EVALUATING WILDLIFE MORTALITY HOTSPOTS, HABITAT CONNECTIVITY, AND POTENTIAL MITIGATION IN THE MADISON VALLEY

FHWA/MT-16-016/8217-001

Final Report

prepared for
THE STATE OF MONTANA
DEPARTMENT OF TRANSPORTATION

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

November 2016

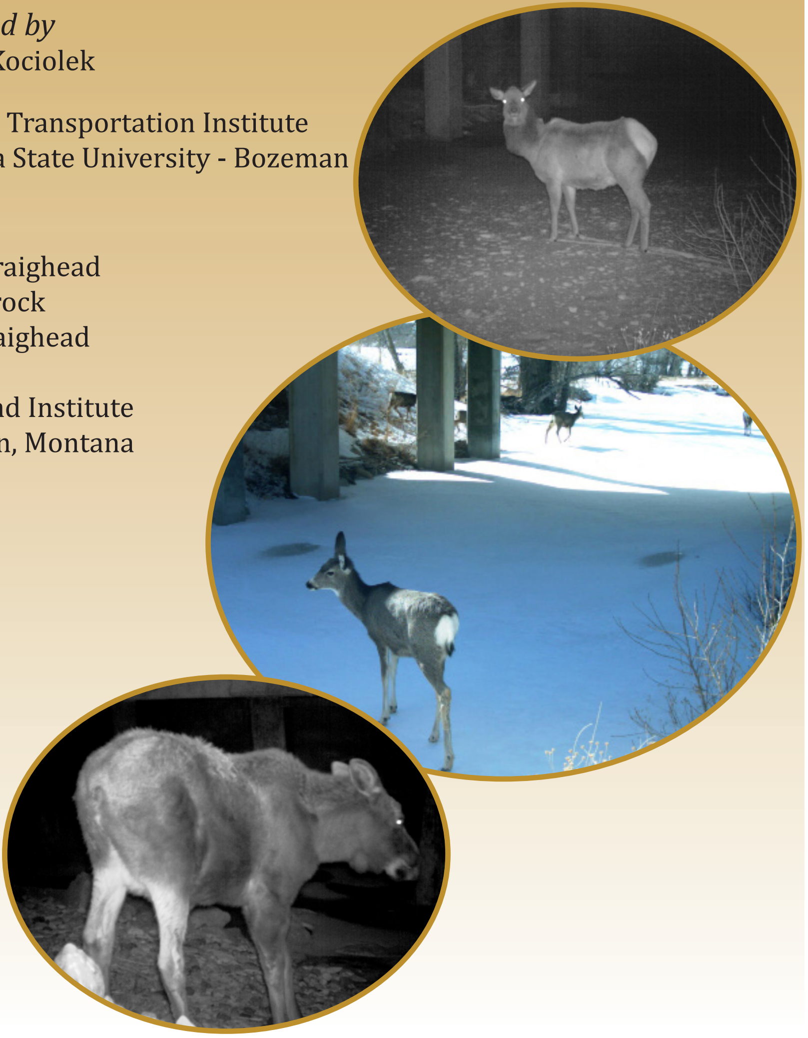
prepared by
Angela Kociolek

Western Transportation Institute
Montana State University - Bozeman

and

Lance Craighead
Brent Brock
April Craighead

Craighead Institute
Bozeman, Montana



RESEARCH PROGRAMS

Evaluating Wildlife Mortality Hotspots, Habitat Connectivity and Potential Accommodation along US 287 and MT 87 in the Madison Valley, Montana

FINAL REPORT

Prepared by:

Angela Kociolek, MSc
Western Transportation Institute
College of Engineering
Montana State University – Bozeman
and
Lance Craighead, PhD
Brent Brock, MSc
April Craighead, MSc
Craighead Institute
201 S. Wallace Avenue, Suite B2D
Bozeman, MT

Prepared for:
Montana Department of Transportation
2701 Prospect Avenue, P.O. Box 201001
Helena, MT 59620-1001
November 2016

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. **FHWA/MDT 16-016/8217-001**	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Evaluating Wildlife Mortality Hotspots, Habitat Connectivity and Potential Accommodation in the Madison Valley, Montana**	5. Report Date **November 2016** 6. Performing Organization Code	
7. Author(s) **Kociolek, A., L. Craighead, B. Brock and A. Craighead**	8. Performing Organization Report No.	
9. Performing Organization Name and Address **Western Transportation Institute – Montana State University** **PO 174250** **Bozeman, MT 59717-4250**	10. Work Unit No. 11. Contract or Grant No. **8217-001**	
12. Sponsoring Agency Name and Address **Research Programs** **Montana Department of Transportation (SPR)** **http://dx.doi.org/10.13039/100009209** **2701 Prospect Avenue** **PO Box 201001**	13. Type of Report and Period Covered **Final Report** **April 2012-November 2016** 14. Sponsoring Agency Code **5401**	

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

16. Abstract

The Madison Valley is situated in the Greater Yellowstone Ecosystem (GYE) and plays a key role in connecting this ecologically intact ecosystem to other intact areas of the Central Rockies, particularly the wildlands of central Idaho and the Selway-Bitterroot Ecosystem. US 287 and MT 87 were hypothesized to form a partial barrier for wildlife movement between protected lands around Yellowstone National Park, Hebgen Lake, and a large block of core wildlife habitat on public lands in the Gravelly, Snowcrest, and Centennial Mountains. These highways also bisect important winter range for ungulates. Traffic volumes are likely to increase in coming years, along with risk to motorists and impacts on wildlife. The overall objective of this project was to investigate the effect of the major highways in the Madison Valley on wildlife mortality and movement patterns. If data such as these are available in the early planning stages of highway projects, accommodation measures can be built into planned construction in a way that minimizes cost. The study area, in the Madison Valley, Montana, covered approximately 90 miles along the US 287 corridor from Norris Hill to the junction of US 191, including the portion of MT 87 from the US 287 junction to Raynolds Pass on the Montana-Idaho border. Wildlife carcass data were systematically collected three times per week, year-round for two years and then analyzed to determine patterns in carcass locations and identify hotspots. Animal location and movement data were also collected year-round over the two-year period, and photo monitoring was used to qualitatively assess species movement at 11 existing culverts and bridges. Data were also incorporated from other sources including recent telemetry data from state and federal agencies.

All data gathered were analyzed in the context of highway safety, infrastructure, wildlife use, habitat, and connectivity linkage zones, with special attention paid to ungulates and forest carnivores. A major outcome of this project was a GIS database of the study area that has the potential to help the Montana Department of Transportation (MDT) and other agencies increase efficiency and effectiveness of transportation and natural resource planning. This report presents the results of temporal and spatial analyses of wildlife road mortality data and animal use patterns and exploratory models examining the drivers of carcass locations in the vicinity of the highways. Recommendations are made for possible wildlife-highway accommodation measures involving MDT in partnership with other stakeholders. Similar methods applied to other areas may guide transportation agencies in making highway design improvements to reduce or eliminate wildlife road mortalities while increasing connectivity for wildlife.

17. Key Words **Animal behavior, Collisions, Data analysis, Evaluation and assessment, Fences, Geographic Information Systems, Habitat (Ecology), Highway safety, Madison Valley, Montana, Wildlife, Wildlife crossings, Ungulates**	18. Distribution Statement **Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161.**

19. Security Classif. (of this report) **Unclassified**	20. Security Classif. (of this page) **Unclassified**	21. No. of Pages **226**	22. Price

Disclaimers

This document is disseminated under the sponsorship of the Montana Department of Transportation (MDT) and the United States Department of Transportation (USDOT) in the interest of information exchange. The State of Montana and the United States assume no liability for the use or misuse of its contents.

The contents of this document reflect the views of the authors, who are solely responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or official policies of MDT or the USDOT.

The State of Montana and the United States do not endorse products of manufacturers.

This document does not constitute a standard, specification, policy or regulation.

This study focused on the effect of the major highways in the Madison Valley on road-related wildlife mortality and movement patterns. This study does not specifically address driver safety related to wildlife vehicle collisions. An in depth analysis of crash data as it relates to incidences and severity of wildlife related accidents was not completed for the purposes of this study.

Alternative Format Statement

MDT attempts to provide accommodations for any known disability that may interfere with a person participating in any service, program, or activity of the Department. Alternative accessible formats of this information will be provided upon request. For further information, call 406/444.7693, TTY 800/335.7592, or Montana Relay at 711.

Acknowledgements

We thank local community members and Montana Fish, Wildlife and Parks employees for their contributions to the carcass dataset. We also thank the Montana Department of Transportation Duck Creek and Ennis crews for their helpfulness. Thanks to volunteers, Stefan Michel and Malcolm Gilbert, who assisted with data collection and data entry, and to Vikina Martinez, who assisted with creating the graphs. Thanks also to Marcel Huijser for technical review. Finally, we are very grateful to Carla Little, whose editing and technical writing expertise greatly improved the final report.

Terminology Note

This report includes a discussion of wildlife-vehicle collisions (WVCs). The Montana Department of Transportation (MDT) has access to two databases containing information on wildlife vehicle collisions. The MDT Carcass database contains information on carcasses collected by MDT maintenance personnel; however, not all MDT Maintenance Sections consistently report the number of carcasses. Additionally, those Sections that do report carcasses may not have a regular schedule of when they go out to collect carcasses, making it difficult to match a carcass report to a crash report to ensure the carcass is not counted twice in a detailed study.

MDT also has access to wildlife vehicle collisions reported as accidents by or through the Montana Highway Patrol (MHP). This dataset is limited by the fact that many wildlife vehicle collisions are not reported, or if they are reported, it may be well after the time of the accident. Additionally, the crash form does not have a data field for the type of animal; however, the reporting officer may note in the narrative what type of animal was impacted.

It is important to note that the data collection methodologies employed for this project included roadkill surveys, in which researchers observed and recorded wildlife carcasses along the roadway. Not all carcasses can be absolutely verified as being the result of a WVC, or roadkill. Therefore, in the chapters that follow, this report refers to carcass locations, carcass hotspots, etc., when describing the data collected from the roadkill surveys (with the implied assumption that most if not all of the carcasses were the result of WVCs). In the data analysis discussions, the term wildlife-vehicle collision refers only to confirmed collisions (reported accidents) or the potential for a collision between wildlife and vehicles.

Table of Contents

Table of Figures

Table of Tables

Acronyms and Abbreviations

AIC	Akaike Information Criterion
CAPS	Crucial Areas Planning System
ChI	Craighead Institute
DEM	Digital Elevation Model
GIS	Geographic Information System
GPS	Global Positioning System
GYE	Greater Yellowstone Ecosystem
Hwy	Highway
IBA	Important Bird Area
IGBST	Interagency Grizzly Bear Study Team
IR	Infrared
KDE	Kernel Density Estimates
MDT	Montana Department of Transportation
MHP	Montana Highway Patrol
MTFWP/FWP	Montana Fish, Wildlife and Parks
MTNHP	Montana Natural History Program
MVRG	Madison Valley Ranchlands Group
NGO	Non-governmental Agency
NRCC	Northern Rockies Conservation Coop
NRIS	Natural Resource Information System
PDA	Personal Digital Assistant
ReGAP	Regional Gap Analysis Program (Montana Land Cover 2010)
ROCS	Roadkill Observation Collection System
ROW	Right-of-way
RP	Reference Post
RSF	Resource Selection Function
SBE	Selway Bitterroot Ecosystem
USFS	United States Forest Service
USGS	United States Geological Survey
WCS	Wildlife Conservation Society

WPCCD	Wild Planner Cumulative Current Density
WTI	Western Transportation Institute
WVC	Wildlife-vehicle collision

1 EXECUTIVE SUMMARY

On behalf of the Montana Department of Transportation (MDT), the Western Transportation Institute at Montana State University (WTI) and the Craighead Institute (ChI) conducted a two-year study to investigate the effect of the major highways in the Madison Valley on road-related wildlife mortality and movement patterns, and to identify locations and strategies for potential wildlife accommodations[1].

Along United States Highway 287 (US 287) and Montana Highway 87 (MT 87), wildlife-vehicle collisions (WVCs) can create a public safety risk and a habitat connectivity issue, which has generated some public concern. Prior to this project, the patterns and effects of WVCs and wildlife movements across this highway corridor had not been studied in depth.

Madison Valley is situated in the Greater Yellowstone Ecosystem (GYE) and plays a key role in connecting this ecologically intact ecosystem to other intact areas of the Central Rockies, particularly the wildlands of central Idaho and the Selway-Bitterroot Ecosystem (SBE). US 287 and MT 87 in Montana form a partial barrier for wildlife movement between protected lands around Yellowstone National Park, Hebgen Lake, and a large block of core wildlife habitat on public lands in the Gravelly, Snowcrest, and Centennial Mountains. They do not block movement completely for the species studied, but they can delay travel and may impose stress on resident wildlife. Although there is a growing body of data documenting animal movement across the highway by elk, grizzly bear, wolverine, and other species, the barrier effect of the highway and road-related wildlife mortality patterns were poorly understood prior to this study.

The overall objective of this project was to determine the effect of the major highways in the Madison Valley on wildlife mortality and movement patterns.

While this study focuses primarily on the effects of the highway corridor on wildlife connectivity, it is recognized that the movements of wildlife across highway corridors can be a serious concern from the perspective of safety for the travelling public. This study does not specifically address driver safety related to wildlife vehicle collisions. An in depth analysis of crash data as it relates to incidences and severity of wildlife related accidents was not completed for the purposes of this study. Any future implementation of the recommendations for wildlife accommodations put forth in this study must be further evaluated based on an in-depth analysis of both safety and connectivity considerations. The implementation of any wildlife accommodations within the Madison Valley are dependent on funding availability, cost-effectiveness, statewide transportation priorities, and the potential nomination and development of future highway projects within this corridor.

Species of interest from a safety perspective are any large-bodied animal:

- pronghorn (*Antilocapra americana*),
- bighorn sheep (*Ovis canadensis*),
- mountain goat (*Oreamnos americanus*),
- deer (*Odocoileus sp*.),
- elk (*Cervus canadensis*),
- moose (*Alces alces*), and

---

[1] For this report, the authors use the term “accommodation” because it is consistent with MDT terminology in their internal planning and guidance documents. In research literature and among road ecology specialists, the term “mitigation” is more widely recognized and used.

- bear (*Ursus sp.)*.

From a connectivity perspective, it is important to consider barrier effects that traffic may impose on species whose combined connectivity needs encompass those of all other species in the Madison Valley (Brock et al. 2006). These species are:

- grizzly bear (*Ursus arctos horriblis*),
- pronghorn,
- wolverine (*Gulo gulo*), and
- boreal toad (*Bufo boreas boreas)*.

The research team conducted systematic surveys on US 287 and MT 87 in the study area three times per week for two full years (April 2012 to April 2014), totaling 310 surveys. During the surveys, researchers recorded locations of carcasses and of live animals on or near (visible from) the highway. There was a minimum of one day and a maximum of two days between each survey.

The survey route was along the US 287 corridor from Norris to the junction of US 191 and included the portion of MT 87 from the US 287 junction to Raynolds Pass on the Montana-Idaho border. The survey route roughly resembles an upside-down "Y" and is approximately 90 miles (144 km) in length, 180 miles (290 km) round trip.

The research team also conducted photo monitoring to collect data on animal movement. A total of 12 remote-trigger infrared (IR) digital cameras (nine RECONYX PC85 Professional cameras, three RECONYX PC800 Hyperfire Professional IR cameras) were placed at 11 bridges or culverts. In addition, during winter months when snow conditions were favorable, the research team recorded locations where tracks crossed the highway throughout the study area.

Following data collection activities, the research team developed a Geographic Information System (GIS) database to facilitate data analysis for this project, and as an ongoing resource for MDT. The geodatabase was used to analyze existing and generated data in order to elucidate temporal and spatial patterns of carcasses and successful crossing sites. The existing and generated data, along with the data from remote cameras at potential crossing structures (bridges and culverts) were analyzed in the context of wildlife habitat, infrastructure, topography, land cover, land use, and land ownership. To the extent possible, ArcGIS Model Builder (a model development toolset in ArcGIS) was used to create automated processes for repeating analyses. This will allow analysts to easily run future analyses using the most up-to-date layers available for the area of interest.

