL underpass should occur over intervals not exceeding one day. For this analysis, data accumulated over longer intervals provided questionable observations when considering that more animals may pass over more days between recording track observations but, simultaneously, the loss of data from the track beds due to longer exposure to weather and other elements confounds these data. A recommended sampling schedule could include visiting the track bed 5 days in a row (i.e., rake on day 0, monitor for day 1, day 2, day 3 and day 4) every 2 weeks to provide a slightly larger sample size than what was collected prior to the installation of the fence (~35 days per season) while not increasing survey effort dramatically.

Interpretation of the pre-mitigation culvert photo data was limited to determining species presence. Researchers recommend that photo monitoring continue similar to preconstruction methods to qualitatively assess changes in species presence; alternatively, cameras may be better applied at the fence ends to quantify numbers and species moving around the fence ends.

Post-fencing UVC data will be compared to pre-fencing UVC data annually to determine if there were changes in UVC rates within the fenced area; 0.2 miles immediately outside the fenced area; within the fenced area and 0.2 miles immediately outside the fence; and within the 10-mile post-fencing road kill monitoring study area (mile markers 309-319). Any detectable reduction in UVCs in these areas may be considered an effective outcome assuming a reduction in one area is not offset by an increase in UVCs of equal or greater magnitude in the other areas.

Estimated numbers of individual species moving under the MRL bridge and around the ends of the fences will be compared to pre-fencing movement data to determine effectiveness. Because the capability to statistically detect changes in wildlife movements is unknown, effectiveness may be determined quantitatively or qualitatively, depending on the limitations of the data, and other factors that may affect wildlife movements. Movement or a potential increase in movements compared to the pre-fencing movements under the MRL bridge will be considered effective.

MDT, FWP, American Wildlands, WTI and CERI will meet to discuss these data annually. If it appears there may be issues with the fencing that require attention (e.g., increases in UVC rates or no wildlife movements under the MRL bridge), this group will consider adaptive management options including the use of additional signing or DMS advisory messages; landscaping a natural path or planting native vegetation to encourage animal movements at the MRL bridge; removing, extending, reducing, moving the fencing; or installing systems that detect animals moving around the ends of the fences and then dynamically warn drivers at the time such events occur. Discussions from these annual meetings will be documented over time to explore how time and additional data affect observed outcomes.

6.4. Maintenance Operations Impacts Conclusions and Recommendations

Maintenance operations opportunistically remove, dispose of and report animal carcasses from the roadways in their divisions. Reporting appears to vary somewhat from division to division; e.g., some divisions report all animal carcasses observed, while others may not report domestic animal carcasses or carcasses that were moved but not removed and disposed of outside of the right-of-way, or there were a few divisions that reported carcass locations to the nearest mile marker while most divisions reported locations to the nearest tenth of a mile. Effort and expenses associated with these duties is challenging to quantify because this task is lumped with other “debris removal” activities associated with routine road inspections; however some divisions estimated that these duties may comprise 1-3% of their division’s annual budget. It is recommended that activities associated specifically with carcass removal and disposal be tracked by creating a unique category in MDT’s Maintenance Management System. This would both raise awareness of the importance of this issue and allow managers to quantify the time and effort dedicated to these activities more easily and accurately.

Signs are currently the main mitigation measure used in most if not all divisions, but several mentioned there were AVC mitigation measures (e.g., wildlife fencing with underpasses on US 93 south and north of Missoula, an overpass on US 93 north of Missoula and on MT 83 near Clearwater Junction) planned for their divisions. Maintaining different mitigation measures may be relatively new to most divisions, however, and more time may be needed to do a quantitative assessment of the impacts of these installations on operations. At this time, it is not clear how much effort will be required to maintain other mitigation techniques such as wildlife fencing and crossings or animal-detection systems, nor is it apparent how well the mitigation may perform. Hence, assessment of the trade-offs of proactive investments in mitigation measures and associated on-going maintenance versus the time and expense for removing and disposing carcasses may be premature given the relatively new or planned mitigation installations.

This qualitative survey did not result in as much detailed information as was originally hoped. However, responses indicate that the maintenance chiefs do not necessarily compile and synthesize data on carcass removals or time spent maintaining mitigation; instead this information is compiled at Headquarters. Researchers recommend working with Headquarters staff to gather more information to better quantify the time and fiscal expenditures associated with carcass removals and maintaining mitigation measures.

The maintenance operations impacts survey was initiated in association with the Bozeman Pass Wildlife Channelization ITS Project with the hopes of weighing the expense and effort involved in posting seasonal wildlife advisories messages the permanent and portable DMS against the potential for reducing AVCs, to assess if the “payoff” may be worth the investment. Although researchers were not able to relate how the observed speed reduction affected actual AVC rates, the fact that the DMS messages induced a speed reduction during dark conditions implies that there is the potential to reduce AVCs. If the investment of time to post seasonal DMS wildlife advisories is relatively minimal, and drivers respond to the messages either by reducing speed, increasing awareness or both, there may be a "payoff" in terms of fewer carcasses to remove and report over the years.

6.5. Synthesis of Conclusions and Recommendations

The occurrence of an AVC is a complex interaction of ecological variables, human and animal behavior, and roadway design and placement. Mitigation techniques of AVCs may target animal behavior or driver behavior. This study examined how drivers responded to seasonal animal advisories delivered on DMS in the field; additionally, driver responses to such messages on DMS and other enhanced signs compared to the standard wildlife crossing sign were assessed in a simulated environment.

Results of both efforts indicated that drivers reduce speeds and increase awareness when exposed to unique animal advisory messages (i.e., when delivered via enhanced signs or DMS versus the standard wildlife crossing sign). Responses are temporary, but it appears that if the signs are appropriately placed relative to the area of concern, that drivers may alter their behavior to provide additional response time to avoid a collision with an animal. Careful application of such signs in terms of location, message, the type and design of sign, and the duration that the sign is seen by drivers likely affects drivers' responses to the messages. Further study of driver responses to these variables in a simulated environment may provide additional insights that could be experimentally tested in the field.

Finally, maintenance operations impacts in terms of time and funds used for carcass removal and disposal versus proactive investment in mitigation measures and the time and funds required for installation and maintenance of mitigation measures are not apparent when querying maintenance chiefs in the divisions around the state. However, additional information may be available from Headquarters to quantify these tradeoffs and operations may need time to gain more experience with the mitigation measures (beyond static sign installations) in their divisions to better quantify their commitment of time toward deploying and maintaining mitigation infrastructure. In the mean time, if divisions have DMS and/or enhanced signs available for seasonal animal advisories, documentation of the effort to deploy these measures and long term monitoring of AVC rates and carcass removals at these sites before and after the deployments (i.e., a meta-analysis across all deployment sites in the state to increase statistical power to detect changes in AVC rates and carcass reporting) could help quantify these tradeoffs, while proactively increasing the potential for drivers to reduce speeds, increase awareness and ultimately respond faster to avoid a collision with an animal.