Spatial correlations were calculated to examine whether carcasses are occurring in the same locations as general habitat use, as indicated by live observations and telemetry data, indicating that carcass locations are primarily a function of relative animal presence, or alternatively, if factors independent of relative animal use contribute to the likelihood that an animal will be struck by a vehicle (e.g. visibility). Secondly, the correlation between tracking and visual observations was tested to determine to what degree these observation methods were interchangeable. Finally, comparisons between elk GPS locations and elk observations derived from this study were tested.

Multiple linear regression models were also developed to explore which characteristics contribute to locations of carcasses. Full model development was beyond the scope of this project. Models presented should be considered preliminary. They are intended as "exploratory" to add to an understanding of which landscape features are contributing to the patterns of carcasses observed in this study. Further development with testing against independent data is necessary before the models should be applied to predict carcass locations in other areas.

Collectively, the data used for this report demonstrate that wildlife interact with the highways throughout the length of the study area. There are only two 1-mile (1.6 km) segments within the study area where no carcasses were observed (RP 14–15, and 17–18). Similarly there were few segments where animal tracks were not recorded or live animals were not seen.

Elk are the biggest concern in terms of motorist safety. They are the largest animals that are frequently hit by vehicles, and they occur in the greatest numbers in the vicinity of the highway in the Madison Valley. US 287 bisects important elk winter range, and elk prefer areas away from roads and other disturbance.

Overall, all four models (mule deer, white-tailed deer, elk, and pronghorn) performed generally well, with models explaining 69-93% of the variability in locations of carcasses depending on the species. However, it should be noted that predicted values were fitted to the same data used to train the models and represent a best case scenario of model fit. Comparisons with independent data would likely yield lower correlations.

In the final models, parameters estimating landscape development patterns ranked first (mean structure density) and third (Wild Planner Cumulative Current Density [WPCCD]) in importance overall and were included in four and three of the final models, respectively. Distance to fence corner ranked second and was included in all four models. Land cover and the remaining fence-related parameters ranked in the middle and were all included in three of the four models. Local structure density and visibility parameters ranked lowest in importance. However, species responses to individual parameters varied.

There are specific road sections that stand out where highway accommodation measures would increase motorist safety and/or benefit wildlife. The importance of the Madison Valley as winter range for ungulates will remain the same or perhaps increase in the future given the permanent habitat protections that exist in the form of government lands and conservation easements on private lands. Traffic will likely increase in the future. Accommodation measures of the appropriate type and size are an investment that will benefit motorists, sportsmen, wildlife watchers, and the general public. Such accommodation would promote safe passage of wildlife across a highway that acts as a partial barrier to movement and which bisects critical winter range.

2 INTRODUCTION

On behalf of the Montana Department of Transportation (MDT), the Western Transportation Institute at Montana State University (WTI) and the Craighead Institute (ChI) conducted a two-year study to investigate the effect of the major highways in the Madison Valley on road-related wildlife mortality and movement patterns, and to identify locations and strategies for potential accommodation measures. This final report summarizes the activities, findings and recommendations of this project.

The following introduction presents relevant context and background information for the project. It includes a discussion of the problem that the research addressed, the highway corridor where the project occurred, previous research in this area, and the goals and objectives of the project.

2.1 Problem Statement

MDT is responsible for maintaining 25,000 lane miles of roadway throughout the state (MDT 2015). In areas where wildlife populations are present, roads have ecological and safety impacts for both animals and humans.

The ecological effects of roads and vehicles are diverse and include 1) loss of habitat due to pavement or other unnatural substrate; 2) direct mortality by collisions with vehicles; 3) habitat fragmentation due to barriers that affect animal movements; and 4) reduced habitat quality adjacent to roads (e.g., because of chemical or noise pollution; Forman and Alexander 1998, Beckmann et al. 2010).

Roads not only affect wildlife; people are also at risk when large mammals enter the roadway. Between 1 and 2 million collisions with large animals occur in the United States each year, with about 29,000 human injuries and 135–200 human deaths (Conover et al. 1995, Khattak 2003, Huijser et al. 2008, Langley 2012). Total estimated costs of animal–vehicle collisions exceed $8 billion annually, including costs associated with vehicle repair, human injuries and fatalities, accident investigation, carcass removal and disposal, and the monetary value of the animal to hunters (Huijser et al. 2009).

Along United States Highway 287 (US 287) and Montana Highway 87 (MT 87), wildlife-vehicle collisions (WVCs) can create a public safety risk and a habitat connectivity issue, which has generated some public concern. Prior to this project, the patterns and effects of WVCs and wildlife movements across this highway corridor had not been studied in depth.

This research provides information regarding the wildlife populations that live along the corridor, where wildlife movements occur, the locations of collisions and carcasses, and potential accommodation measures that may be applicable and effective. The need for this information is relevant for several reasons:

1) traffic volumes are expected to increase throughout the west in coming decades along with WVCs, risk to motorists, and impacts on wildlife;
2) expanding populations of several species of interest (e.g., grizzly bear, wolverine) will continue to need safe crossing points across the highway to access habitat needs and to maintain gene flow;
3) land use change and/or other anthropogenic alterations to the environment may trigger species to shift to new areas in search of suitable habitat; because of the uncertainties of

these changes and how species ranges may shift, it is best practice to keep the landscape as permeable as reasonably possible to allow for wildlife adaptation; and

4) the data collected will inform the development of a process to assist with gathering and analyzing data regarding ecology and safety impacts for transportation projects.

Based on these challenges and information needs, this project was initiated to collect and analyze data regarding wildlife mortality and movement patterns along US 287 and MT 87. Results from this study will provide MDT with information to consider as opportunities arise in the future to address motorist safety and wildlife conservation in the Madison Valley. By viewing the data that emerges from this project in the context of previous work as well as current and future land use, this project has the potential to guide highway design improvements to reduce wildlife mortality, enhance safety for motorists, and increase connectivity for wildlife.

While this study focuses primarily on the effects of the highway corridor on wildlife connectivity, it is recognized that the movements of wildlife across the highway corridor are a serious concern from the perspective of safety for the travelling public. This study does not specifically address driver safety related to wildlife vehicle collisions. An in depth analysis of crash data as it relates to incidences and severity of wildlife related accidents was not completed for the purposes of this study. Any future implementation of the recommendations for wildlife accommodations put forth in this study must be further evaluated based on an in-depth analysis of both safety and connectivity considerations. The implementation of any wildlife accommodations within the Madison Valley are dependent on funding availability, cost-effectiveness, statewide transportation priorities, and the potential nomination and development of future highway projects within this corridor.

TERMINOLOGY NOTES:

Wildlife Vehicle Collisions: This problem statement included a discussion of wildlife-vehicle collisions (WVCs). It is important to note that the data collection methodologies employed for this project employed roadkill surveys, in which researchers observe and record wildlife carcasses. Not all carcasses can be absolutely verified as being the result of a WVC, or roadkill; therefore, in the chapters that follow, this report refers to carcass locations, carcass hotspots, etc., when describing the data collected from the roadkill surveys (with the implied assumption that most if not all of the carcasses were the result of WVCs). In the data analysis discussions, the term wildlife-vehicle collision refers only to confirmed collisions between wildlife and vehicles.

Wildlife Accommodation: For this report, the authors use the term “accommodation” because it is consistent with MDT terminology in their internal planning and guidance documents. In research literature and among road ecology specialists, the term “mitigation” is more widely recognized and used.

2.2 Corridor Description

Madison Valley is situated in the Greater Yellowstone Ecosystem (GYE) and plays a key role in connecting this ecologically intact ecosystem to other intact areas of the Central Rockies, particularly the wildlands of central Idaho and the Selway-Bitterroot Ecosystem (SBE). US 287 and MT 87 in Montana form a partial barrier for wildlife movement between protected lands around Yellowstone National Park, Hebgen Lake, and a large block of core wildlife habitat on public lands in the Gravelly, Snowcrest, and Centennial Mountains. They do not block movement completely for the species studied, but they can delay travel and may impose stress on resident wildlife. Although there is a growing body of data documenting animal movement across the highway by elk, grizzly bear, wolverine, and other species, the barrier effect of the highway and road-related wildlife mortality patterns were poorly understood prior to this study.

The study area is displayed in Figure 1.

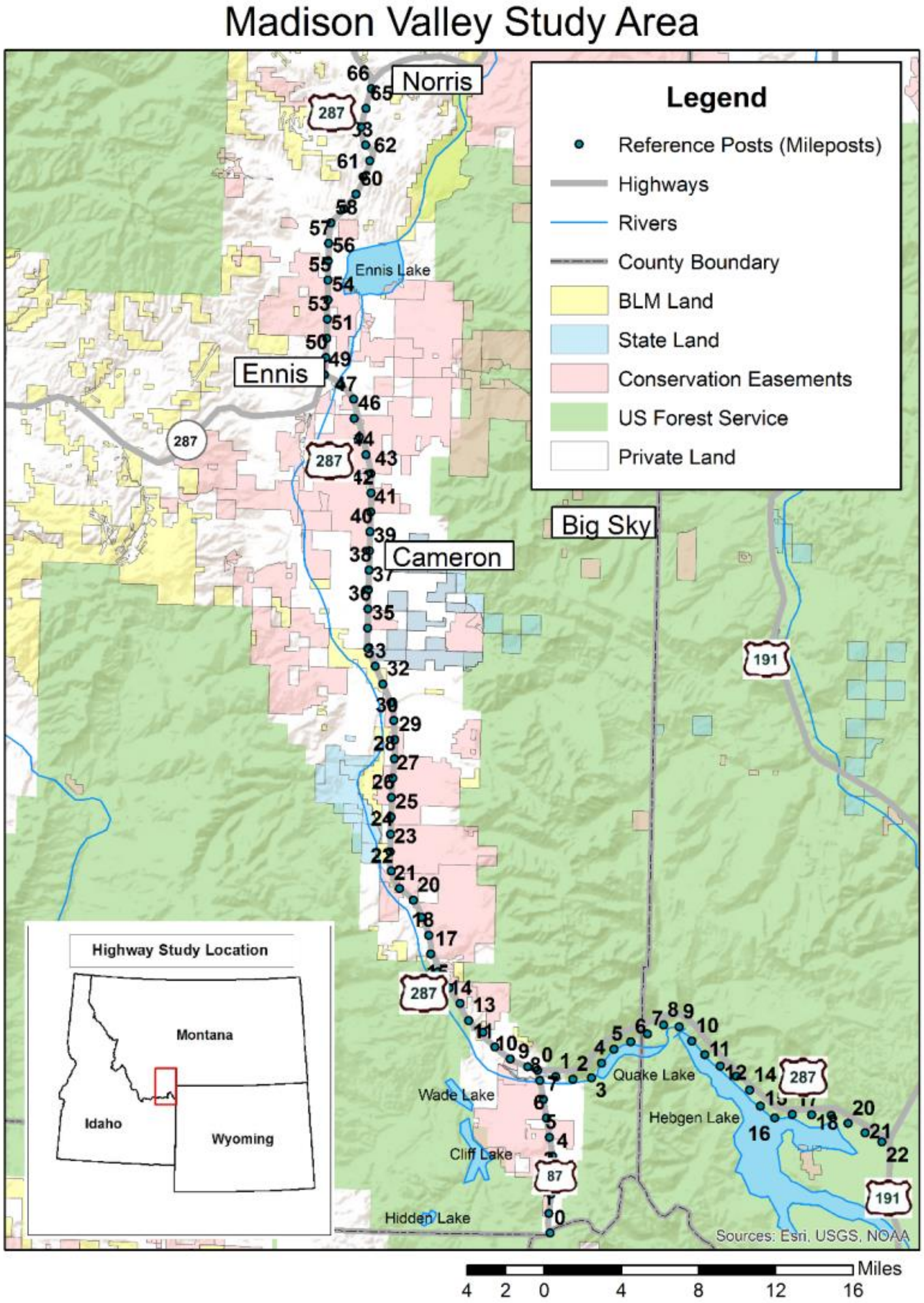


Figure 1. Study area map with reference posts labeled.

2.3 Previous Research

The Craighead Institute (ChI, formerly Craighead Environmental Research Institute) began mapping wildlife habitat and potential movement corridors in the Madison Valley in 1996 and identified the need for a better understanding of highway impacts on wildlife. The need for data on spatial patterns of wildlife mortalities and accommodation opportunities in the Madison Valley was reinforced by growing concern among Madison Valley residents about impacts on local wildlife.

Past wildlife habitat and connectivity modeling by ChI and the Wildlife Conservation Society (WCS) identified three key areas for wildlife movement:

1) the Northern Linkage between Norris Hill and North Meadow Creek,
2) the riparian strips along the Eastern Drainage Linkage including Jack and Indian Creeks, and
3) the Southern Linkage extending from Papoose Creek to Raynolds Pass.

FWP biologists identified a fourth area of concern along US 287 near Hebgen Lake.

These four areas comprised the major focus for this project in terms of deploying monitoring tools (i.e., cameras) during the data collection process. However, data were collected along the entire length of the study area in order to identify additional crossing sites, movement barriers, and other possible effects of the highway on animal behavior. These methodologies are discussed in greater detail in Chapter 4. As part of the literature review process, researchers identified additional background information on wildlife-highway accommodation in the Madison Valley (Chapter 3).

2.4 Goals and Objectives

As a result of the previous research and in response to public concern about safety and wildlife mortality along the Madison Valley corridor, MDT conducted a series of discussions that led to this two-year field study to generate credible data about the location of mortalities, habitat connectivity, and recommendations for accommodation opportunities, as well as the development of a study protocol and GIS database for future transportation-related wildlife evaluations.

The overall objective of this project is to determine the effect of the major highways in the Madison Valley on wildlife mortality and movement patterns. Species of interest from a safety perspective are any large-bodied animal:

- pronghorn (*Antilocapra americana*),
- bighorn sheep (*Ovis canadensis*),
- mountain goat (*Oreamnos americanus*),
- deer (*Odocoileus sp.*),
- elk (*Cervus canadensis*),
- moose (*Alces alces*), and
- bear (*Ursus sp.).*

From a connectivity perspective, it is important to consider barrier effects that traffic may impose on species whose combined connectivity needs encompass those of all other species in the Madison Valley (Brock et al. 2006). These species are:

- grizzly bear (*Ursus arctos horriblis*),

- pronghorn,
- wolverine (*Gulo gulo*), and
- boreal toad (*Bufo boreas boreas)*.

Specific goals and tasks developed for this project included:

- Conduct a literature review of the state of the practice of wildlife-highway accommodation measures and land use planning documents specific to the Madison Valley.
- Acquire existing data on roads and traffic, animal movements, and relevant GIS information about the corridor and surrounding area, and conduct reconnaissance of the area to collect additional spatial data.
- Conduct systematic carcass surveys of the study area for a two-year period.
- Conduct year-round wildlife monitoring to collect animal movement data for a two-year period.
- Develop a GIS database (in a format consistent with MDT standards) based on GIS data and map results for future transportation-related wildlife evaluations.
- Analyze the data gathered in the context of highway safety and connectivity linkage zones. Map data to determine movement patterns and to identify mortality hotspots.
- Identify accommodation opportunities that reduce risk to motorists and enhance connectivity, based on existing conservation easements, county land-use planning and future trends.

2.5 Organization of Report

The remaining chapters of this report are organized as follows. Chapter 3 summarizes key findings from the Literature Review that are relevant to the project. Chapter 4 describes the methodology for the data collection and wildlife monitoring, as well as the data analysis process. Chapter 5 describes the results from the data collection and analyses tasks, organized by species, and Chapter 6 summarizes conclusions drawn from the results. Chapter 7 describes the resources and recommendations that were developed as part of this project; this includes the GIS database, a protocol for future evaluations, accommodation opportunities, and issues for future research. Additional resources, such as an acommodations bibliography, detailed monitoring data, and sample remote camera images, are included in the Appendices.

3 LITERATURE REVIEW AND BIBLIOGRAPHY

3.1 Overview

At the outset of the project, the research team consulted literature on various topics related to this project.

The literature review focused on identifying information related to land use planning in Madison Valley. Key findings have been summarized in Section 3.2.1 (Subdivision Impacts on Wildlife) and Section 3.2.2 (Land Use Planning in the Madison Valley). A more comprehensive version of this literature review is included as Appendix A (9.1).

In addition, the research team identified extensive literature related to the state of the practice of wildlife-highway accommodation measures. Key findings that are potentially relevant to safety and accommodation measures in Madison Valley are summarized in Section 3.3 (Safety and Wildlife-highway Accommodations). Furthermore, the wildlife-highway accommodation literature was compiled into a bibliography with the following subtopics: *Overview of Issues and Solutions*; *Wildlife–Vehicle Collision Reduction*; *Planning and Funding Wildlife Crossing Structures*; *Placement, Design and Evaluation of Wildlife Crossing Structures*; *Roadside Animal Detection Systems*; *Simple Strategies to Reduce Road Impacts to Wildlife and the Environment*; and *Habitat Conservation, Corridor Design and Context-Sensitive Solutions*. The bibliography is included as Appendix B (9.2).

3.2 Land Use Planning Issues

3.2.1 Subdivision Impacts on Wildlife

Conversion of rural lands for human housing is the most pervasive form of land use change affecting wildlife habitat in the American West (Brown et al. 2005). Based on the literature reviewed, the research team concluded that rural development significantly alters patterns of species abundance. Although native species often decrease with increasing housing density while non-natives increase, individual species responses are complex. Individual species responses may be increasing, decreasing, or non-linear, often with sharp thresholds of decline. Wildlife species differ in their tolerance of human development with the most sensitive species disappearing at lower densities of development than more tolerant or human-adapted species.

These impacts extend well beyond the development footprint. For example, a study that included the Madison Valley suggested that reduced reproductive success of yellow warblers in rural development “hot spots” could affect populations in adjacent nature preserves 6 km (3.7 miles) away (Hansen et al. 2002, Hansen and Rotella 2002). In another example, Cleveland (2010) found that elk in Montana moved faster when they approached within 750 meters (1/2 mile) of houses and preferred areas 1600 meters (1 mile) from human development.

The literature identifies several mechanisms responsible for changes in species abundance, including:

- Habitat alteration,
- Alteration of biotic interaction,
- Human disturbance, and
- Alteration of ecological processes.

Because the impacts vary substantially by species, the research team identified literature addressing impacts on ungulates, due to their cultural and economic importance in Montana, as well as their relevance to this study on the Madison Valley corridor. Based on in-depth syntheses provided by Polfus (2011) and Polfus and Krausman (2012), it can be deduced that subdivisions have the potential to alter ungulate movement patterns and road crossing behaviors in several ways. Because ungulates often avoid rural developments, movement patterns can be altered as their populations decline or they avoid formerly preferred habitats by moving elsewhere. If development blocks a migration path, then movement patterns may be significantly altered for many miles beyond development boundaries. Additionally, increased vigilance and flight associated with human developments could increase the frequency of panicked animals running into traffic. Finally, habituated ungulates in developed areas may cease migratory behavior and therefore alter road crossing patterns along the traditional migration route. Simultaneously, permanent concentrations of habituated ungulates near dwellings would likely create localized increases in ungulate road crossings and increase potential for animal–vehicle collisions.

3.2.2 Land Use Planning in the Madison Valley

Human development patterns influence patterns of wildlife habitat use and movement, and therefore, land use planning should be integrated into efforts to accommodate the impacts of roads on wildlife and improve transportation safety. In recent years, significant progress has been made toward improving land use planning to protect wildlife resources. This section identifies key provisions of state and local law and policy that govern land use planning in Madison Valley.

3.2.2.1 State Law

At the state level, land use planning is guided by the Montana Subdivision and Platting Act (76-3-608(3), MCA). There are several provisions that influence local land use planning with regard to planning for environmental impacts:

- The Act requires counties to review subdivision applications based on a minimum of seven public interest criteria, including
    - effect on wildlife
    - effect on wildlife habitat
- The Act also defines certain requirements for subdivision applications. Unless a subdivision application is exempted by the Montana Subdivision and Platting Act, developers must submit an environmental assessment with their application for subdivision.

3.2.2.2 Madison County Policy and Regulations

The Madison County Growth Policy and Madison County Subdivision Regulations reflect the requirements of state law. In 2007 the County adopted a *Revised Growth Management Action Plan for the Madison Valley,* which was incorporated into the Madison County Growth Policy in 2013 (Madison County, 2013). These documents include several provisions that address the protection of wildlife and wildlife habitat:

- Policy Goals. One of the growth policy goals calls for protection of the environment, including "the quality of our air, groundwater, surface waters, soils, vegetation, fish and wildlife habitat, scenic views, cultural and historic resources." The objectives within this goal include:
    - Promote best management practices by all land users.
    - Encourage new development that is compatible with the environmental goals and objectives of this Plan.
    - Support the establishment, expansion, and upgrading of community sewer/water systems.
    - Review new development proposals for the full spectrum of potential and cumulative environmental impacts.
    - Where necessary, more clearly define the resources we want to protect.
    - Promote noxious weed control.
- Subdivision Applications.
    - Unless exempted by state law, developers must submit an environmental assessment with their application for subdivision. County regulations require the assessment to include specific wildlife provisions, including:
        - Identification of species affected
        - Identification of plans of known wildlife areas, such as habitats, nesting areas and wetlands
        - Descriptions of proposed measures to protect habitat.
    - The subdivider must also show that the environmental assessment has taken into consideration the public interest criteria cited in state law (which include effect on wildlife and effect on habitat). The county regulations include a detailed list of nine questions to guide developers in identifying and assessing potential impacts on wildlife.
- Land Stewardship Plan. The Growth Policy recommends that new developments should include a land stewardship plan that "addresses management responsibility for such things as noxious weed control, public access (where provided), wildlife, livestock grazing, other agricultural uses, recycling, and protection of water resources." The Madison County Subdivision Regulations require submission of a land stewardship plan. The wildlife provisions of the stewardship plan call for developers to identify measures that will be implemented to "avoid habituating the wildlife, harassing the wildlife, obstructing wildlife migration patterns, unnecessarily attracting dangerous wildlife, and/or causing game damage on adjoining properties."

3.2.3 Madison Valley Wildlife Planning Studies and Guidance Tools

Implementation of the Madison County Growth Policy to protect wildlife and their habitats depends on good scientific information and appropriate tools to translate that information into sound land use decisions. The research team identified several studies regarding wildlife in Madison Valley, and several tools for conducting wildlife planning. These studies and tools are described in the full version of the literature review in Appendix A (9.1).

3.3 Safety and Wildlife Accommodation Measures

The research team identified extensive literature related to the state of the practice of wildlife-highway accommodation measures. This section summarizes key findings that are potentially relevant to safety and accommodation along the Madison Valley corridor (see also full bibliography in Appendix B (9.2)).

3.3.1 Safety

Wildlife mortalities along roadways, particularly those related to WVCs, can have safety implications for travelers. Mortality hotspots may warrant accommodation measures for enhancing safety benefits as well as reducing impacts to wildlife.

The literature reviewed suggests that WVCs are on the rise. Huijser et al. (Report to Congress, 2008) concluded that animal-vehicle collisions increased by approximately 50% from 1990 – 2004. The same report estimates that only small proportions of these collisions result in injury (4-10%) or fatality (0.5%). However, these safety risks also appear to be increasing; for example, Sullivan (2011) concluded that fatal animal-vehicle collisions doubled from 1990 – 2008.

Based on national Fatality Analysis Reporting System (FARS) data, Montana had 66 fatal animal collisions from 1990 – 2008. Proportionally, Montana has the second highest rate of fatal animal crashes, when viewed as a percentage of total animal-vehicle collisions (Sullivan, 2011).

3.3.2 Wildlife Accommodation Techniques

As interest has increased in reducing WVCs for both safety and environmental concerns, researchers have expanded research into the effectiveness of various accommodation techniques. In a national study, Huijser et al. (Report to Congress, 2008) reviewed 34 techniques and identified several types that are regarded as good practice or show promise for reducing WVCs; these techniques included integrated planning efforts, wildlife fencing and wildlife crossing structures, animal detection systems, and public information and education. However, the report also concluded that “there is no single, low-cost solution for WVCs that can or should be applied everywhere. A successful mitigation strategy requires a detailed, location-specific analysis of the problem and often involves a combination of different types of mitigation measures.”

In similar research specific to Montana, Huijser et al. (2007) reviewed 39 measures that reduce animal-vehicle collisions and provide habitat connectivity for wildlife across highways, with a focus on measures targeted at animals that are deer size or larger. These options were grouped into three categories:

- Fourteen measures that modify traffic and/or driver behavior;
- Thirteen measures that use small or minimal infrastructure to attempt to modify animal behavior or influence population size; and
- Twelve measures that use large infrastructure to alter animal behavior or physically separate animals from roadways.

The research evaluated the costs and benefits of each measure, addressed implementation pros and cons, and discussed the suitability of the measures to reduce collisions and to provide safe crossing opportunities for different species and species groups in Montana.

3.4 Implications for Madison Valley Corridor

The literature review and bibliography developed for this task informed the subsequent research, particularly analyses, conclusions and recommendations. The following key findings had significant relevance or implications for assessing highway safety and impacts on wildlife along the Madison Valley corridor:

- Impacts of land use and land development on wildlife, particularly elk
- Highway accommodation measures aimed at increasing safety and reducing risk to motorists
- Highway accommodation measures aimed at maintaining or increasing wildlife habitat connectivity

The bibliography provides extensive supplemental information, which can serve as a reference to MDT in any future efforts to consider accommodation measures in the Madison Valley.

4 METHODS

This section describes the methods used by the research team to collect and analyze data for evaluating wildlife mortality and connectivity in the context of motorist safety along the Madison Valley highway corridor.

4.1 Existing Data Layers

Prior to the collection of new data, the research team gathered relevant existing data from a variety of sources.

Through interviews with biologists and organization representatives working in the Madison Valley, the team conducted an inventory of existing data that could be used to build the foundation of data layers for the GIS database, and that would support the analysis of data collected in subsequent tasks. Researchers identified available data for the corridor and surrounding area, with a focus on:

- Animal movements
- GIS information
- Motorist safety
- Road characteristics

Many of the data layers identified are periodically or continuously updated. Therefore, researchers submitted requests for some of the data layers needed at a later date to ensure analyses were based on the most recent data available.

Through this process, the team identified 27 relevant existing datasets pertaining to wildlife, connectivity, highway characteristics, and county planning. A description listing is included in Appendix C (9.3).

4.2 Generated Data

Over the course of the project, the team collected several sources of new data. This section describes the activities that supported the collection of new data, focusing on the methods for the four main components of data collection: carcass surveys, live animal observations, photo monitoring, snow tracks and other data.

4.2.1 Carcass Surveys

A key component of this project entailed the collection of wildlife mortality data. In order to collect a robust dataset, the research team conducted systematic carcass surveys on Hwy 287 and 87 in the study area three times per week for two full years (April 2012 to April 2014). There was a minimum of one day and a maximum of two days in between each survey. Researchers conducted a total of 310 surveys over the course of the data collection period.

The carcass survey route was along the US 287 corridor from Norris to the junction of US 191 and included the portion of MT 87 from the US 287 junction to Raynolds Pass on the Montana-Idaho border. The survey route roughly resembles an upside-down “Y” and is approximately 90 miles (144 km) in length, 180 miles (290 km) round trip (Figure 1).

To conduct the survey, researchers began at Norris and drove the entire round trip back to the starting point in one trip (unless circumstances or conditions warranted conducting the full survey in separate parts). The surveyor stopped at each carcass to record the following data using a Roadkill Observation Collection System (ROCS) unit Personal Digital Assistant/Global Positioning System (PDA/GPS) device:

- Latitude and longitude
- Species (or other taxonomic classification if identification to species was not possible)
- Sex of animal (if possible)
- Age (adult or juvenile, if possible)
- Additional useful comments or observations in free text

If the ROCS unit was unavailable, the surveyor used a handheld Garmin Vista GPS recorder to document latitude, longitude, and waypoint number. Additional observations were recorded in a field notebook and transcribed later into an Excel database along with the GPS data to be combined with the ROCS data.

Despite the systematic nature of the carcass surveys (3 days/week), the carcasses counted were likely a subset of the actual number of animals killed. Therefore, the data reflect the minimum number of carcasses. This is due to inevitable scavenger bias whereby a road-killed animal may be consumed by a scavenger before it is detected by the surveyor, or searcher bias whereby the surveyor misses carcasses that may be camouflaged, out of view or beyond the right-of-way boundary. Carcasses may also be removed by MDT personnel or the public, as discussed below.

To check survey accuracy, additional unscheduled carcass surveys were conducted on several occasions. These surveys were often completed on the same day as scheduled surveys, or within one day of scheduled surveys. However, they were often done opportunistically and recorded only the species and approximate reference post (RP) location. Because of the low number of carcasses present along the highway at any one time, there was little chance of confusing one carcass location with another if they were recorded by RP by one method versus GPS location by another method. Since opportunistic records were used mainly to assess the accuracy of the systematic search effort, they were not combined with those data. Moreover, no carcasses were found that had not been recorded during systematic surveys.

It is important to remember that even the systematic surveys are only an index of the total number of carcasses. If this study were being compared to another study and survey effort per carcass was an important variable, then only those carcasses recorded during regular surveys should be used. However, the primary purpose of this effort was to collect a more representative index of animals killed; therefore other sources of carcass data in the final totals were acquired and included.

In addition to these direct data collection efforts, the research team also identified and gathered several other sources of carcass data:

- MDT carcass removal data.
- The Montana Department of Fish, Wildlife, and Parks (FWP) carcass removal data and salvage permit data.
- Other miscellaneous carcass reports from various researchers.
- Carcass observations reported by interested landowners. These reports were investigated by the WTI field biologist and those deemed credible were included in the data set. An example of a landowner carcass report is displayed in Figure 2.

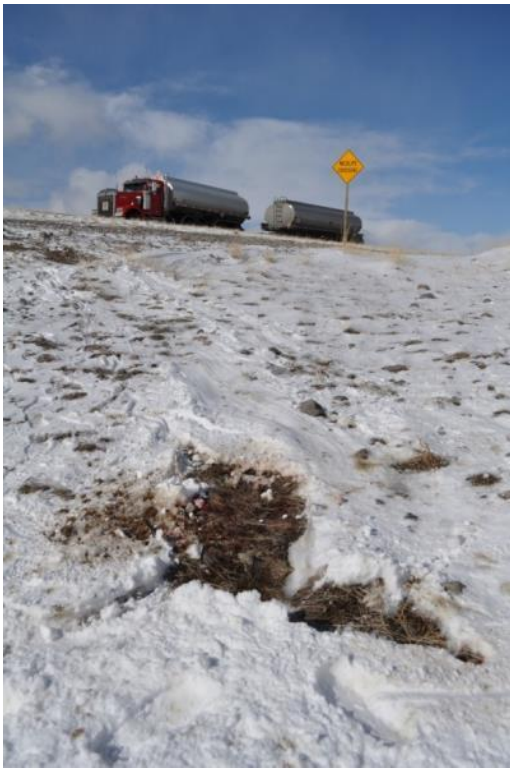


Figure 2: This photo shows the outline in the snow of an elk that had already been removed from the roadside. The field biologist took this photo while investigating and confirming a carcass location that was reported by a landowner (photo by Western Transportation Institute).

4.2.2 Live Animal Observations

During the carcass surveys, researchers also recorded locations of live animals on or near (visible from) the highway. The following information was documented from these observations:

- A GPS location recorded at a point on the highway that was approximately perpendicular to the animal location
- Species
- Estimated number of animals
- Estimated distance from the highway
- Direction from the highway

The team recorded the information using the ROCS device used for the carcass surveys. As with carcass surveys, when the ROCS unit was not available, similar data were recorded using a Garmin Vista handheld GPS unit.

In general, only animals within about 500 m (546 yards or 0.3 miles) of the highway were recorded. However, during the winter large herds of elk were often visible at greater distances and their locations were also recorded.

Animal location data were located in the GIS database by producing a point location at the approximate spot the herd was seen (using the GPS location and the offset distance). Each point was attributed with the species and number of animals.

At distances greater than 500 m (546 yards or 0.3 miles) from the highway, researchers generally were not able to observe and record animals, because at that distance animals are difficult to spot, especially while driving. When the group sizes or individual animals were larger, it was more likely that observers were able to see wildlife at a greater distance. Because of this, it is difficult to directly compare, for example, the number of coyotes to the number of elk observed or the number of pronghorn observed at a close range to the number observed at a greater distance.