Efforts to reduce AVCs on Bozeman Pass will continue with the evaluation of the wildlife fencing that will be installed at the vicinity of the Montana Rail Link bridge underpass (installation is anticipated at the conclusion of the bridge reconstruction project in the fall of 2006). Monitoring of wildlife movements and AVCs in this area will continue for at least two years after the fencing is installed. In the event that the fencing is not performing as desired, there are several adaptive management options that may be applied, including the use of DMS or other Intelligent Transportation System technologies such as animal detection systems at the ends of the fences that dynamically warn drivers of animals moving across the road as the crossing occurs.

In closing, this project addressed a unique research question regarding driver responses to wildlife advisories delivered via non-traditional sign applications. The use of DMS to disseminate messages cautioning drivers about wildlife in the area appears to be a relatively inexpensive tool with good potential to increase driver awareness and decrease speeds if applied thoughtfully with respect to when and where drivers are most likely to encounter wildlife. This increased awareness or decreased speeds has not been directly correlated with reduced AVCs; long-term research is required to address this specific question. However, it can be inferred that more attentive drivers that slow down and watch for wildlife are more likely to be able to respond to an animal crossing the road to avoid a collision than an a driver that is unaware of the potential for encountering wildlife. In addition to modifying driver behavior, this study also provided significant support for the on-going efforts to evaluate methods to modify wildlife movements using wildlife fencing to limit at-grade crossings and encourage wildlife to move under the interstate. Future results from that effort will be incorporated with the results of this study and a final, inclusive report detailing all the efforts to increase driver safety and decrease wildlife mortality on Bozeman Pass will be made available at the conclusion of the wildlife fencing evaluation study.

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8. APPENDIX A: PUBLIC OUTREACH CAMPAIGN MATERIALS

Bozeman Pass "Driving with Wildlife in Mind" Fact Sheet

Where is Bozeman Pass?

Located in Southwest Montana, Bozeman Pass is a mountain pass separating Bozeman and Livingston.

Why is Bozeman Pass important for wildlife?

Bozeman Pass lies in between the Gallatin, Bridger and Bangtail Mountains in the Greater Yellowstone Ecosystem. These mountain ranges are home to many different kinds of wildlife. Wildlife use Bozeman Pass as a way to move between the mountain ranges and due to its high quality habitat. Numerous wildlife species reside or move through the Bozeman Pass area: including: elk, deer, moose, black bear, coyote, mountain lion, fox and wolf.

What is a wildlife corridor?

Wide-ranging wildlife species need secure core habitat where human activity is limited, ecosystem functions are still intact and wildlife populations are able to flourish. Many more species of wildlife core areas are not large enough for long-term health and they must move from one core area to another. Corridors are areas that connect these core areas. In order to ensure the long-term health and survival of wildlife populations in the U.S. Northern Rockies key cores and corridors must be protected. Numerous scientific studies and land management policies, including those by American Wildlands, Craighead Environmental Research Institute (CERI), Interagency Grizzly Bear Committee, Reed Noss, the U.S. Forest Service, and Montana Fish, Wildlife and Parks, recognize Bozeman Pass as a priority wildlife corridor.

What is the "Driving with Wildlife in Mind" campaign?

The Montana Department of Transportation was recently granted funding to use Intelligent Transportation Systems (signs, public education) to address wildlife-vehicle conflicts and wildlife connectivity on Bozeman Pass. The ITS project also includes wildlife monitoring that serves to evaluate the effectiveness of ITS, as well as the wildlife fencing that will be installed in the MRL overpass reconstruction, in reducing animal vehicle collisions and maintaining or improving animal movements in the Bozeman Pass area. Montana DOT is partnering with Western Transportation Institute, Craighead Environmental Research Institute and American Wildlands.

What is the goal of the campaign?

To raise driver awareness of wildlife presence and movements in the Bozeman Pass area and allow for better wildlife movement through the Pass.

To increase the safety of drivers traveling through Bozeman Pass by reducing the wildlife-vehicle collisions.

How many vehicles a day are traveling over the Pass?

Montana Department of Transportation records indicate that between 8,000-12,000 vehicles a day are traveling over the Pass in the winter and 10,000 to 15,000 daily in the summer.

How many wild animals are being killed yearly by vehicle collisions on Bozeman Pass?

One hundred and eighty four individual ungulates were killed and 20 carnivores were killed between 2001 and 2002. From 2001 to 2003, a total of 597 animal carcasses, including 349 ungulates were sighted on I-90 over Bozeman Pass.

What types of animals are being killed?

Black bear, mountain lion, wolf, coyotes, red fox, American Marten, mule deer, whitetail deer, elk and moose.

What can drivers on Bozeman Pass do reduce their chances of hitting an animal?

* Stay alert and scan the roads as you drive.

* Pay attention to wildlife warning signs posted on roads. Signs are posted in areas where animals most often cross roads. Keep in mind that some species, like deer, travel in groups, so when there is one crossing the road, it is important to slow down and look for others about to cross.

* Be especially alert at dawn and dusk when animals are most active.

* Drive slower, especially at night. Drivers have more time to avoid hitting wildlife when driving at slower speeds. Lowering your dashboard lights while driving at night will often help you to see the reflection of your headlights in the eyes of animals near the road in time to break.

9. APPENDIX B: FIELD DRIVER SURVEY COMMENTS

Table 13. Comments included on the mail-in surveys that were distributed at the Bozeman and Livingston exits during the field speed study.

Comments
Had no problems
saw several dead animals on roadside, saw 2 live deer about 2/3 feet off road near bend in road
I frequently see dead animals although I drive infrequently the road (6x yr)
It's very pretty. Please don't hurt the animals
I have not driven this corridor at night yet, when most animals vehicle collisions occur
Elk often cross I-90 on east slope of Bozeman pass in pre-??
1st time here I had commented to my husband about few road kills But did see several today going east a few like a mom and baby raccoon and one small deer
Before we saw the sign we commented on the number of deer!
This was our first trip
We saw a mountain lion cross I-90 once. It was cool!
slippery in winter
no comments, I rarely use the road
I have heard about the suggestions for reducing collisions in that area and I am very much in support of making the area safer for man and animals
Beautiful drive!
I really enjoyed the journey between Livingston and Bozeman. I watched for those stinky animals because you guys did a good job warning concerned motorists like us. Keep up the good work and kill all the animals. Thanks much
It breaks my heart to see the dead animals along the Interstate or to even read about it
Appreciated the warning sign
I like the idea of the flashing lights when animals are close (like in West Yellowstone)
We only go to Livingston a couple of times / year, but we go less often during winter due to the iciness of the pass
Yuma AZ, It would be smart for the Highway Dept to pick up and dispose of dead dear / elk carcasses. They look Horrible for our tourists! I know you used to , Why did you stop?