4.2.3 Photo Monitoring

The research team conducted photo monitoring to collect data on animal movement. A total of 12 remote-trigger infrared (IR) digital cameras (nine RECONYX PC85 Professional cameras, three RECONYX PC800 Hyperfire Professional IR cameras) were placed at 11 bridges or culverts (Table 1).

Table 1. Table showing remote camera locations and installation dates.

Camera Location	Location (Hwy)	Location (RP)	Date Installed	Date Uninstalled	# Days Installed
Beaver Creek bridge (east end)	287	7.3	16-Apr-12	7-Apr-14	721
Indian Creek bridge	287	29.6	16-Apr-12	2-Apr-14	716
N. Meadow Creek bridge	287	57.5	16-Apr-12	2-Apr-14	716
Underpass south of Madison R. bridge	287	48.4	2-May-12	4-Apr-14	702
Grayling Creek bridge	287	20	2-May-12	7-Apr-14	705
Madison River bridge at Ennis	287	48.5	16-Jun-12	7-Apr-14	660
O'Dell Creek bridge	287	48	16-Jun-12	4-Apr-14	657
Beaver Creek bridge (west end)	287	7.3	16-Jun-12	7-Apr-14	660
Stock culvert at RP 5.2	87	5.2	16-Jun-12	29-Jan-14	592
Stock culver at RP 3.5	87	3.2	16-Jun-12	31-Mar-14	653
Stock culvert at RP 6.7	87	6.7	23-Jun-12	28-Mar-14	643
Madison River bridge, Hwy 87	87	8.1	26-Sep-12	4-Apr-14	555

The locations are displayed on the map in Figure 3. Photos of the camera locations and sample images are displayed in Appendix K (9.11).

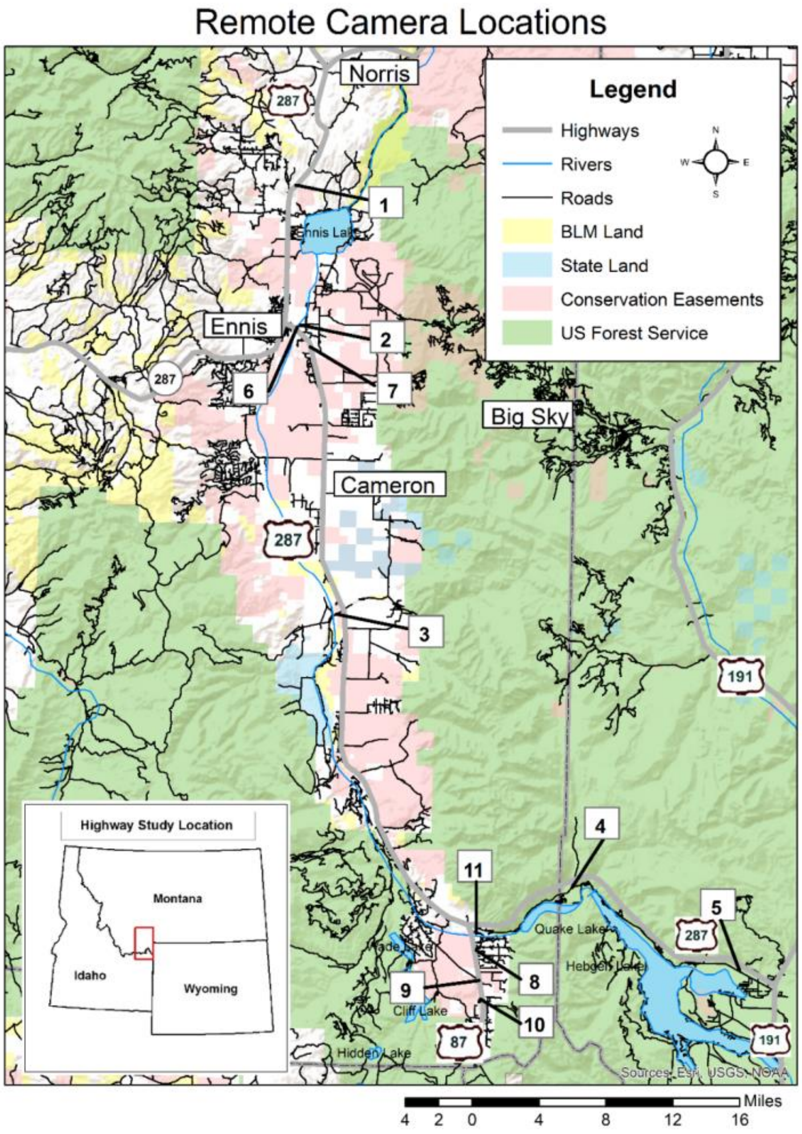


Figure 3: Study area map with camera locations. The cameras are numbered in the order in which they were installed (There are two cameras at location 4).

For each event in which wildlife were present under or near an underpass, the following data were recorded:

- Underpass location
- Species (or other taxonomic classification if identification to species was not possible)
- Number of each species
- Date
- Time

In addition to wildlife use, human use and crossings at these structures were also recorded and tabulated. These data were anecdotal and were intended to elucidate current wildlife and human use at existing structures. These data are summarized and presented in Appendix F (9.6).

Researchers calculated a minimum of the number of days that each camera was in operation to facilitate comparison with data from other projects. In some instances, it was not possible for the team to determine the exact number of days that the cameras were in operation (i.e. if the. batteries died before being replaced). Also, some remote cameras were not operational at times due to extreme cold temperatures, blowing snow, snow drifts, and other environmental factors (Figure 4).

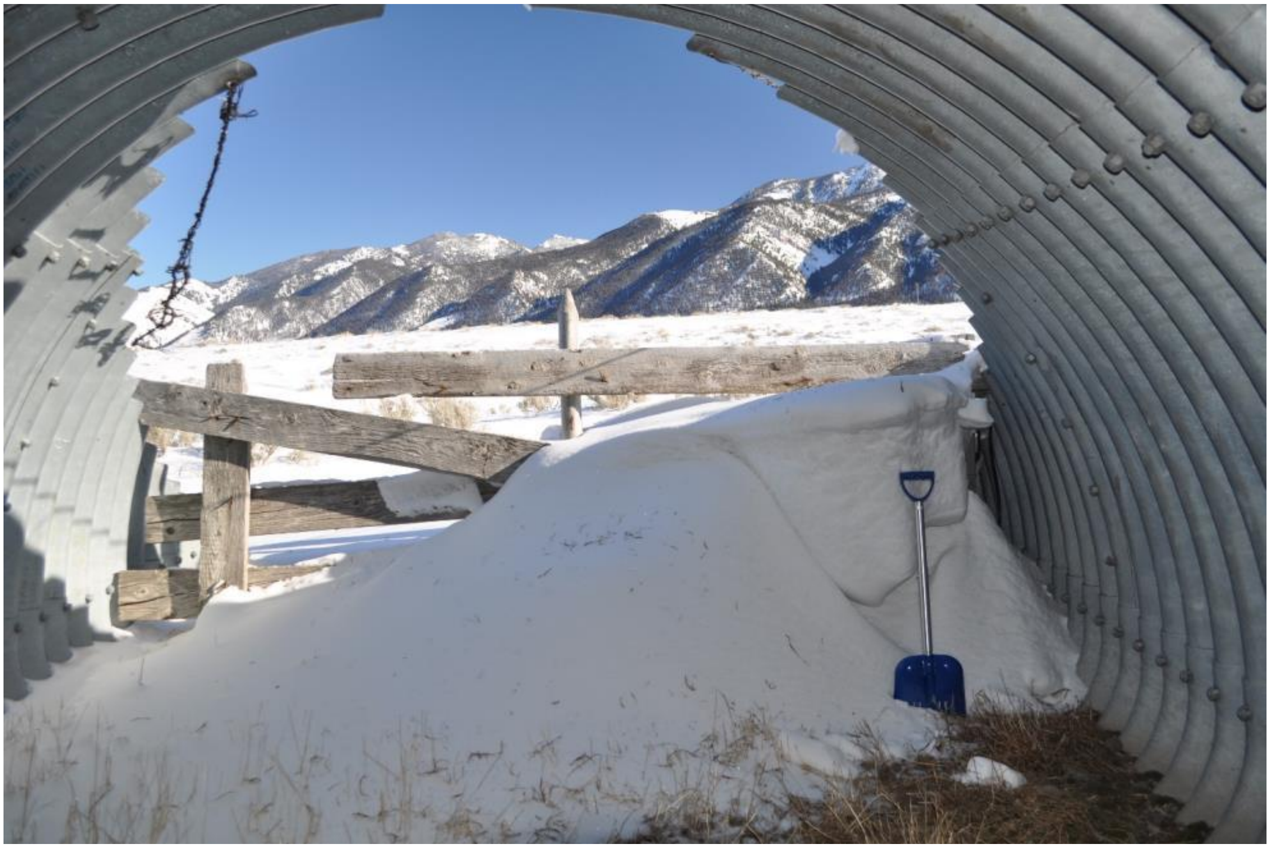


Figure 4. This photo shows a remote camera covered by a snow drift, one of the environmental factors reducing the number of days remote cameras were operational (photo by Western Transportation Institute).

The data gathered from these cameras do not constitute a rigorous survey of the number of animals using crossing structures, but are a sample, or indication, of the species and provide rough estimates of relative use by those species.

4.2.4 Snow Track Crossing Locations

During winter months when snow conditions were favorable, the research team recorded locations where tracks crossed the highway throughout the study area. These track crossing locations were recorded either with the ROCS unit or the handheld Garmin Vista device (used with a field notebook). For each observed snow track crossing, the following data were recorded:

- Species (or other taxonomic classification if identification to species was not possible; e.g., mule deer and white-tailed deer tracks are indistinguishable and so were recorded as deer species combined)
- Estimated number of animals that crossed
- Location (Longitude/Latitude and Highway/Milepost)
- Date

Surveys focused on large animal tracks (primarily ungulates) that are of concern from a motorist safety standpoint. Other tracks, however, were recorded when observed. Few track locations were recorded during the first winter of the study due to poor snow conditions. Favorable snow conditions during the second winter allowed many track locations to be recorded.

4.2.5 Generated Data Layers

Researchers also collected data in the field to supplement the existing data sets (discussed in 4.1). These data were used to produce new data layers (Table 2) for development of the GIS database and subsequent analysis activities. The new layers were merged with the previous layers obtained from other sources.

Table 2. Generated data layers.

Type of data	Format	Measurement Method
Culvert locations (greater than 12” diameter)	Latitude/longitude	GPS
Bridge locations	Latitude/longitude	GPS
Infrastructure (fences)	Latitude/longitude	GPS
Camera locations	Latitude/longitude	GPS
Reference Posts	Latitude/longitude	GPS
Distance between Reference Posts	1/10th mile increments	Odometer

Measurement note: Reference posts (RPs) are the primary metric used in highway design, maintenance, repair, and re-construction. However, the ROCS and GPS units used in the study record location data in latitude/longitude. To convert GPS locations to the nearest 1/10 mile between RPs, researchers used an ArcInfo script that determines the nearest 1/10 mile marker to the GPS location of a record and applies this to all RPs. This assumes a uniform distance of 1 mile between RPs. Alternately, if RPs are much greater, or less, than a mile apart, the nearest 1/10th marker can be calculated on an individual RP basis. To determine if this approach was applicable, the research team measured the distance between all RPs using vehicle odometers. Two sets of measurements were taken, and both sets revealed that only one of the reference posts may be more than 1/10th of a mile in error (Appendix D (9.4)). Although odometers are not precise to the 1/10 increment, they are the instruments commonly used by maintenance crews and field surveys. The research team feels that the similarity in distance between RPs is close enough that carcass locations recorded by ROCS units can be translated into 1/10th RP units for the purposes of this study.

4.3 GIS Development

Following data collection activities, the research team developed a Geographic Information System (GIS) database to facilitate data analysis for this project and as an ongoing resource for MDT. Twenty-two of the 27 existing data layers were used.

The team compiled GIS data and map results in a format consistent with MDT standards. The geodatabase includes the existing and generated data and data layers described above in sections 4.1 and 4.2.

Researchers bundled data layers into file geodatabases that are compatible with ArcGIS and facilitate data organization and transfer. Layers required for each step of analysis were formatted and brought into the geodatabase as needed. This approach results in a geodatabase that is efficient and as compact as possible, without any extraneous data layers that take up storage and memory and can slow down processing time.

The geodatabase was used to analyze the existing and generated data in order to elucidate patterns of carcasses and successful crossing sites. The existing and generated data, along with the data from remote cameras at potential crossing structures (bridges and culverts) were analyzed in the context of wildlife habitat, infrastructure, topography, land cover, land use, and land ownership. To the extent possible, ArcGIS Model Builder (a model development toolset in ArcGIS) was used to create automated processes for repeating analyses. This will allow analysts to easily run future analyses using the most up-to-date layers available for the area of interest. Model Builder is a standard scripting toolset built into ArcGIS, so it is easily accessible by anyone using that software. It also has the capabilities and adaptability necessary for the types of analyses conducted for this project.

4.4 Data Analysis

Using all the collected data and the geodatabase, the research team analyzed all data gathered in the context of highway safety and connectivity linkage zones. Researchers used temporal data analysis and spatial data analysis to identify patterns and hotspots of carcasses and live wildlife observations.

4.4.1 Temporal Data Analysis

Successful highway crossings and carcasses have temporal as well as spatial patterns. Temporal patterns are caused by the behavior of the animals and their movements in response to environmental factors. Seasonal movement patterns may result in WVCs as animals migrate across the highway or live in the vicinity of the highway at certain times of year. These patterns were examined within the resolution of data used in this study. Some bias may exist in the observation of live animals, because the surveys were conducted driving from north to south and then the route was retraced. Thus mornings were spent further north at cooler times of the day. Live observations were generally recorded only during the first transit of the route except in cases where new groups of animals were definitely known to have appeared on the reverse trip. The surveys of live animals are not intended to be a complete census; they provide a sample of animals located near the highway. This sample is affected by many factors such as temperature, visibility and seasonality. Though systematically collected in the same manner for each survey, the data may be biased due to the fact that some areas were always surveyed in the morning, while others were always surveyed in the afternoon. However, data collected one day should be comparable with data collected days later using the same protocol. Over the course of two years it is likely that the locations of animals using habitat near the highway has been well documented.

Daily movement patterns may result in WVCs that tend to occur more frequently at certain times of the day or night. Movements across highways at times of low light and poor visibility may result in greater frequency of collisions at night and crepuscular periods, but those patterns are beyond the resolution of the data used for this study. The time of carcass collection or carcass observation indicates only the time at which the carcass was found. If collisions were reported to law enforcement personnel, then the actual time of the accident is known; however, these are too few in number to analyze for this study.

4.4.2 Spatial Data Analysis

Spatial data are created in two basic structures: raster data or vector data. Raster data is formatted in individual pixels (arranged in a 2-dimensional grid), while vector data comes in the form of points, lines, and polygons. Three broad categories of data were analyzed:

1. Carcass locations (points),
2. Live animal locations (points) and movement (lines or highway crossing points), and
3. Modeled habitat and movement (pixels).

Carcass locations were collected using the methods described previously, using GPS locations wherever possible or converting reference post locations (collected by MDT, FWP, and others) into GPS locations.

Live animal locations and movements were collected by visual observations from the highway recorded with GPS, telemetry data from FWP, aerial survey data from FWP, snow track crossing locations recorded with GPS, and camera trap photos. Data from camera traps were treated separately in the GIS analysis because they are qualitatively different; they are data always collected at the same point rather than anywhere within the study area.

Habitat models were obtained from the FWP Critical Areas Planning System (CAPS) datasets, from non-governmental organization (NGO) habitat models (Resource Selection Function (RSF) and expert opinion models) obtained from ChI, and from WCS. Evaluation and use of these models are described in a subsequent section of this chapter (“Contributing factors to carcass patterns”).

Briefly, all empirical wildlife-related data used in this analysis is vector data occurring in the form of point locations, or lines between two points. Carcass locations and snow track crossing locations are points located on the highway. Animal observation, GPS locations, and aerial survey locations form ‘clouds’ of points located anywhere within the study area. To simplify the analysis, these locations were ‘clipped’ to include only those points located within 5 miles (8 km) of the highway on either side.

Hotspot analysis

Hotspot analysis was conducted to test the following hypotheses:

H_{O1}: Carcasses are randomly distributed among mile long highway segments.

H_{A1}: Carcasses are distributed with high (and statistically significant) concentrations at some road segments relative to others.

H_{O2}: Live animal observations are randomly distributed among mile long highway segments.

H_{A2}: Live animal observations are distributed with high (and statistically significant) concentrations at some road segments relative to others. Hotspot analysis uses vectors to identify the locations of statistically significant hot spots (more dense clustering than random) and cold spots (less dense clustering than random) in the data.

The research team summarized point observations by highway reference post (RP) by first generating Thiessens polygons around RP locations and then clipping those polygons to a ½ mile buffer around the highway centerline. This results in a series of 1-mile wide polygon segments with an RP at the center and with boundaries that cross the highway at the midpoint of the RP and each of its neighbors. Selected sets of point data were summed for each polygon to yield total counts per RP. This procedure constrains the data to a linear format and associates the resulting analysis to RPs so the results are 'tied' to highway segments and allowed for testing H_0.

Selected sets were based on combinations of species (or species groups) and observation type. Selections included the following species groups: all species, bighorn sheep, elk, deer (mule and white-tailed deer combined), mule deer, white-tailed deer, pronghorn, all ungulates, and all non-ungulates. Selections also included the following observation categories: carcass, live, successful crossing, and unsuccessful crossings. Successful crossings included track or visual observations of animals crossing the highway. A visual observation was considered successful even if the animal(s) made several unsuccessful attempts before finally succeeding in crossing the highway. Unsuccessful observations included all carcass counts plus visual observations of animals that appeared to an observer to be attempting to cross the highway but were unsuccessful during the period of observation. The period of observation varied in both time of day and in duration from one observation to the next, depending on animal behavior, traffic, safety of the observer and other factors. To avoid bias caused by visibility and time of observation, only snow tracking data was used for mapping live observation hotspots. The exceptions were for pronghorn, mule deer, and white-tailed deer because tracks of these species could not be reliably separated, so visual observations were used instead. An additional data set was included for elk GPS data to compare study survey observations with general elk habitat use obtained from GPS locations. The available data from 2005 and 2006 were combined and normalized by animal ID so that each collared individual contributed equally to the hotspot estimate.

The research team used the ArcGIS Hotspot (Getis Ord GI*) tool to map statistically significant hotspots for each selected set. It calculates a z-score and p-value for each RP polygon to test the hypotheses that carcasses or live animal observations are randomly distributed among highway mile segments. Z-scores indicate whether the observed spatial clustering of high or low values is more pronounced than one would expect in a random distribution of those same values. A high z-score and small p-value for a feature indicates a spatial clustering of high values. A low negative z-score and small p-value indicates a spatial clustering of low values – the higher (or lower) the z-score, the more intense the clustering. A z-score near zero indicates no apparent spatial clustering.

Researchers specified the following parameters:

- Conceptualization of Spatial Relationships = ZONE OF INDIFFERENCE;
- Distance Method = EUCLIDEAN DISTANCE;
- Distance Threshold = 1609 m (1 mile).

These parameters force the analysis to a one mile scale such that a given mile segment is considered a hotspot or coldspot if it is significantly different from its two nearest neighbors.

A Model Builder model was created to facilitate replication of all analysis process steps.

Spatial correlation of live animal and carcass observations

Spatial correlations were calculated to examine whether carcasses are occurring in the same locations as general habitat use, as indicated by live observations and telemetry data, indicating that carcass locations are primarily a function of relative animal presence, or alternatively, if factors independent of relative animal use contribute to the likelihood that an animal will be struck by a vehicle (e.g. visibility). Secondly, correlation between tracking and visual observations was tested to see to what degree these observation methods were interchangeable. Finally, comparisons between elk GPS locations and elk observations derived from this study were tested.

To test for spatial correlation, the Geospatial Modeling Environment (Beyer 2012) was used to generate kernel density estimates (KDE) on selected sets of point data. KDEs map probabilities from point clusters in 2-dimensional space. KDE is most frequently used for estimating animal home ranges where areas of high density indicate a high probability of a point falling within an animal’s home range. The research team used the same selected sets of point data described for hotspot analysis, except that KDE was calculated for track and visual observation data for each species group. An additional selected set was included for elk GPS data to compare study survey observations with general elk habitat use obtained from GPS locations. For this selected set, data from 2005 and 2006 were combined and normalized by animal ID so that each collared individual contributed equally to the KDE estimate. KDEs were generated at 90m (98 yards) resolution for each selected set using the “PLUGIN” bandwidth estimator. Researchers then used the ArcGIS “Band Collection Statistics” tool to generate a correlation matrix to produce a correlation coefficient for each KDE pair-wise combination.

Contributing factors to carcass patterns (Regression Models)

Multiple linear regression models were developed to explore which characteristics contribute to locations of carcasses. Full model development was beyond the scope and budget of this project, and the models presented should be considered preliminary. They are intended as “exploratory” to add to an understanding of which landscape features are contributing to the patterns of carcasses observed in this study. Further development with testing against independent data is necessary before the models should be applied to predict carcass locations in other areas.

General Modeling Approach

Models were developed using the R statistical computer language (R Core Team 2014). Global models (models using all candidate variables) were developed for four ungulate species (elk, mule deer, pronghorn, and white-tailed deer) using a general linear model with Poisson link function, which is appropriate for analyzing count data. The research team used an informatics approach to select the most important variables from each global model. They used the MuMIn: Multi-model inference package (Barton 2014) to generate a list of all possible candidate models and ranked them by second order Akaike Information Criterion (AICc). AIC is a measure of the quality of a statistical model and AICc contains a correction factor that is appropriate when sample size is small compared with the number of parameters (Burnham & Anderson 2002). Models with ΔAICc < 2 are considered statistically equal to the top model, so these were selected from the pool of candidate models and averaged to create the final model. Final models were then used to calculate predicted values for each of the original training data input records.

Candidate Variable Selection

The dependent variable for all candidate models was the total number of carcasses at each RP by species. This count was derived using the same methods described for hotspot analysis, except that final counts were assigned to the original RP points rather than polygons. For independent variables, candidates were selected to include in the global model only if there was a plausible a priori hypothesis to avoid using a “kitchen sink” approach of including variables without reasonable justification. Table 3 lists the variables included in the global models and their justifications. A cross-correlation matrix was generated to test for co-linearity of variables. A threshold of 0.70 was set to determine if variables were cross-correlated. If so, one of the variables would be removed from the global model. No variables were correlated at the threshold value.

Table 3. Candidate variables included in global models.

Variable	Source	Description	Justification
Distance to Fence Corner	From study survey data	The distance from a reference post to a corner created by a fence running perpendicular to the roadway and attaching to a fence parallel to the roadway	Potential influence on animal movement (animals likely to cluster at fence corners)
Distance to Opening	From study survey data	The distance from a reference post to an opening in fencing along roadway. Openings include open gates, roads, dropped fences, and areas with no fencing.	Potential influence to animal movement. Openings more likely to facilitate movement.
Fence Type	From study survey data	Broad categories of fencing present parallel to roadway. Fence type was classified separately for each side of the roadway	Classification of potential barriers to animal movement
Majority Land Cover Class	Derived from 2013 MT Landcover Classification (Level 1)	The majority land cover class within a 2 mile radius of a reference post	A broad indicator of species habitat preference and concealing cover
Mean Structure Density	Derived from Montana Structures Framework (NRIS)	Structure density averaged over a 2 mile radius.	A measure of broad landscape level development patterns that potentially influence animal movement and habitat use.
Mean Visibility	Derived from National Elevation Dataset (30m digital elevation model)	Average line of site distance 360 degrees around a reference post	Indicator of animal visibility to drivers in all directions
Mean Visibility on Axis	Derived from National Elevation Dataset (30m [32 yard] digital elevation model)	Average line of site distance along roadway from a reference post.	Indicator of animal visibility to drivers on roadway
Number of Strands	From study survey data	The number of wire strands present (where applicable)	Potential barriers to animal movement
Structure Density	Derived from Montana Structures Framework (NRIS)	Density of houses/sq mile within ½ mile of a reference post	Indicator of degree of human disturbance near roadway that could influence animal movement and habitat use.
Wild Planner Cumulative Current Density	Wild Planner model outputs derived from Montana Structures Framework (NRIS), National Elevation Dataset (30m [32 yard] digital elevation model), and Circuitscape modeling	Predicted bottlenecks in landscape permeability for animal movement using circuit theory based on structure density and broad habitat preferences	An indicator of potential concentration points for animal movement based on broad landscape level development patterns and general habitat preferences.

Candidate Variable Development

The following detailed methods were used to derive candidate variables.

Distance to Fence Corner: Observations in the field indicate that ungulates often congregate at fence corners (often where the right of way [ROW] fence and a private fence, perpendicular to the highway, meet) before crossing a fence. One possible reason would be if animals follow along a fence line looking for a good place to cross but eventually run into another fence. If animals are more likely to cross fences at corners, then they could concentrate animal movements across roads and increase the probability of a WVC near corners. Fence corners were mapped during a fencing survey conducted as part of this study. Fence corners were defined as a location where a fence running parallel to the highway is joined by a fence running perpendicular. The distance from each RP to the nearest fence corner was calculated for each side of the highway. Distance to corner was included as an interaction term in the global model because locations near corners on both sides of the road could perform differently than locations near a corner on only one side.

Distance to Fence Opening: Wildlife have been observed using fence openings rather than navigating obstacles posed by fences. Fence openings were mapped during a fencing survey conducted as part of this study. Openings were defined as areas parallel to the roadway where no fence is present, breaks in a fence due to open gates or road intersections, or sections of fence that were purposely dropped to the ground at the time of the survey. Open gates and dropped fences are problematic because their status can change at any moment. However, gates are often left open or fences dropped purposely during times when livestock are not present in adjacent pastures. Many openings present at the time of the survey may have changed during the study period so any results relating to open fences are necessarily tentative. The research team converted vertices along lines representing areas with no fence present to points and merged them with point locations for open gates or road intersections. They calculated distance from each RP to the nearest point location of any opening for each side of the highway. Distance to opening was included as an interaction term in the global model because locations near openings on both sides of the road could perform differently than locations near an opening on only one side.

Fence Type: The type of fence influences the barrier it presents to wildlife. Most ungulates can jump high and they can jump far, but they can’t jump high and far simultaneously. Therefore it is believed that deep fences like buck and rail construction pose a greater barrier than shallow fences of a comparable height. Pronghorn represent an exception because they generally prefer to go under fences rather than over them. Therefore, wire fences with clearance under them are believed to be more permeable than fences that are tight to the ground such as woven mesh fencing. Fence construction type was recorded during the study fence survey and then lumped into seven general classes: barbed wire, buck and rail, mesh, mesh and barbed wire mix, smooth wire, wood, and none. Any fence lying on the ground was not considered a fence and its condition was noted. For the analysis, these sections were treated as not a fence. Fence condition can also influence the barrier effect that fences have on wildlife movement. For example, loose wires may be easier to crawl under or jump over but are also more likely to cause entanglement. Fence conditions such as missing top strand or loose top strand, were recorded but were only included in the analysis so far as the condition influenced the number of strands. A “fence condition” parameter was not included because fence condition is an ill-defined term and developing a meaningful classification system is difficult. For example, a fence with loose wires and another that is leaning over might both be considered “poor” condition but have very different influences as wildlife barriers. Conversely, if fence condition classes are more finely parsed then there is a risk of every fence becoming a unique case and the parameter would lose statistical power to detect its influence. Recommendations for developing a more quantitative fence classification system are discussed under *Recommendations for Data Collection and Analysis* (7.2*)*. Each RP was assigned the fence type that was nearest to it on each side of the road. Fence type entered the global model as an interaction term because of possible interactions between fence types on both sides of the highway.

Number of Strands: This parameter provides a continuous variable analog to fence type for testing the influence of fence construction on animal movements and WVCs. The hypothesis is that fences with fewer wires would be more permeable to wildlife than fences with more wires. The number of strands was recorded during the fencing survey of this study. Each RP was assigned the number of strands reported for the nearest fence segment on each side of the road. Fence sections with no strand data reported were assigned values of zero. If fence strands were lying on the ground, it was considered zero strands. This parameter did not account for fence condition other than condition as it affected the number of strands above the ground that an animal would need to cross. It should be noted that the inclusion of this parameter in the global model is potentially biased because it only applies to sections with barbed or smooth wire fencing. However, since these models are exploratory, the variable was included to see if it performed better than the fence type class variable. This parameter was included in the model as an interaction term because of possible interactions between the number of strands on each side of the road.

Majority Land cover Class: This variable was included to represent the influence of the general habitat preference of a species on carcass locations. It is expected that WVCs are more likely to occur in areas of preferred habitat. The research team used the level 1 classification of the 2013 Montana Land Cover layer that divides the landscape into seven broad cover classes, but only five are present in the study area: Forest and Woodland Systems; Grassland Systems; Human Land Use; Open Water/Wetland and Riparian Systems; and Shrubland, Steppe and Savanna Systems. The research team calculated a focal majority over a 2-mile radius to determine the dominant land cover type surrounding each 30m (32 yard) x 30m cell and assigned each RP with the class of the cell at the RP location. This variable was included in the global model as a main effect and as an interaction term with the two visibility variables because of potential interactions between visibility due to vegetative cover and due to topography.

Mean Visibility and Mean Visibility on Axis: The research team developed two indices of visibility to estimate the ability of drivers to see wildlife on or near the roadway and vice versa. Mean visibility is defined as the average line of sight distance that can be over 360 degrees from a point (an RP) and estimates the ability of a driver to see wildlife to the sides as well as in front of the direction of travel. In other words, it is an estimate of how well a driver could see and become aware of animals in the general vicinity of the road. Mean visibility on axis is the mean line of site distance that can be seen along the highway center line from an RP and estimates the ability to see wildlife on the roadway. The research team used the ArcGIS "Visibility" tool to calculate the visible landscape within a three mile radius around each RP based on a 30m (32 yard) resolution digital elevation model. They specified an observer offset of 2.5 m (2.7 yards) to simulate the elevated height of a driver in a vehicle above the terrain. This value was chosen as an average between eye level of drivers of passenger vehicles and semi-tractors. Next, the ArcGIS "Construct Sight Lines" tool was used to construct a series of straight lines at a 100m (109 yards) sampling distance radiating from each RP. These lines were clipped to the immediate area visible from each RP, and the average line length was calculated. Mean visibility on axis was calculated the same way except instead of constructing sight lines, the highway centerline was clipped to the immediate area visible from each RP and split at the RP point. The two line segments extending in each direction from the RP were averaged to derive the final index. As previously described, these parameters were entered into the global model as interaction terms with majority land cover.

This method of estimating visibility is limited by the resolution of the elevation data used. The resolution of elevation data is particularly relevant to incorporating the influence of fine-scale features (such as cut/fill slopes) near the roadway since these can influence the near and far distance visibility of wildlife approaching the roadway to drivers. Cut slopes would allow animals near the road to be seen while obscuring the visibility of animals just beyond the cut, whereas fill slopes are likely to have the opposite effect. The 30m (32 yard) data used for these analyses are fine enough resolution to capture the topography of large cut/fill features but are not fine enough resolution to capture small features. Finer resolution elevation data would reveal influences of increasingly small topographic features on the landscape. Recommendations for improving this parameter are discussed in more detail under *Recommendations for Data Collection and Analysis. (*7.2*)*

This method of estimating visibility also does not account for the influence of vegetation on visibility. The models compensate for this by entering visibility parameters as an interaction term with majority land cover class, which adjusts coefficients for the combination of visibility and land cover type if an interaction is found. An alternative method could be to estimate vegetation height for each land cover class and add that value to the elevation data before calculating visibility indices. However, this latter method does not account for the influence of vegetation density on visibility so may not improve model performance over the method used.

Structure Density and Mean Structure Density: These two parameters were included to test the influence of development patterns on animal movement and carcass locations. The research team included variables at a local scale to represent potential influences of local disturbances around human developments on wildlife and at a landscape level to represent potential influences of development on broad-scale patterns of habitat use that ultimately influence where WVCs may occur. Researchers calculated structure density as the number of structures/mile^2 within a ½ mile radius. This radius was chosen because it is the distance reported for elk behavioral response near human developments (Cleveland 2010) and is a good general estimate for the threshold distance for localized disturbance on ungulates. Mean structure density was calculated as the focal mean of structure density over a 2-mile radius. This radius was chosen because it was the preferred distance from structures reported for elk (Cleveland 2010) and is a good general estimate for the outer boundary for disturbance surrounding human dwellings.