Poor drivers who are in a hurry let the trucks drive at the same speed as cars so traffic can flow more evenly
I think warnings like the electronic message are effective- Keep up the Good work
Good idea!
Lower the Speed limit continue efforts to raise public awareness
I did not use any dead animals on I-90 between Bozeman & Livingston but saw lots of dead deer south of Billings toward Sheridan, WY.
There seems to be many collisions but they get cleaned up quickly.
Am cautious at dusk
Anyone that has driven in MT for any length of time SHOULD know that evening and night are prime time for animals crossings.
Keep the weeds/grass mowed so animals will be seen.
If you are driving at night on the interstate at 75 mph it is difficult to avoid colliding with deer or elk
There is so much high speed traffic it would be hard to avoid
I support increasing awareness of the potential for animal vehicle collisions and encouraging drivers to slow down and to be more vigilant
If everyone paid attention, & focused on the task at hand (driving) taxpayers' dollars wouldn't have to be spent on studies like this.
I feel the pass speed is too high still.
High priority! Protect the wildlife!
They are going to happen
I always watch for animals and keep alert for high winds, and I always wear my seat belt
Public awareness is important - same animal crossings - under or above 0 are important
More caution signs? Slower speed limits. Q1: Bozeman to Belgrade - drives daily
We just moved here from AK and OR. Had residence in Both. Had animals vehicles collisions in both states. Slowing and looking side to side helps these animals
03 late summer eve we hit a pack of coons - it was gross.
Jackson Creek is the worst. High fence on top of the hill?
Seems to be less there than between Livingston and Columbus
I didn't realize the problem was worse there

Q1: twice a day during the school year. I drive 7th to Bear Canyon.
bad by road curve close to Bear Canyon. Its an animal corridor.
The sign telling how many animals have been killed "in the next 2 miles" is a great idea - slowed us right down !!
As a truck driver have drove this section many times at weight, seen many deer and hit one
I see dead bear each summer and new deer almost every week- we need an overpass at bear canyon and s. for animals
Please don't waste my taxpayer dollars on this issue
Saw lots of deer and antelope Always try to be alert for animal crossing so sign didn't change driving
Bozeman to Billings is "bad" re this issue.
It is a good idea.
It's a good idea!
We are cautious as we have heard lots of stories of accidents near accidents
I drive the area between exits for 19th & Main daily and see many many dead deer along the way. Hope this helps! Good luck with the survey.
I thought the sign was very helpful, however I hope is wasn't used as a ploy to make motorist slow down.
Spray knapweed under N7th interchange. It is spreading rapidly Knap Weed
The speed limit should be 50 mph and enforced thru Bozeman Pass where the roads are curvy. They should be going slower until getting to the west side of bear canyon exit. Signs noting wildlife corridor, This could help thru wildlife corridor
drivers need to slow down and be able to avoid animals when they are xing I-90 - or any road for that matter. Slow down!!!
Maybe should reduce the speed limit on this section of I-90?
I did not modify my driving because the weather wasn't bad. I wondered why that sign was on today, now I understand
I have lived in MY and MT most of my life and grew up in MY- I always watch out for animals when driving- not just between BOZ and LIV
"Outstanding roadway." Thank you for such a great highway to travel on. If there is a problem with animal-vehicle collisions; hunting it the best way to keep this under control.
I have narrowly avoided deer a couple of times near the east exit to Bozeman. I always try to watch out for them there in the evening hours.
Reduce the speed to 65 mph, nobody needs to go 75mph anywhere

What in the F are you worried about? If people can't drive, get them the hell off of the road!!!!!!!
Sign Good idea- Build underpass for animals
Can't say much, Only moved to Big Sky 10 months ago and mainly travel between there and Big sky 2x week
Any attempt at providing protection from an animal is appreciated and worth it
Scratch the animal worries and sand the shit out of the last corner that always has ice on it.
Improved fencing and dedicated crossing corridors are needed. (makes me sad that wild things die because of traffic)
Don't drive east of Bozeman much.
Thanks for your concern
Folks need to slow down
Built some under road wildlife corridors for moose, bear, elk, deer, coyotes, wolves
Mostly its speed and lacking attentiveness(diversion) Possibly more at night (reduced visibility) an early am hours when animals are on the move
So are there LOTS of animals? Are elk down that low?? Good no set speed limit
maybe put signs up for tourists, to warn them, but not enough to block out MT Beautiful scenery, mountains.
no
Clean up of dead animals.
Wider roads would be nice!
the corners/curves are terrible in icy conditions
Bridge for critters over Interstate
It is too dark, put in some more lights and a higher bank for winter
I am all for ways that help animals cross if they work, corridors are very important- fences maybe another issue that need tackling
Truck traffic is bigger concern than animals. Trucks seem to be going faster than may be safe on tight turns.
As long as we have radios, cell phones, kids, other passengers, the sights in the pass, we'll always have distractions. As long as animals can cross the highway we'll have collisions. After all, this is MONTANA.
Maybe deer fence could be put up with below roadway animal corridors

Speed limit should be 65!!!!
I think the sign with the # of animals killed is a very good reminder to drive cautiously - well done.
Glad you are raising awareness about it.
None. However when the electric signs are used to warn of high winds, they need to be kept current, closer to "real time" or people start ignoring the signs
Fill in pot holes and bank the turns
Grizzly tourist attraction may attract wild bears- I have swerved on the pass to avoid a grizzly bear on the pass some 3 years ago
Animals and travel warning signs are great asset and a reminder to be aware, careful and slow down
It is so sad and at times cause one to drive out of your lane to miss the carnage
I very rarely see dead deer on I-90 between Bozeman and Livingston HWY 89 Livingston-Gardiner is absolutely Hellacious however
I would support a well-placed underpass or other animal passage means within the Bozeman-Livingston corridor.
Today we saw a dead dog on Main St Exit (7pm) Been there a couple of days
Keep up the good work & scare the animals away from the HWY
Need Deer Crossings Like Canada/Banff National Park
HWY needs resurfacing & better maintenance. During Winter road needs more attention!
I noticed that the MSG signs don't work most of the time and if they do only one is working. I would suggest having all of the signs on and working to make your campaign more effective
A common problem, especially prevalent on 191 N. of Big Timber & Hwy 12 E. & W. of Harlo. - compared to there, I-90 not a problem. #2 - How many animals hit this year - 192
Maybe a higher fence so the deer cannot jump it and a couple of spots where the deer could go under the interstate to get to the other side???
Each time I make a trip on I-90 there is a dead deer on the side of the road
Put up new yellow signs w/cartoon that shows picture of deer + car = $2000, elk + car = $3000, moose + car = RIP.
I feel that if people would drive for the road conditions and pay attention far ahead they could avoid problems
Way too frequent people need to pay more attention. Too many Californians here driving like they are on the 405. Slowdown
One of the hazards-privileges of living in MT