Wild Planner Cumulative Current Density (WPCCD): This parameter was included to test the ability of wildlife connectivity models to predict locations of wildlife crossings and carcasses. Wild Planner is another estimate of the influence of development patterns on wildlife movement. The research team investigated several connectivity models for inclusion in the global models, including the large landscape block model developed by MTFWP and the models developed by WCS and ChI for *A wildlife conservation assessment of the Madison Valley, Montana* (Brock et al 2006). However, those models were developed for more broad-scale analysis and lack the resolution needed to be useful for these analyses.

Wild Planner (Brock 2011) is designed to build upon broad-scale models by predicting potential movement pathways within broader landscape corridors. The research team used the “Evaluate Movement Landscape” and “Measure Landscape Resistance” tools to create a generic model of ungulate movement between large blocks of public lands east and west of the Madison Valley. These tools create a friction surface based on structure density, general habitat preference, and sensitivity of wildlife to human disturbance and apply Circuitscape (McRae 2013) to estimate animal movement across the landscape. Wild Planner is based on the assumption that human development creates zones of influence beyond the building footprint that can alter animal behavior and that the wildlife movements are influenced by a combination of habitat quality and human disturbance. Areas of high habitat quality and outside the zones of influence of development receive the lowest friction values (are considered best options for animal movement). However, as discussed in section 3.2.1 and in model results, animals do not always avoid areas near human development and may even become habituated to human activities and preferentially use habitat in developed areas.

Researchers specified a minimum corridor width of 200m (219 yards) and a disturbance distance of ½ mile based on Cleveland's (2010) reported disturbance distance for elk. They developed a very simple habitat preference model by classifying elevation in the Madison Valley into five natural break classes and assigning lowest elevation class the highest habitat value and vice versa. This simple model reflects the general ungulate use pattern of the valley with concentrations of ungulates at low elevations in winter where snow accumulation is low. The output of the model is cumulative current density as an estimate of relative concentrations of animal movement based on landscape permeability as derived from the input parameters. Areas with high cumulative current density are predicted as bottlenecks where animal movements are concentrated in small areas. The research team hypothesized that animal movement, and therefore carcasses, would be higher in areas where these bottlenecks cross the road. Alternatively, a negative correlation with cumulative current density would indicate animals are using habitat closer to developments and are therefore likely habituated to, or at least tolerant of, human activities. The cumulative current density at the location of each RP was included in the global model.

5 RESULTS

5.1 Results Overview

An overview of the data used for this report demonstrates that wildlife interact with the highways throughout the length of the study area (Figure 1). There are only two 1-mile segments where no carcasses were observed (RP 14–15, and 17–18). Similarly, there were few segments where animal tracks were not recorded or live animals were not seen. This figure also illustrates the wealth of data collected in the field for analysis that are included in the geodatabase for this project.

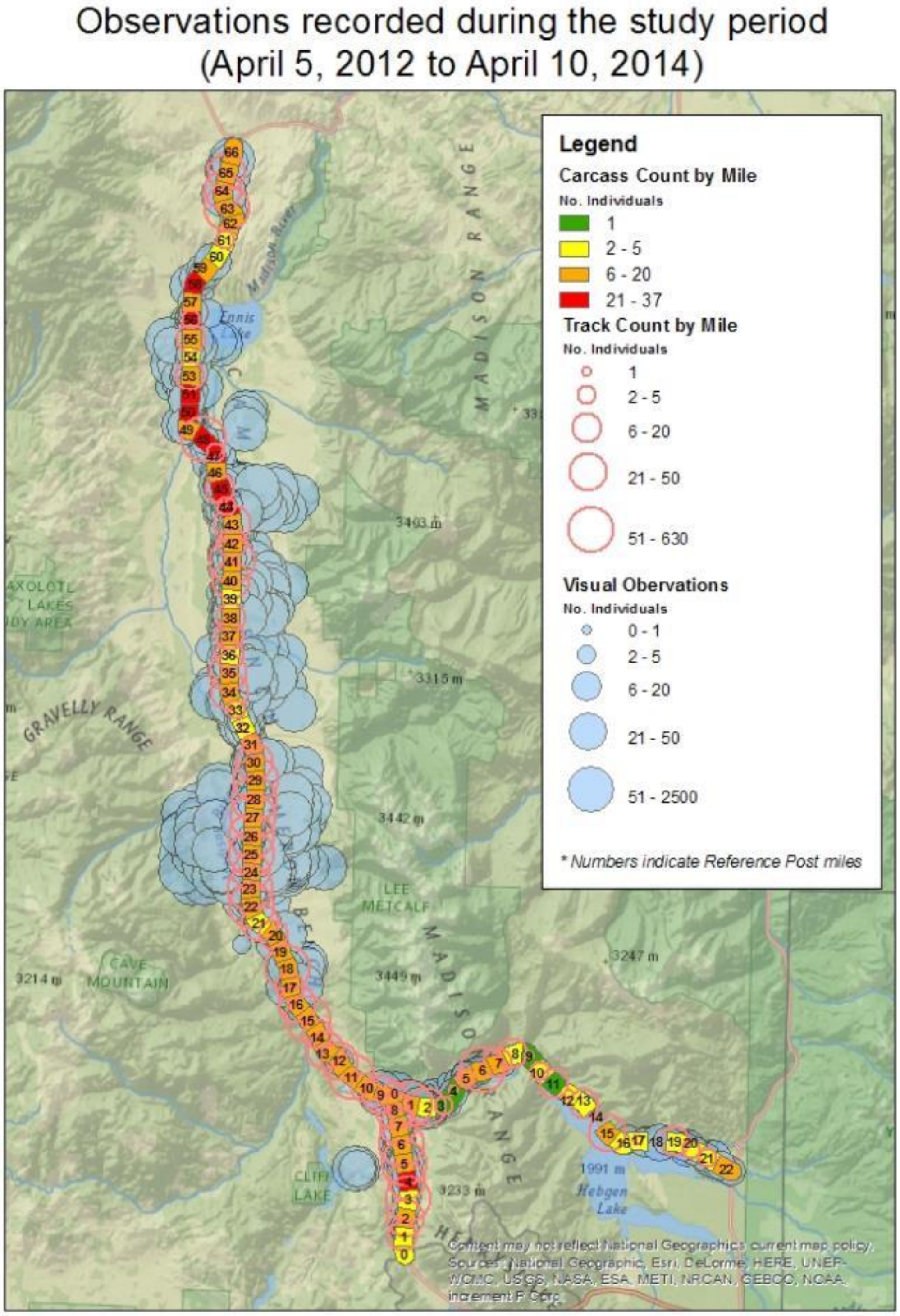

Observations recorded during the study period (April 5, 2012 to April 10, 2014)

Figure 5. Wildlife-related observations recorded during the study.

Overall, all four models (mule deer, white-tailed deer, elk, and pronghorn) performed generally well, with models explaining 69-93% of the variability in locations of carcasses depending on the species (Table 4). However, it should be noted that predicted values were fitted to the same data used to train the models and represent a best case scenario of model fit. Comparisons with independent data would likely yield lower correlations.

Table 4. Correlation between observed and predicted values of final models.

Species	Coefficient of Determination (R^2)
Mule Deer	0.69
White-tailed Deer	0.93
Elk	0.72
Pronghorn	0.93

Table 5 summarizes the relative importance of parameters included in the final models. Parameters estimating landscape development patterns ranked first (mean structure density) and third (WPCCD) in importance overall and were included in four and three of the final models, respectively. Distance to fence corner ranked second and was included in all four models. Land cover and the remaining fence-related parameters ranked in the middle and were all included in three of the four models. Local structure density and visibility parameters ranked lowest in importance. However, species responses to individual parameters varied.

Table 5. Relative importance of parameters included in models.

		Mean Structure Density	Distance to Fence Corner	Wild Planner Cumulative Current Density	Distance to Fence Opening	Factor (Fence Type)	Factor (Majority Land Cover Class)	Number of Fence Strands	Mean Visibility Distance (360°)	Structure Density	Mean Visibility Distance (On Axis)
Elk	Importance[1]:	1.00	0.21	1.00	0.16	1.00	1.00	1.00	0	0	0
	N containing models[2]:	4	1	4	1	4	4	4	0	0	0
Prong-horn	Importance:	0.64	1.00	0.28	0.85	0	1.00	0	1.00	0	0.54
	N containing models:	3	5	2	4	0	5	0	5	0	3
White-tailed Deer	Importance:	1.00	1.00	1.00	1.00	1.00	0	1.00	0	1.00	0.28
	N containing models:	2	2	1	2	2	0	2	0	2	2
Mule Deer	Importance:	1.00	1.00	0	0	1.00	1.00	1.00	1.00	0	0
	N containing models:	1	1	0	0	1	1	1	1	0	0
Totals	Importance:	3.64	3.21	2.28	2.01	3.00	3.00	3.00	2.00	1.00	0.82
	N containing models:	10	9	7	7	7	10	7	6	2	5
	N containing final models[3]:	4	4	3	3	3	3	3	2	1	2

[1] Relative importance of the predictor variables (including interactions), calculated as a sum of the Akaike weights over all of the models in which the parameter of interest appears. Importance values range 0-1 with 1 indicating high importance in all candidate models.

[2] The number of candidate models that were averaged to produce the final model containing the variable.

[3] The number of final models containing the variable.

5.2 Results by Species

This section presents results by species, with an emphasis on focal species from a safety perspective for which there were enough data to conduct analyses: mule deer, white tail deer, elk, pronghorn and bighorn sheep. For each of these species, results include carcass and live observation and/or track hotspots and model results.

This section also presents summarized results for species documented in smaller numbers, or for which there were no records at all during this study, including grizzly bear, black bear, wolverine, wolf, mountain goat, moose and boreal toad.

Live animal observations are summarized by species in Appendix G (9.7). The count estimates are not population size estimates; they sum the total number of animals seen at that distance from the highway over the entire time period (quarter). In this format, the total seen during each quarter serves as an index to the relative abundance of each species near the highway during each quarter.

Snow track crossing locations were summarized by species, and the full results may be found in Appendix H (9.8).

5.2.1 Deer species combined

A total of 67 deer (mule deer and white-tailed deer combined) carcasses were recorded during the two years of the study (Appendix E: Carcass Observations by Species from April 4, 2012 to April

9, 2014. (9.5)). Near Ennis, deer carcass hotspots were similar to live observation hotspots (Figure 6, Figure 7) indicating that deer are being hit by vehicles primarily in areas where they concentrate. However, this is not the case further south in the study area. When the data are examined according to species, this relationship becomes clearer and is discussed below.

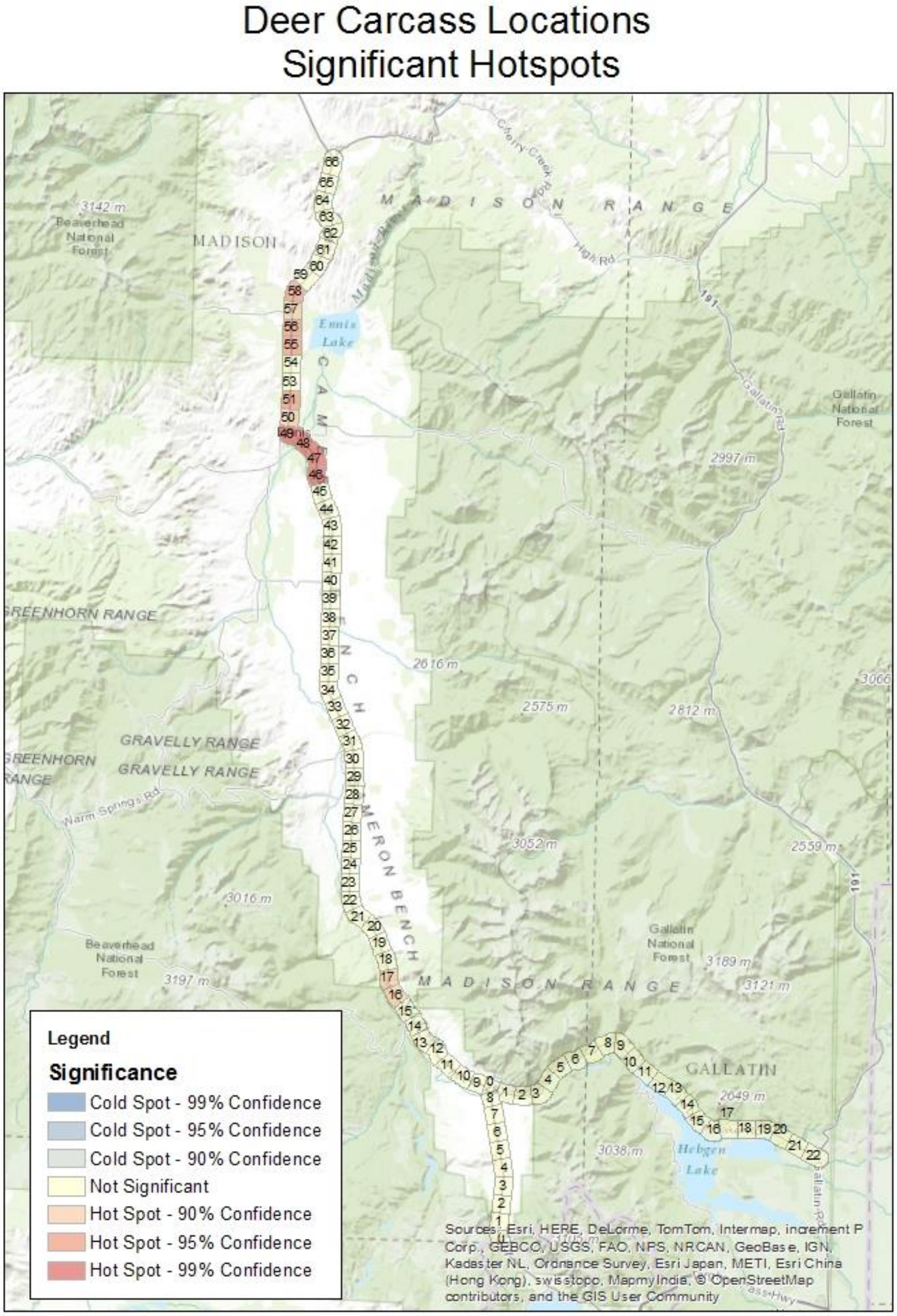


Figure 6. Deer (mule deer and white-tailed deer combined) carcass locations.