We built out interstate crossing a major migratory path. What ca we expect?
I saw the sign in Livingston on I-90 9/18/04 about # of animals hit in next two miles-Great!!
Keep letting immigrants build where ever they like and problems with animals are bound to compound
I have traveled between Bozeman and Livingston since 1977 and never hit a n animal on I-90
like warning signs in ???
This area isn't any worse than many areas in Montana.
Tend to see more dead animals closer to Bozeman.
may need to focus on some kind of animal overpasses like they do around Banff
We would like to see a safe corridor for the animals
Animal crossing corridors (e.g. tunnels, bridges, etc.) would be great!
Animal detection units would be a good idea and less idiots on the road. #2 - 29 animals killed this year - next 2 miles.
I appreciate the electronic signs warning of imminent danger & weather
Almost hit deer a few times in late fall on north side of Rodey Canyon.
We feel very strongly that there should be come overpass or underpass along the corridor for animal crossing
Like reader board but for those that don't have cell phones it doesn't help for 511
A few animals seen on Road, but I personally haven't had any problems
Put up Bear or Cougar moose elk crossing signs. People will watch just to see them and slow down because of watching.
Fix it I don't care how, just fix it
Could use better lighting!
Animal overpass just like Banff National Park in Canada
There seem to be frequent animal vehicle collisions judging from the number of animal carcasses; speed enforcement should be stricter
The interstate 90 is like the DMZ for the animals
The westbound animal crossing warning sign should be set up near Trail Cr. Exit or farther east. Didn't see an eastbound warning.
I think some people exceed the speed limit making it harder to stop if they see an animal

People drive too fast and getting faster! Should not allow passing on some turns
there are a lot, if something can be done I'm behind it at reasonable cost
Perhaps the speed limit should be lowered in this corridor. In my opinion most drivers drive to fast
The State uses too coarse of sand on Icy rds.
What the big thing about animal-vehicle collision in this area? I live in Montana and in Montana animal are a part of the things we dodge when driving.
Please clean gooey spots.
Seems like the animals cross, get stopped by the dividing wall and don't stand a chance
The rock coming down on the road at the end of the canyon is very dangerous. The HWY Dept should go up the hill and knock down a lot of the loose rock and haul it away
I believe it to be a safe piece if interotate. We have encroached into animal territory. We have to expect possible collisions.
Dead animals appear to be removed from road and roadside. Rather quickly. Big sign closest to Livingston were not working today
I have not noticed a difference between this corridor; other roads.
Several sections of this corridor are hazardous - because they may be prime animal crossing spots but there is very little room to maneuver to avoid a collision.
I feel that if speed limit was lowered!! There would be fewer animal-vehicle collisions.
1. I think strongly that we need permanent signs warning to slow down if necessary due to possible deer crossing signs. 2. Mandatory anti-deer horns should be required.
I've seen a dead bear, several dead deer, & lots of dead raccoons, skunks, & porcupines. We need to add more tunnels so they can travel safely to creeks and back. I strongly support the creation of corridors for animals to cross the I-90 highway.
Have seen the sign when it read "25 animals hit this year next 2 miles" as I neared Bozeman, I did slow down and pay more attention.
I have noticed far less there than in between Belgrade and Manhattan. There is always several fresh kills there almost everyday
Trucks travel too fast
The winter road crew is awesome!
Lighting on the bridge of Livingston would help
Speed limits are ridiculously high on all Montana Highways considering the amount of wildlife. A gross lack of enforcement of speed limits.

Adjust Hunting Season dates / quotas to better control game population
There are other areas of I-90 that seem to have more animal-vehicle issues.
It's Fine.
Underpass/overpass needed. More than one look at road going to Banff Canada- Stop corridor development
Good Road, Don't see how it could be improved Dead animals seen are usually wild deer mostly then skunks and porcupines, These animals do not observe fences only way this can be avoided is if the entire distance is within a tunnel!
Curve West of 55mph s bends East of Bozeman should also be posted at a slower speed limit
Like the electronic sign during winter.
Don't know how frequently because they stay on or beside the road forever
The alert sign is a very good idea.
I have seen a lot worse areas
even in speed restricted area of 55- most vehicles don't observe or feel if is for trucks only. Solution more policing or maybe camera speed controls.
What is this about?? Animal human conflicts will always exist because we are taking over animal habitats. A slower speed may help
Highway 89 north is much worse than this stretch of road
Worse between Big Timber and Reed Point/Columbus.
It would be nice to create tunnel corridors for animals to pass under along this stretch of migration route, like they have in Canada!
Raise the center divider so that hi-beams can be used to see the animals w/out hindering on-coming traffic.
The sign (# (26-29) Animals killed) does not help to avoid animal-vehicle collisions because the animals do not read the sign.
Q1: halfway between Bozeman & Livingston - Daily. Q2: I see the signs daily, do not remember which message was on it today.
Please put an animal crossing tunnel/overpass by the pass/Bear Canyon area! The animals killed are diverse & I love seeing them. Since we live in a migration corridor lets protect them as they migrate!
When you live in Montana it's going to happen sooner or later
I see more dead animals on 89 south between Livingston and Gardner
#6 - But close to hitting an elk

Maybe use signs that asks drivers to slow down and save wildlife (15 mile section from E. Main exit to 1st Livingston Exit
See more dead animals between Mammoth and Livingston on Hwy 89 than on I-90 corridor, though no mega fauna like bears.
it's Montana, Animals are crossing everywhere!!
Have seen at times where there were collisions however we never had one
Q4: I saw small sign about animals.
#7 - Hit a Bobcat
My husband was in a vehicle animal collision in which air bags went off, vehicle was totaled
There are a lot!! When there is an animal on the road in the canyon its pretty tough to avoid them.
TOO MANY!!!
Blind curves in Bozeman Canyon
Very important for awareness
People need to slow down pay attention to road signs mph
You can not stop it.
People need to slow down!
Need to have an under highway crossing for animals
Not much worse than other locations around the state
I don't think there is a problem with animal vehicle collisions on the road in question
I only see dead animals-mostly deer I have not had problems with deer crossing in front of me between Bozeman and Livingston
Re #7 Hit an owl at night breaking headlights and causing 500.00$ damage
There are a lot of dead deer bear and elk between Livingston and Bozeman
I personally have never almost hit or hit an animal on that stretch but have driven by a lot of carcasses. I do modify my driving if necessary based on the sign. Time of day, weather
Sundown to sunset are the worst times
5ft or higher fences-lived on Bohart lane in Bozeman and always saw deer jump low fences or damage ones. Small animals hard to control skunks raccoons ect. On the 5 ft fence along Bohart lane they do not jmp over but get trapped in there and get hit in that area. cedar to Walmart
High Fences

we need to install lights to see them especially between main st. and bear canyon exit. Please hire more snow plow drivers this winter
I once hit a deer at dawn laying in the road. I could not tell anyone it was there then, Now I have a cellular phone GOD!?!?
Wissales have saved me many times
On rights sides of roads lines should be yellow, in winter, white lines blend in with snow
Not anything to do with animal vehicle abut why don't you post Amber alerts on the DMS seems a waste not to use them for everything
People have responsibility to be alert, cautious and cognizant on any roadway in Montana concerning animals.
The sign is very Helpful
The Boards never work?
I have seen 1 dead elk on the I90 last fall, it was gutted, head and legs cut off- must have fallen off a hunters truck
it would be nice if speed were reduced in canyon between bear canyon and trail creek exits and if 55 mph reduced speed are could be enforced. People routinely drive very fast and tailgate in canyon
Yes, concrete barrier does not let smaller animals get thru to the other side of the road
It's a huge waste of tax payers money!!
Should make the speed limit 65 cars 55 trucks due to animals & frequent roll over truck accidents
Just be Careful
If semis and cars weren't speeding like they do, there probably wouldn't be so many killed People need to learn to slow down
I wish something could be done so animals could cross more safely
Semi's drive to fast
Build a Land Bridge on top of Bozeman Hill
Nice drive most of the time.
Electronic reader Boards are a waste of money, common sense needs to kick in
We need to help animals get to water safely
can be messy & were fun luck. Livingston sign constance, on the blink.
Should have routes for animals to cross highway with signs that animals understand stating such

Biggest problem I have is visibility in bad weather - trying to see lines and markers.
Slow the westbound lanes as they come to the valley- animal frequent often this bridge
I think it is a waste of tax dollars. There are other areas that have more problems in other areas of the state
The mountains come very close to the road and of course would have more animals. Slower traffic may avoid deaths of animals and more hunting opportunities!
signs are very effective (at least for us) THANKS!
Where there are animal -vehicle collision "hotspots" these areas should be flagged &have a reduced speed with double fine penalties
Hire more attractive women. Bikinis for work attire
Animal bridges and corridors should be built
In the areas where animals have been known to cross and get hit they should flag these areas and reduce speeds
Drivers need to be mindful in All road conditions of wildlife - use logic! Message on roadside is not always legible. Why? It should work all the time.
Keep the out of staters out
Curve west of S bends East of Bozeman should be at a lower speed limit
It doesn't seem that dead animals are removed very frequently.
people should be more careful and not hit animals, there are a few who deliberately hit animals
I have seen many animal vehicle collisions on I-90 at this location and have seen some close calls
I never drive after dark because of wildfire on the roads
There is always a lot of traffic, which makes animal-vehicle collisions inevitable, without taller fences and better precautions.
Most animals (moose, bear, elk) are noticed in the Bozeman Canyon.
signs waste of money for the amount of time they are on or working. Or mesg is too late or not relevant this last year there has been more dead elk, wolves chase elk back and forth across hwy
Higher animal proof fences
Fix all announcement boards so they are able to read?? Board before Livingston is not legible Maybe msgs should be programmed to flash & get unobservant drivers attention??
Please build a corridor for the animals to cross. Protect the GYC migration.
How about better night lighting? Noticed electronic message signs were being used more during this

survey. Hope it stays that way.
All drivers need to slow down and pay attention
People need to slow down and be alert.
I have never seen a problem with it, know matter what time of the year.
more speed enforcement needed.
Too many skunks dead in middle of rd.
I feel like I'm dirving thru the slaughter house thru the canyon. This is a priority project in my opinion!
Get rid of the electronic signs it's a waste of money
It upsets me to see dead dogs because of the dipshits that haul their dogs in the back of their trucks.
I pay attention to the messages, thank you
There does seem to be a lot of animals hit More at night I think
Had a near collision involving a mama Black bear and 2 cubs crossing at the end mouth of the canyon eastbound
People drive to fast
Need a tall fence and access bridge or underpass for the animals
More police patrols would solve the problem
Need some Greenways like I78 in NJ
My truck is equipped with animal deterrent devices which produce ultrasonic noise
The big signs(light boards) are tacky and worthless - hardly ever useful to drivers. I bet they cause accidents themselves. Take them down.
Need more speed enforcement
I think all my friends have hit an animals either there or on 89. Some have totaled cars. #2 - See it often not today. #4 - Did see on sign 3 hundred some killed between Livingston and Bozeman.
Bear Canyon needs lights
I commend the MDT maintenance people on their excellent efforts to plow, sand ect. Thru the winter- it makes my commute safe and pleasurable! Collisions happen but any way to allow safe passage would be commendable
I see far more dead animals between Livingston and Big Timber than Livingston and Bozeman. However, its important - thanks for the warning.
Could see better in canyon if new paint and better reflectors

Most of the time the sign near Livingston has random short lines but no message displayed
Many times the electronic signs haven't been working, so I no longer pay attention to them. The State should do a better job removing roadkill as dead animals attract other animals
I have hit 3 deer between Bozeman and Livingston in a 1.5 year span
It would be nice to see them removed off the side of the hwy rather than watch them rot everyday
They are scary!
Many could be avoided if people drove at a reasonable speed 55mph
Need to get dead animals off the road quickly especially at night.
Dangerous - hope it doesn't happen to me. (or others)
I hate seeing mangled dead animals on the roadside, especially doe's with their dead fawn a few yards away. I often wonder how I would react in the face of such a situation.
People need to look for animals instead of talking on cell phones.
Thanks for anything you can do to get people to slow down!
Beautiful drive! Dig seeing the trains!
Its defiantly a risk, not much to eliminate the problem can be done
use solar warning lights like YNP
Need animal crossings
animal corridors by trail creek. Q1: in the summer. Q5: lately none, moose 9/18
Don't see any way to stop it.
I'm glad to see the electronic message boards telling people to watch for animals. People who don't travel this road very often don't know the spots where there are a lot of animals.
If more private land was open to hunting, it would move the deer & elk away from the roads where they get hit! The wolves are also chasing animals out into the roads.
Tree Huggers Suck
Livingston Sign was broke down
most cars or p.u. seen hitting animals were not from this area.
Road safety concerns are addressed after 7:00 &:30 AM. Icy roads and road conditions ignored til shift starts.
Have never seen live animals on side of HWY trying to cross. Would be much more concerned with HWY 89 btwn Gardiner and Livingston

Yesterday I saw the sign with the number of animals killed this year - 26? It made me think - be more aware of animals crossing I-90. Even with the sign gone/off I will be more alert for animals in those 2 miles.
saw the sign for the first time on this morning's commute & immediately remembered to slow down. Thank you. Hope the signs influence more people as they did me.
The main problem is the influx of Big City people to the 20 acre rural tracts.
Some animals lay on side of road forever
Need animal under/overpasses. Q3: I read it the day before.
I would guess most happen at night. Slowing down would probably help but don't think most people really care enough to do that.
Hope they finish the underpass or overpass for animal crossings. I heard that American Wildlands is working on this.
Terrible Poor animals don't stand a chance
I won't drive anywhere in MT without GOOD QUALITY deer whistles on my car; they work for other animals too. Residential construction is displacing animal habitat.
over/underpasses for animals would be good. This is a major migration route for them.
I appreciate the signs and warnings and take them seriously
Who ever is responsible for dead animal clean up isn't doing there job
Also answered on 9/21 I like mice and accident alerts
Unfortunate- but inevitable I think you should leave the carcasses on the side of the road
I usually avoid vehicle - animal collisions by watching my speed and scanning the ditches. Inattentiveness and excess speed seem to be a major factor.
Clean up the dead ones
I have seen the animal crossings sign before, I don't remember it! Today and have seen weather advisories high winds & road construction signs very helpful
We're delighted that you're addressing this very serious problem. We are very careful drivers yet we were unable to avoid a collision with a doe at Bear Canyon & I-90.
I believe animal underpass corridors should be in plans of Hwy, construction in areas of wildlife migration, speed and 4 lanes of traffic at dark makes a very tough situation.
I have only noticed small animals and a few deer killed by road- we usually do read the electronic board, often one at Livingston
curves@Rocky Canyon need to be fixed- very dangerous. Most accidents related to animals or not, occur there