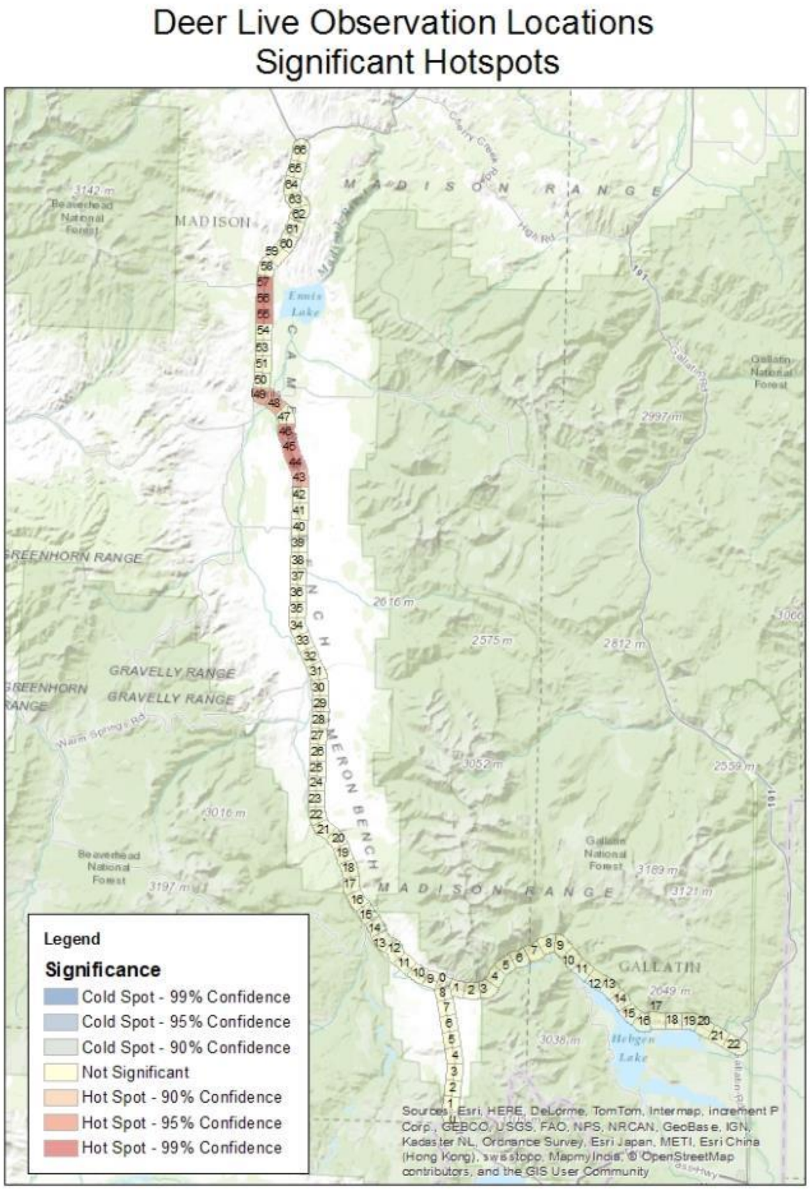
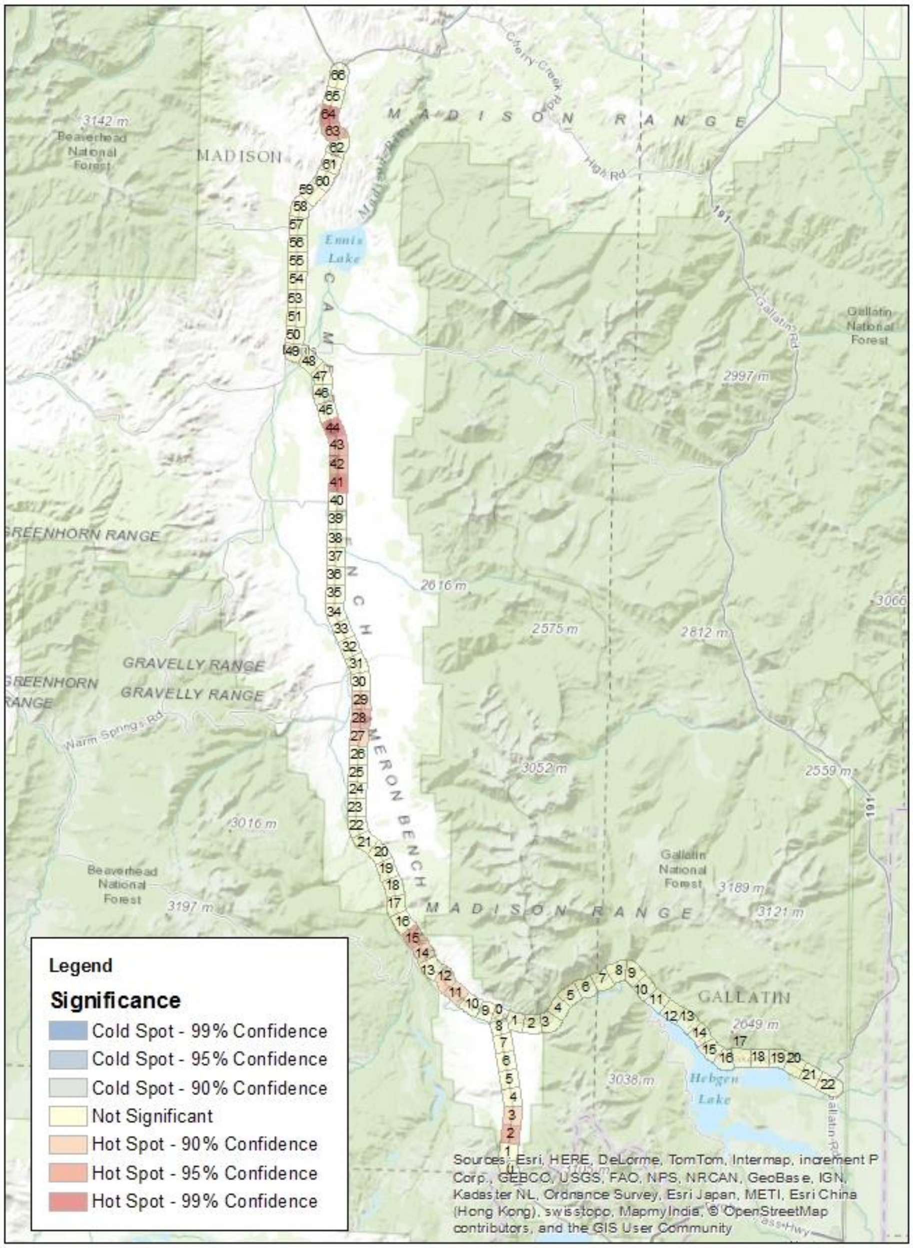


Figure 7. Locations of live deer (mule deer and white-tailed deer combined) observations.

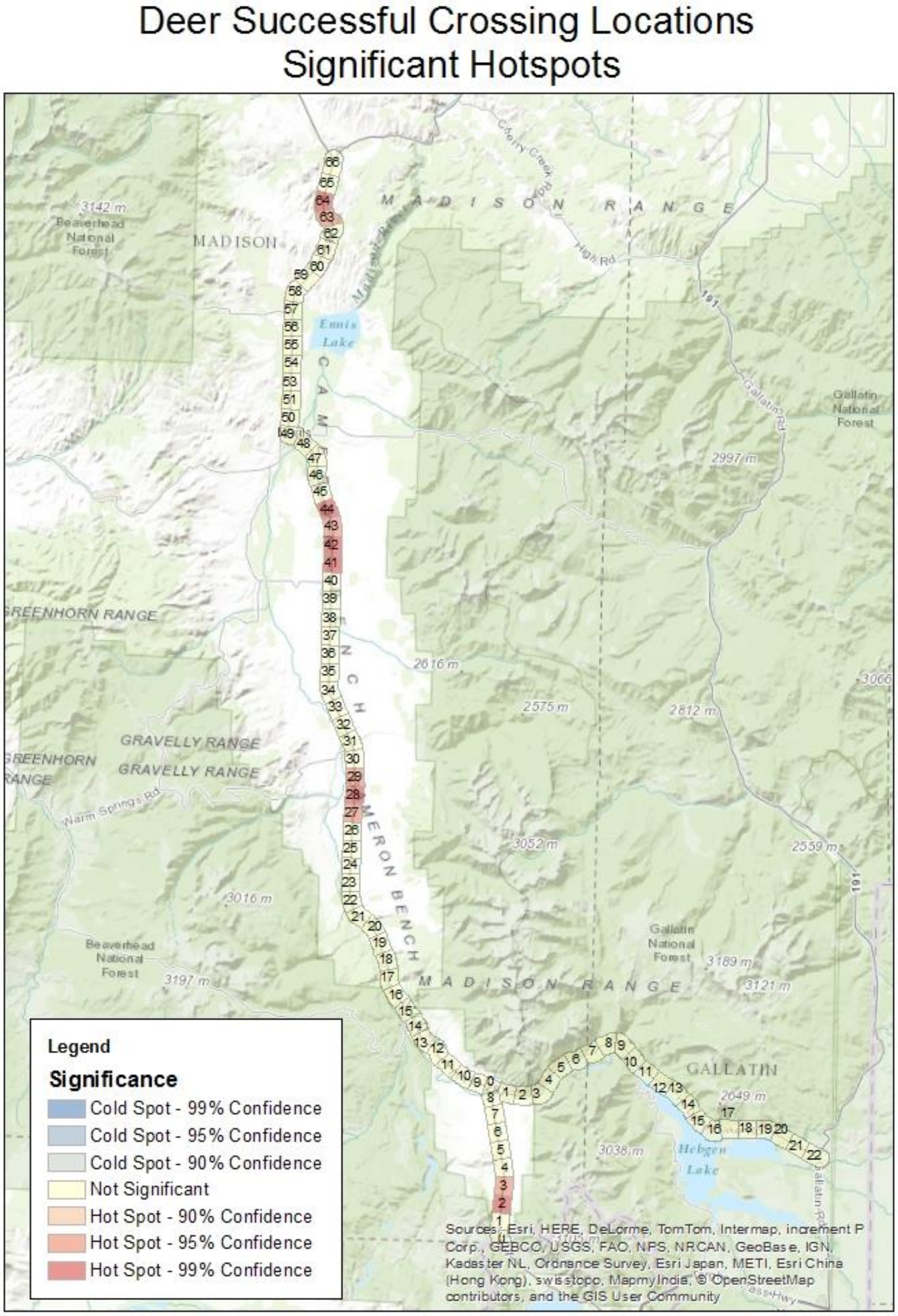
Because deer snow tracks could not be distinguished by species, all deer carcass hotspots were examined and compared with deer track location hotspots (Figure 8) and all successful deer crossing locations, including visual crossing locations (Figure 9). Deer carcass and deer track locations were not highly correlated spatially ($R^2 = 0.66$), and deer track and visual observations were not spatially correlated ($R^2 = 0.26$; Appendix J (9.10)).

Deer Track Locations
Significant Hotspots



Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 8. Locations of deer (mule deer and white-tailed deer combined) tracks.



Deer Successful Crossing Locations
Significant Hotspots

Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 9. Locations of successful deer (mule deer and white-tailed deer combined) crossings.

Deer successful crossings were not spatially correlated with unsuccessful deer crossings (R^2 = 0.56; Appendix J (9.10)). Note that successful vs. unsuccessful comparisons are different from tracks vs. carcass locations because they include visual observation of animals attempting to cross the road. Unsuccessful locations contain animals that were observed trying to cross the road but did not, or where carcasses were located.

5.2.2 Mule Deer

Mule deer visual observations indicate a clear pattern of winter use by the majority of mule deer (Figure 10), but small numbers were observed in the vicinity of the highway during summer. Few mule deer were observed between June and November each year.

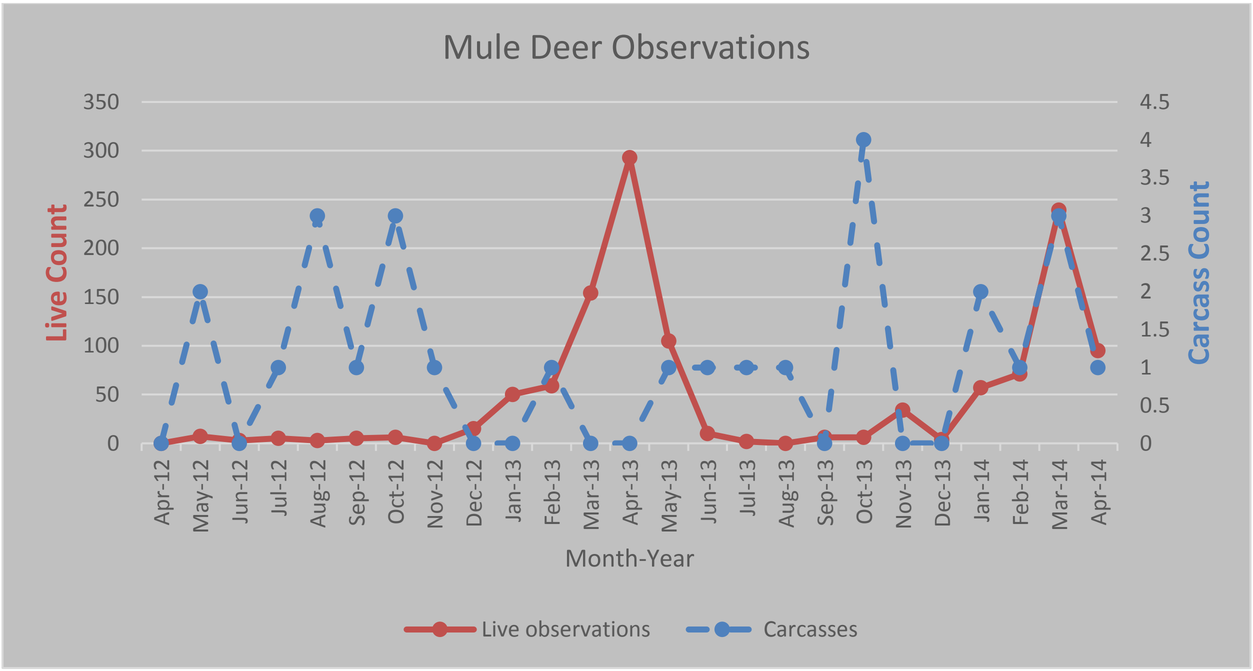


Figure 10. Mule deer observations (live and carcasses) recorded by date.

A total of 27 mule deer carcasses were observed during the study (Appendix E: Carcass Observations by Species from April 4, 2012 to April 9, 2014. (9.5)). They occurred throughout the two years and there does not appear to be a clear seasonal pattern (Figure 10).

Mule deer observations correlate with the location of carcasses around the town of Ennis at RP 46-51 (Figure 11, Figure 12). However, there is no overlap between observations and carcasses elsewhere in the study area.

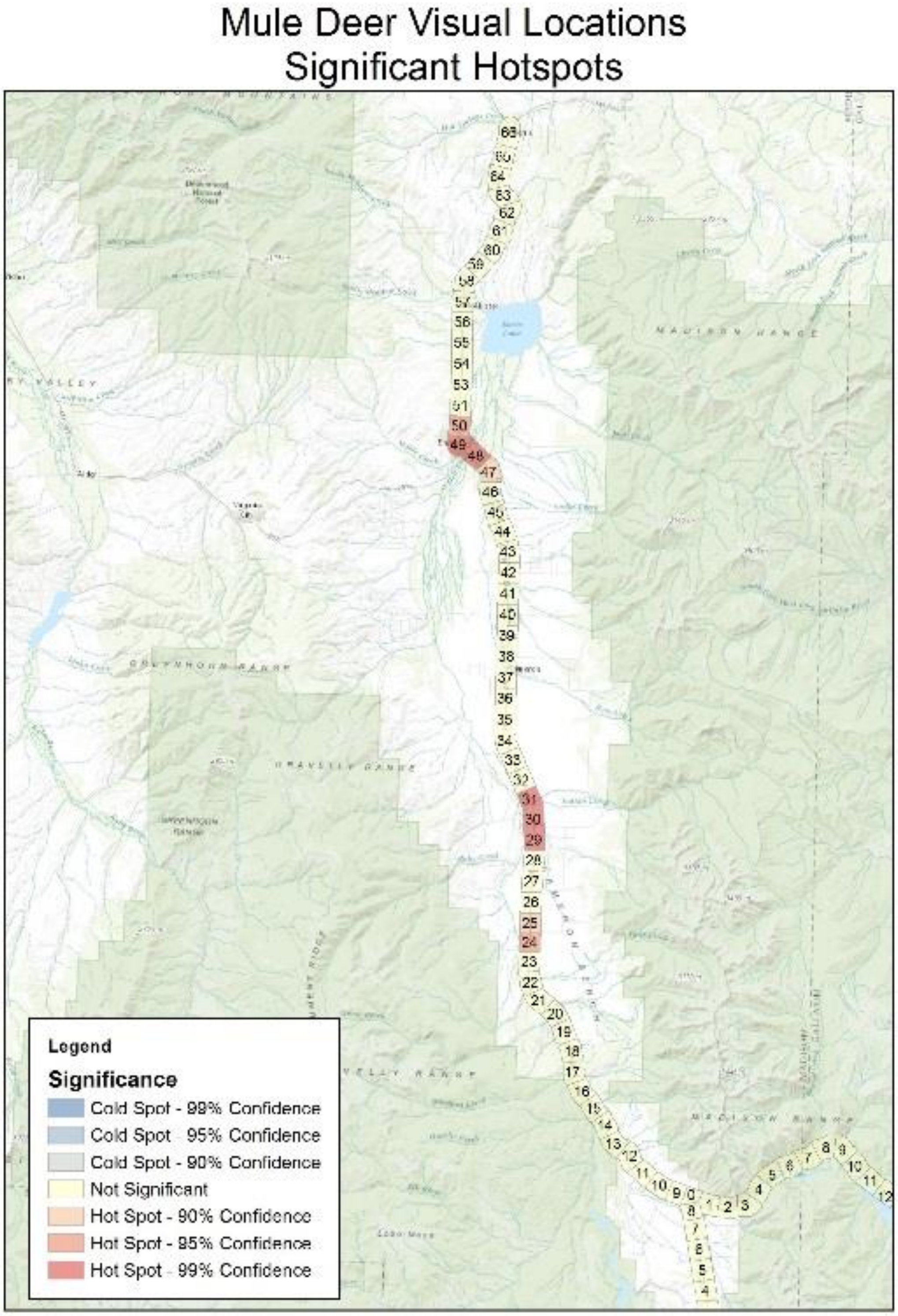


Figure 11. Mule deer visual locations.