I know that in Europe they are doing drastic measures to avoid A-V collisions Hopefully we can find a way to positively co habitate atop dominating Wildlife
The electronic message sign eastbound at Livingston exit has not worked for a long time.
Keep sub-dividing the mountains and it'll get worse! Note: HWY 89 N for 20 miles is the worse for animals.
In Wyoming along I-80 they use game fences. Is it cost feasible here?
how about an animal bridge
There is a new sign that has been posted just after Bear Canyon on into the city limits warning of animals on next 2 mile stretch of road - Excellent! *Bozeman could be a little quicker cleaning the road kill.
It's a risk you take anytime you drive in Montana. You just have to be aware of your surroundings.
When the animals are hit someone should clean them off the road. Not let them sit there for a week.
Fencing to tunnel to 2 crossing area.
The Westbound Lane on Bozeman side of Hill need LARGE rocks removed more frequently or pushed away from shoulder! Note: overall DOT maintains hill very good all year long - I am a truck driver.
Certain stretches of this road are more prone to animal activity
I think people have to because that the animals are going to be crossing. We have lived out here for 40 years. Some times you just can't miss them.
Eastbound signs not working today.
I must have seen at least 1 moose, 2 bears, 1 Elk numerous deer, skunks, dogs cats coyotes porcupines Ect..
It seems to take a long time for medians/shoulders to be cleared of animals if at all.
Crowded
Animal warning signs seen previously on I-90 are very helpful and remind me to slow down
People in a hurry and driving out of control for conditions are a bigger problem than the animals
Slow the tractor trailers down, especially at night
I think the electronic signs are helpful to increase alertness, but often they are not functioning(I have not seen any msgs for the past week at least
Your sign should say 175, I hit one last night
Sweet
The Jersey walls are necessary in the "S" curve but they are also the biggest problem for wildlife. They get trapped and confused, then hit

If you could convince the people who live in between said locations to allow hunters to help manage herds this could be helped
Concerns me travel at dusk, early morning, and night
A commuter train or bus system would help lower car/animal interaction.
I think the speed limit should be lowered because of animal especially the canyon area - 1 mile before & 1 mile after.
Trailer sign in Bear canyon useful for non-residents
The sign I referred to is the trailer that was set up east of bear canyon, the permanent signs are worthless
If you want to do something about it change speed limit and police it Fervently (?)
I've heard of a possible 'corridor' for the animals because I'90 crosses a migratory route. I wish this would happen - my heart has been broken often by the death of moose or bear or deer (being guilty)
Set up passenger train transportation - please! Plow the roads, early enough that accidents don't occur - especially sand the black ice: both before rush hour.
(A PROBLEM)
Appreciate the "EMS" I reduce my seep to 55=60 mph VIP Taxi, Inc.
All you can do is continue to warn drivers
None-be alert do not talk on the cell phone while driving- my pet peeve
I wish that someone would remove all the dead animals off the streets!
signs are a waste of money. We need more law enforcement. I drive the speed limit and get passed all the time. Never see a cop except maybe once a week.
How about fixing the westbound curve where all the trucks keep overturning?
Slow traffic down. Maybe high fences to allow animals to cross in certain areas.
148 animals killed this year!
I've seen hundreds of animals dead and alive along the corridor over the past 10 years including dead mountain lions, moose, bear , elk, and deer. You need a fence/ bridge or tunnels to minimize it
As animal populations continue to expand, and traffic load increases- more collisions are unavoidable
Warning signs help the non-frequent traveler.
Appreciate the signs indicating animal migration at or near interstate.
The electronic signs are a waste of money.

It's very hard to predict animal behavior along the corridor besides the obvious (i.e. dusk) But really like the use of electronic signs for rd and weather conditions
Slow down the Semi trucks- use sand instead of gravel in winter-reduce the speed in the animal (heavy() areas, More police patrol
For deer (and bears) maybe an animal fence and/or underpass would help also I saw dead dog probably from truck-no help for that
Fix the signs especially the eastbound. Display something even if it is the ranger football score, get rid of the random character garbage
1. Clean up the carcasses! 2. Truckers are more dangerous than any animals! 3. I've yet to see a trucker stopped for speeding in 4 years of commuting!!
I-90 is a disaster for wildlife. We need wildlife crossings (under and overpasses). Also need to protect open space on adjoining private lands to preserve these wildlife corridors from sprawling development.
Inevitable w/o high fencing the corridor ?? That impedes natural movement - people need to slow down everywhere.
OPEN the TRAIN!
In Canada near Banff They use tunnels to direct animals for safe crossings with very high fencing along the highways.
29 dead sign very impressive & 68 next 20 miles. Build fences
Thank you for putting up the reader boards - the trailer board should be placed before getting in to the canyon.
Suggest lowering the speed limit to 65 mph
I think semi trucks are responsible for a lot of road kill that goes unreported
People drive way to fast. Hey pass me like I am driving Backwards
Need to Straighten the RD on the West end! Need to fence areas off where there isn't room to react…..See survey for complete comments… The card is full of them!
Night vision limited by bright lights from opposing traffic with difference in height of road at mile 327 to 328
Someone needs to remove the dead animals off of the interstate. A lot of other states have people do removals.
I try to avoid night driving because I am fearful of the animal activity. Maybe helpful to have higher fencing.
lower collisions equals lower night speed limit in that area And then it has to be enforced
Forget them! Put up an electronic message for people going under 45mph to put their blinkers on! Keep the Bridge decks as smooth as the rest of the free way!

Semi Truck Drive too fast well over the posted limit. They need to issued tickets
maybe a 6' fence along the corridor like they have in Wyoming.
Hwy patrol need to issue tickets to slow people down inside the rocky canyon
Speed needs to be reduced along this stretch of HWY
All cars and semi trucks drive too fast, most travel 80 to 85, need hwy patrol to issue tickets
I support this effort, Keep working on this
The Highway was built to make money and the animals are the afterthought only
The signs are rarely pertinent. Usually, the give information that is a day old or older.
I was very glad to see the sign warning about animals! I think it will help! At least I hope! Something needs to be done!
Westbound Livingston message board should have message, instead of the usual illuminated blocks
My speed today was 70mph Semi trucks were passing me. They were going over the limit of 65 Needs Hwy Patrol to issue tickets
Mt needs to be designing some sort of animals crossing under I-90 to help with this problem
put an animal barrier fence up, clean up dead animals
Just assisted an elderly couple who hit a deer on I-90 b/w Bozeman and Livingston at Cokedale Road area; called 911; their car disabled; no injuries.
You have to be aware of the animals early in the morning hours. And drive careful!!
A deer ran into the side of my vehicle at 6:30 a.m. yesterday, Sept. 20th about a mile past the sign by Bear Canyon. Broke the driver's side mirror and dated in side of vehicle driving 50 mph because of sign & still didn't see deer coming
Think it's a good idea! Hope it works!
I think it is great that you are finally takin' a look at this!! Lets try to help the animals some way
The big signs each side of the pass are really ugly and don't seem to provide useful information yet
The speed limits is to fast between the two towns 65 for all should be the Speed limit The dead animals need to be removed they are a Hazard as well. 55 for trucks and enforced!
My eyes are always open for animals regardless of where I drive. On the stretch mentioned I have never had to slow down for an animal. Good luck!
Thank you for your attention to the matter.
Looking forward to having animal corridors put under the interstate

The sign is superfluous and usually out of date. Spend your time on something useful
The permanent signs are worthless. Never current useless messages- don't work right- waste of money
I totaled my station wagon on deer. Deer most numerous from east exit to east 5 mile.
The Speed Limit should be reduced to 55 Give animals a chance
A safety sign is only helpful when it works. The big sign at F. Ellis seldom has all the lights working. There are some strange words.
Please do everything possible to help reduce collisions caused by animal crossing
Greatly overblown- don't spend tax dollars on this issue. Increased elk visibility and mortality in this section is directly attributed to growth in area and wolves moving elk around
It is a lot worse in the winter and early spring
Tunnels for the animals
commuting for 9.5 years - more than ever
Speeds to high in s turns! Limits not enforced! Tractor trailers speeds too high for road conditions
I have seen more cars and trucks wrecks trucks really go too fast.
More passing lanes, 3rd lane maybe for trucks, winter snow removal faster
If you think animal collisions are bad here, you should drive in Pennsylvania sometime.
Mule deer doe was running down the westbound hill side and stopped luckily right before came to road and moving traffic near exit 316
There should be animal crossing overpasses
Excellent idea to put a msg on screen- it was great when the mobile sign was placed at the entrance of the canyon from bz-liv
Deer reflectors in high crossing areas.
Provide a safe corridor for animals / promptly p/u and dispose of dead animals on I-90 warn drivers w/ signs Lastly too many dead animals
People need to be more aware of their surrounding rather than playing with their cd players and talking on their cell phones
I support the efforts to redesign the I-90 corridor to provide safe crossings by Wildlife
I live out in that area and I know that here is a definite problem. I would like to see the deaths of animals decrease.
Will be glad if and when you get animal crossings in.

Not only do I frequently see dead animals, but these same animals simply sit and decompose where they lay.
Speed limits should be lower in the pass and enforced
Should illegalize animals crossings on the interstate and put up signs on their game trails ;)
I believe that most of the animals are hit by large commercial trucks driving too fast.
Requires alertness the same as anywhere else
It's very bad animals loose their life to cross over just to eat. We should do much more to save their life.
Q2: malfunctioning, unable to read message
I am aware of the animals in that area and try to modify my driving, I live up Bear Canyon Rd. and know of the wild animals
Often animals on freeway and frontage road - maybe animal tunnels ??? Q1: to Bear Canyon Exit.
Q1: trucker
Maybe some random tunnels for animals to cross road safely
I'd love to find away to reduce animal mortality an any of our u.s. roads
I do drive 10-15 mph slower during dusk / dark because of animals
Signs in Orange more attention getting than Electronic sign
#2 - Did not notice the sign east of Bear Canyon exit today - I get on interstate at Jackson Creek.
Surveys marked "19" may have been handed out @ 7th. They tried to change them as they went.
Good idea! I am familiar with similar animal corridors in Banff National Park - fencing needed too.
Signs: # animals hit are effective. I am aware and drive carefully.
I do watch for animals at that section that flashes next 2 miles. Answered previous questionnaire.

10. APPENDIX C: DRIVER SIMULATOR SUBJECT SURVEY COMMENTS

Table 14. Responses to the driver simulator survey question 2 ("*Was there anything different or unusual about any of the traffic signs you saw in the last scenario?")* listed by treatment group.

Question 2
Treatment 2: Flashing Beacon Sign
Speed limit + apparently larger sign
Animal crossing advisories w/ yellow flashing light
The speed limit signs had a black thick border around it. Signs were usually at the straight section of road, where as billboards were at bends
The animal crossing sign was blinking, I have never seen one blink
They all looked realistic and believable except for the WTI billboard (Haha)
the WTI sign and the drive safety sign, the rest seemed normal
Deer Crossing w/ a light flashing-usually not the case-light flas is usually for road advisories or construction
Animal crossing advisories signs are usually not lit with blinking lights
one for WTI wasn't something I would expect
WTI billboard Drive Safely
Treatment 1: Standard Sign
No night or truck speed
Saw WTI sign, just noticed
Treatment 3: DMS Sign
The loan one was hard to read so I was distracted
There was the miles to Livingston sign right next to the corner`
Usually the large electric signs (like the animal crossing one) are for road conditions not animals
One said WTI

Frequent and large
Not that I can remember
I can not see the signs, in the real road, I often see " deer X " signs, that way I can drive slower. But in this test I do not see the sign when some deer cross the road. It is dangerous
Animal warning signs on the lighted billboards (usually weather advisories)
Treatment 4: Flashing beacon sign and DMS combination
Colors not as usual- WTI sign dark
Mileage to billings was too much
Blinking animal crossing signs-don't blink on the pass
Animal crossing next 20 miles: Deer sign with blinking light
Animal crossings had blinking amber light
Animal crossing flashing
There were several speed limit signs: more so than there usually are
Not that I noticed, however simulator environment (at least initially) somewhat demands attention to keeping vehicle between lines

Table 15. Responses to the driver simulator survey question 5 (“*Do you drive differently during the day compared to how your drive at night? If so, how and why do you drive differently at night versus during the day?”)* listed by treatment group.

Question 5 - comments
Treatment 2: Flashing Beacon Sign
I drive slower- more cautiously don't see as well
Slower to allow time for ID of crossing critters
Night = slower, no cruise control, bright lights and dim lights, increased awareness for glowing eyes
Day your visibility is longer and broader, at night your visibility is limited by the throw and spread of your high beams (best case) So I drive little bit more cautiously at night (so that I can brake at an event of mishap)

I drive slower or the speed limit only (in day +5mph) I don't pass as much. Worry about hitting animals, can't see as far ahead.
I obey speed limits at night- tend to drive a little faster during the day (2-5mph faster on highway / interstate)
Slower at night due to less visibility
Drive slower, watch ditches for animals slow down on hills and corners for ice / stalled cars
I tend to drive a bit slower at night-or I stay right on the speed limit- less visibility
Slower and more cautious of animals, scanning the sides of roads more
I drive slower to avoid hitting animals, getting a ticket and generally because I am not as confident at night
Watch for deer and drunk people
Drive more slowly, increased awareness, watch for animals, watch for people 9 esp. in dark-colored clothing
Slightly Slowed, Lights-eyes more sensitive-Look for more movement on the side of the roads
More awareness of animals
I consistently drive % miles an hour slow at night than in the day. Interstate is usually 75 MPH. I usually drive under 80 at night and under 85 in day
slow down some and concentrate on animals much much more
Typically drive a bit slower @ night. More cautious about passing, stay away a further distance from traffic in front of me
Slower at night due to visibility and wildlife. Follow other traffic taillights when available, so may go faster then.
Typically I am more cautious watching for animals and drive slower than I do during day
When I am driving at night I tend to drive the speed limit, or under. I am also more alert for deer crossing the road
I follow the speed limit more closely at night because it seems there are more cops out then
Treatment 1: Standard Sign
More alert at night-harder to see
I drive slower at night due to decreased visibility

My eyes are very sensitive to light. When I drive at night I am very aware of approaching vehicles because of the headlight. I often times need to focus on the road in front of me to avoid glares
More Cautiously at night because it is harder to see
I am more cautious so I drive slower because I can't see as well. I especially drive with caution if it is a road I am not at all familiar with
I tend to stay @ or below the speed limit because of limited visibility
Drive slower, watch ditches for animals slow down on hills and corners for ice / stalled cars
I drive a little slower and more cautious at night because I don't have good night vision and have slower reaction times. At dusk I drive slower and am constantly looking at the sides of the road for deer
slower and more carefully watching for wildlife
Night-not as alert, gets mundane Day- more alert attentive to other cars
drive slower
A little more cautious at night
Slower on unfamiliar roads and streets Drive less at night because it is harder to see
Depends some on the road and conditions, but typically slower-more cautious
slower and more cautious at night
Its harder to see what's ahead of you in the night (such as animals), I am much more aware of the road at night
Slower- I don't trust how far I can see ahead w/ my lights
I feel like I have poor night vision so I tend to drive slower / more cautiously
Treatment 3: DMS Sign
I look for animals on the side of the road a lot more at night
I think it is harder for me to see @ night & I'm more cautious looking for wildlife I also tend to drive the speed limit @ night and over the limit during the day
At night I tend to drive a bit faster on the highway, because there is less people and other traffic is easily visible
More aware, careful, when I drive at night I get tired easily so I try hard to stay awake
I drive slower at night. I have trouble seeing- the glare, etc

more slowly
I drive slightly slower because I have driven around high animal crossing areas many times
I usually drive slower at night. I feel like there is less reaction time for objects entering at the sides of the road, as well the depth perception of break lights is not good
Much slower at night-don't see as well
slower based on visibility
drive slower
more carefully, lights can be bothersome
during daytime visibility is more efficient unlike nighttime
Watch for deer a bit more
More cautiously at night
I drive slower. I cannot see very well in the evening
slower, more alert, more nervous
I drive a little bit slower at night.
Treatment 4: Flashing beacon sign and DMS combination
I drive about 5 mph slower and increase my awareness
Usually I drive a bit slower and I am much more aware of animals and obstacles
Slower at night, night vision not so good
I drive slower and watch for animals a lot more. Am more careful
I drive slower at night because visibility is reduced
slower - limited visual capacity
At night I generally drive slower, in the daytime, I generally drive above the speed limit.
Drive slower at night due to not being able to see the road as well and animals.
Night = slower - I'm more cautious because of the animals.
I drive with more caution _ I'cant see as well and animals are more active

I'm more aware that animals being on the road and drive slower and I'm on the watch out more especially around curves and side of road obstructions
Slower
I tend to be more wary at night in regions where there aren't street lamps and the tendency for animals on the road is high
At night I am more aware
I try to be more alert because of the reduced visibility
visibility and increased likelihood of animals
Generally slower at night, more hazards, you don't react as quickly
More aware at night- watching for animals, plus it's harder to see road issues at night
At night I more alert to every thing because I can't see that good at night, but most of the time I don't drive at night

Table 16. Vehicle damage estimates reported by driver simulator subjects.

Reported Vehicle Damage	
200	
1000	
<100.00	
1000.00 new hood and radiator	
vehicle was totaled	
2500	
2000	
200	
50	
5000	
800	
200	mirror
2000	
0	

0	
200.00 dent in bumper	
3000	damage to vehicle-hit deer
0	it was an old beater work car and I was just creeping along in thick fog. Hit a horse at 2mph
	The front grill was gone and on another occasion the left front blinker was damaged
18250	Total
1073	Average

11. APPENDIX D: MDT MAINTENANCE SURVEY REGARDING ANIMAL-VEHICLE COLLISIONS AND CARCASS REMOVAL PRACTICES

August 31, 2005

To: All MDT Maintenance Chiefs

From: Amanda Hardy, Western Transportation Institute

The purpose of this survey is to characterize and quantify (when possible) the issues and impacts that animal-vehicle collisions (AVCs) and the resultant carcasses impose on maintenance operations state-wide. The results of this survey will be used in two MDT research projects evaluating AVC mitigation methods, to compare the trade-offs (costs and benefits) of AVC mitigation investments relative to your current levels of impacts and associated costs of AVCs.

Please take a few minutes to fill out the survey questions below. Please type your answers in below each question; take as much space as is necessary. After you have completed the survey, *please save the file with your initials added to the file name and return via email to Amanda Hardy at* ahardy@coe.montana.edu (or, if you prefer, fax your completed survey to 406-994-1697) *by September23, 2005, if possible.*

If you have questions, please contact me at 994-2322, or Jaime Eidswick, WTI-MDT liaison at 444-3237. ***Thank you very much for your time!***

1. Please identify yourself and your division
2. Is your field staff *required* to document, remove, and/or dispose of animal carcasses that are found on the road or right-of-way? Please specify what actions are required of your staff in handling and reporting carcasses on your roads.
3. Does your staff conduct the above activities on an as-needed basis (how do they find out?) or are there times (e.g., after a holiday weekend) when your staff conducts systematic surveys for carcasses on any or all of your roads? Please describe if and under what circumstances your staff may conduct systematic surveys.
4. What species of animals (carcasses) do your staff typically document and remove from the road or right-of-way? Does your staff remove some species of carcasses but not document these?
5. How does your staff record the location of these carcasses? To the nearest mile marker, nearest 10^{th} of a mile, on a map, using a global positioning system (GPS), or some other technique?
6. Where do your carcass records go to (e.g. Helena Maintenance Division?)
7. On average, how many carcasses does your staff remove from your district roads annually?
8. Does your staff recognize any seasonal peaks in their carcass removals?
9. Does your staff recognize specific areas on particular roads where more carcasses are found than other areas? Does your staff notice any difference in the numbers of carcasses found on your sections of Interstate vs. lower speed and/or lower volume highways?
10. Where do you dispose of carcasses? Please list all locations.
11. Are there associated costs with any of these disposal sites? Please quantify per carcass.

12. Has your staff experienced any injuries or illnesses that can be associated with removing and/or disposing animal carcasses? Please describe and estimate the frequency of occurrence and costs of lost time and worker's compensation claims annually.
13. Can you estimate the *annual total person hours and resources* (salaries, worker's compensation claims, disposal costs) that your district spends on carcass documentation, removal and disposal? What percentage is this of your annual budget? Do you dedicate specific funds in your budgets for carcass removal issues?
14. Does your district have any AVC mitigation techniques currently being applied (signs, fencing, underpasses)? Please describe all such mitigation measures.
15. How much time and funding do these mitigation applications require of your staff in order to maximize the usefulness of these measures?
16. Since the installation or application of these mitigation measures, has any of your staff observed any changes in animal movements and the occurrences of AVC carcasses?

Any additional related comments, suggestions, and observations are welcome, below. Thank you for your time.