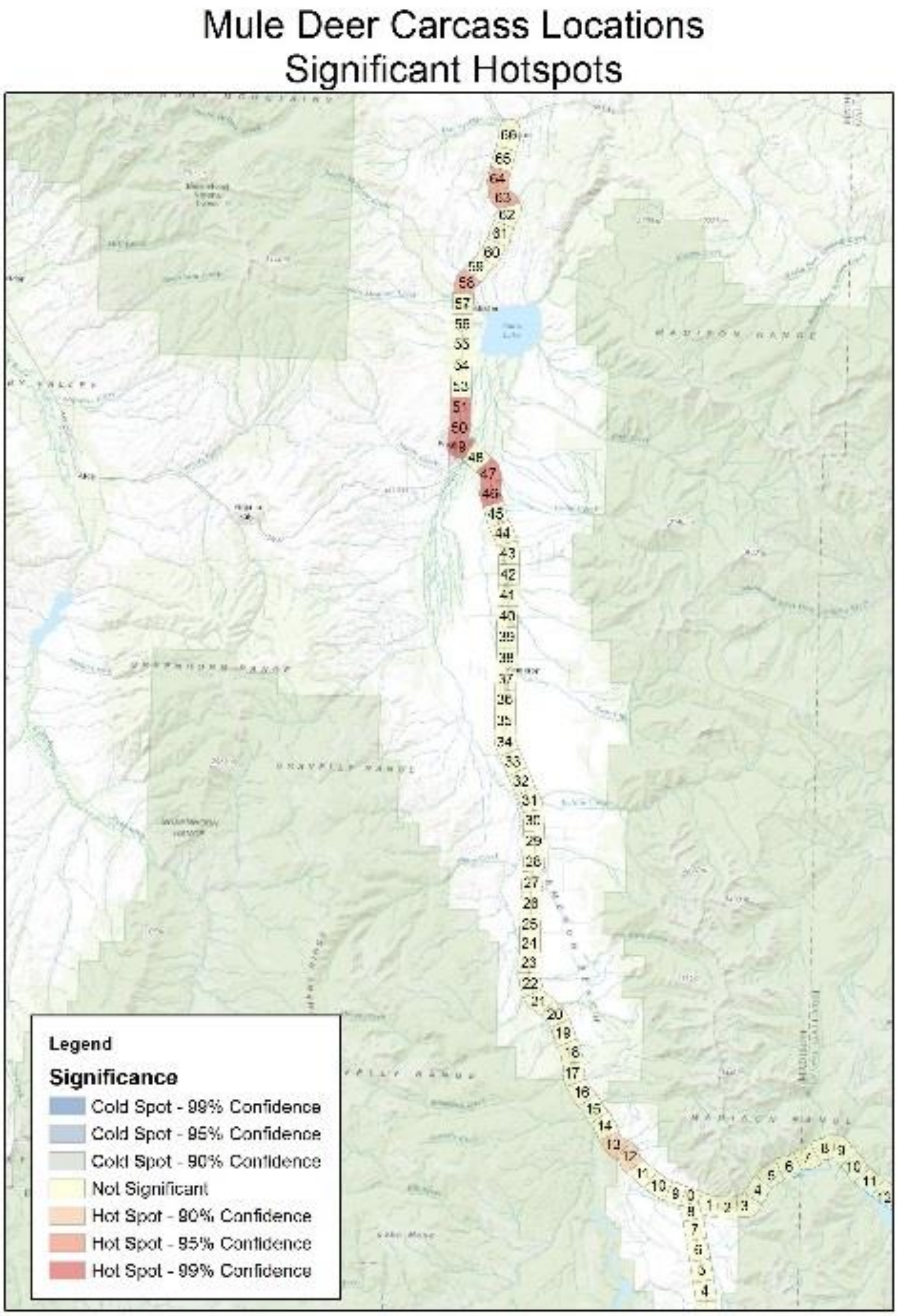


Figure 12. Mule deer carcass locations.

The mule deer model contained 10 parameters and had the lowest correlation with observed carcass counts of all models (Table 6). Mule deer carcasses were positively correlated with distance to fence corners, mean structure density and number of fence strands on one side of the road. There were significant negative correlations with mesh fence or no fence on one side of the road. Other significant correlations include an interaction between mean visibility and mean visibility on axis, and an interaction between numbers of fence strands on each side of the road. Carcasses were negatively correlated with all land cover classes, and there was an interaction between land cover class and mean visibility on axis, although none of these were statistically significant.

A visual comparison of observed mule deer carcasses with model prediction values (Figure 13) indicates a reasonably good model fit.

Table 6. Mule deer carcass model summary.

Coefficients: (1 not defined because of singularities)					
	Estimate[1]	Std. Error	z value	Pr(>|z|)	
(Intercept)	3.457e+01	4.503e+03	0.008	0.993876	
Distance to Fence Corner (One Side)	8.782e-04	1.970e-04	4.457	8.31e-06	***
factor(Fence Type (One Side))Buck and Rail	-2.504e+01	5.718e+03	-0.004	0.996505	
factor(Fence Type (One Side))Mesh	-4.329e+00	1.434e+00	-3.019	0.002534	**
factor(Fence Type (One Side))Mesh & Barbed Wire Mixed	1.974e+00	1.560e+00	1.265	0.205820	
factor(Fence Type (One Side))None	-5.449e+00	1.703e+00	-3.200	0.001374	**
factor(Fence Type (One Side))Smooth Wire	7.973e-01	9.536e-01	0.836	0.403120	
factor(Fence Type (One Side))Wood	-2.201e+01	5.718e+03	-0.004	0.996928	
factor(Majority Land Cover Class) Human Land Use	-7.064e+03	1.787e+06	-0.004	0.996845	
factor(Majority Land Cover Class) Forest and Woodland Systems	-3.648e+01	4.503e+03	-0.008	0.993537	
factor(Majority Land Cover Class) Shrubland, Steppe and Savanna Systems	-3.256e+01	4.503e+03	-0.007	0.994231	
factor(Majority Land Cover Class) Grassland Systems	-3.175e+01	4.503e+03	-0.007	0.994375	
Mean Structure Density	5.656e-02	1.893e-02	2.987	0.002815	**
Mean Visibility Distance (360°)	-1.719e-02	3.334e+00	-0.005	0.995886	
Mean Visibility Distance (On Axis)	-2.994e-01	2.817e+01	-0.011	0.991520	
Number of Fence Strands (Side 1)	1.271e+00	3.026e-01	4.201	2.66e-05	***
Number of Fence Strands (Side 2)	4.374e-01	3.185e-01	1.373	0.169737	
factor(Majority Land Cover Class) Human Land Use:Mean Visibility Distance (360°)	2.564e+01	6.450e+03	0.004	0.996829	
factor(Majority Land Cover Class) Forest and	1.538e-02	3.334e+00	0.005	0.996318	

Coefficients: (1 not defined because of singularities)					
Woodland Systems:Mean Visibility Distance (360°)					
factor(Majority Land Cover Class) Shrubland, Steppe and Savanna Systems:Mean Visibility Distance (360°)	5.739e-04	3.334e+00	0.000	0.999863	
factor(Majority Land Cover Class) Grassland Systems:Mean Visibility Distance (360°)	1.048e-02	3.334e+00	0.003	0.997492	
factor(Majority Land Cover Class) Human Land Use:Mean Visibility Distance (On Axis)	NA	NA	NA	NA	
factor(Majority Land Cover Class) Forest and Woodland Systems:Mean Visibility Distance (On Axis)	2.974e-01	2.817e+01	0.011	0.991577	
factor(Majority Land Cover Class) Shrubland, Steppe and Savanna Systems:Mean Visibility Distance (On Axis)	2.869e-01	2.817e+01	0.010	0.991875	
factor(Majority Land Cover Class) Grassland Systems:Mean Visibility Distance (On Axis)	2.721e-01	2.817e+01	0.010	0.992294	
Mean Visibility Distance (360°):Mean Visibility Distance (On Axis)	3.651e-05	1.066e-05	3.424	0.000618	***
Number of Fence Strands (Side 1):Number of Fence Strands (Side 2)	-3.036e-01	6.936e-02	-4.376	1.21e-05	***

[1] Positive estimate values indicate a positive relationship with carcasses increasing as the parameter value increases. Negative values indicate a negative response with carcasses decreasing with decreasing value. The magnitude of the estimate indicates the slope of the response with high values indicating a greater change in carcasses per increment change in a parameter value compared with smaller estimate values.

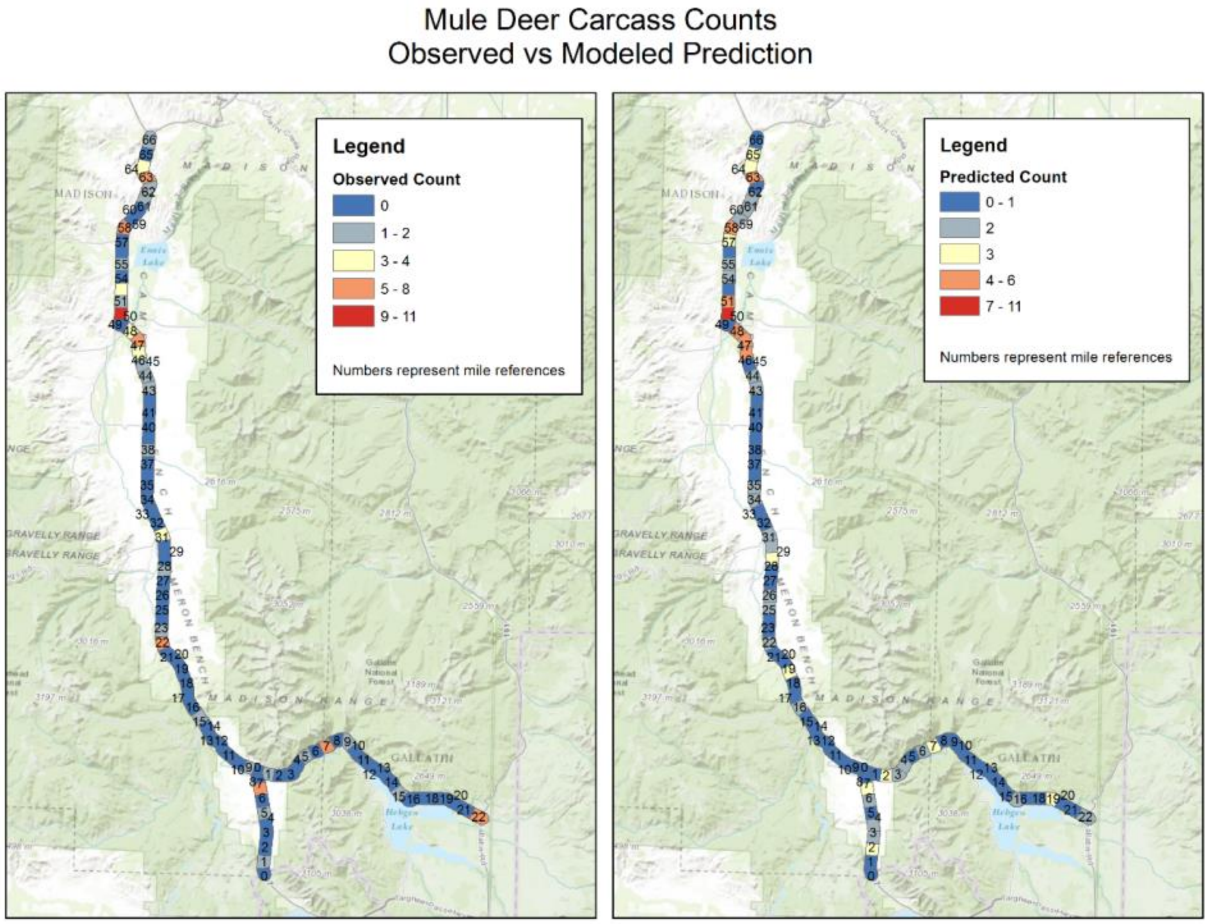


Figure 13. Comparison of observed mule deer carcasses with model prediction.

5.2.3 White-tailed Deer

Although white-tailed deer are not as migratory as mule deer, there was a definite pattern of increased use of habitat in the vicinity of the highway during winter (Figure 14), and there were larger numbers of animals observed in the vicinity of the highway during the second winter than during the winter of 2012. Relatively few white-tailed deer were observed from June through September each year.

A total of 32 white-tailed deer carcasses were recorded during the two years of the study (Appendix E: Carcass Observations by Species from April 4, 2012 to April 9, 2014. (9.5)). They occurred throughout the year with an increase in the fall of both years and in the winter months of the second year of the study (Figure 14).

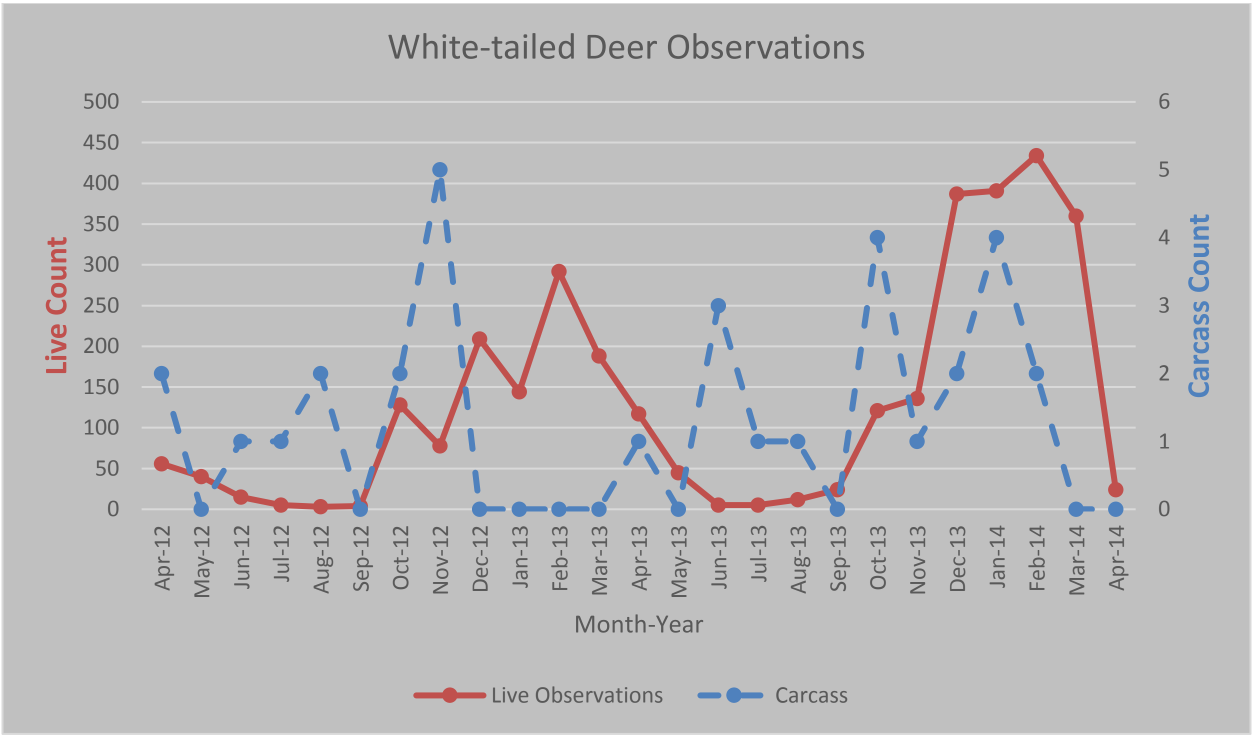


Figure 14. White-tailed deer observations (live and carcass) recorded by date.

White-tailed deer carcass locations are somewhat correlated with visual observations (Figure 15, Figure 16). There are hotspots of carcasses south of the town of Ennis (RP 46-49 and RP 15-17) and further north at RP 55-58.

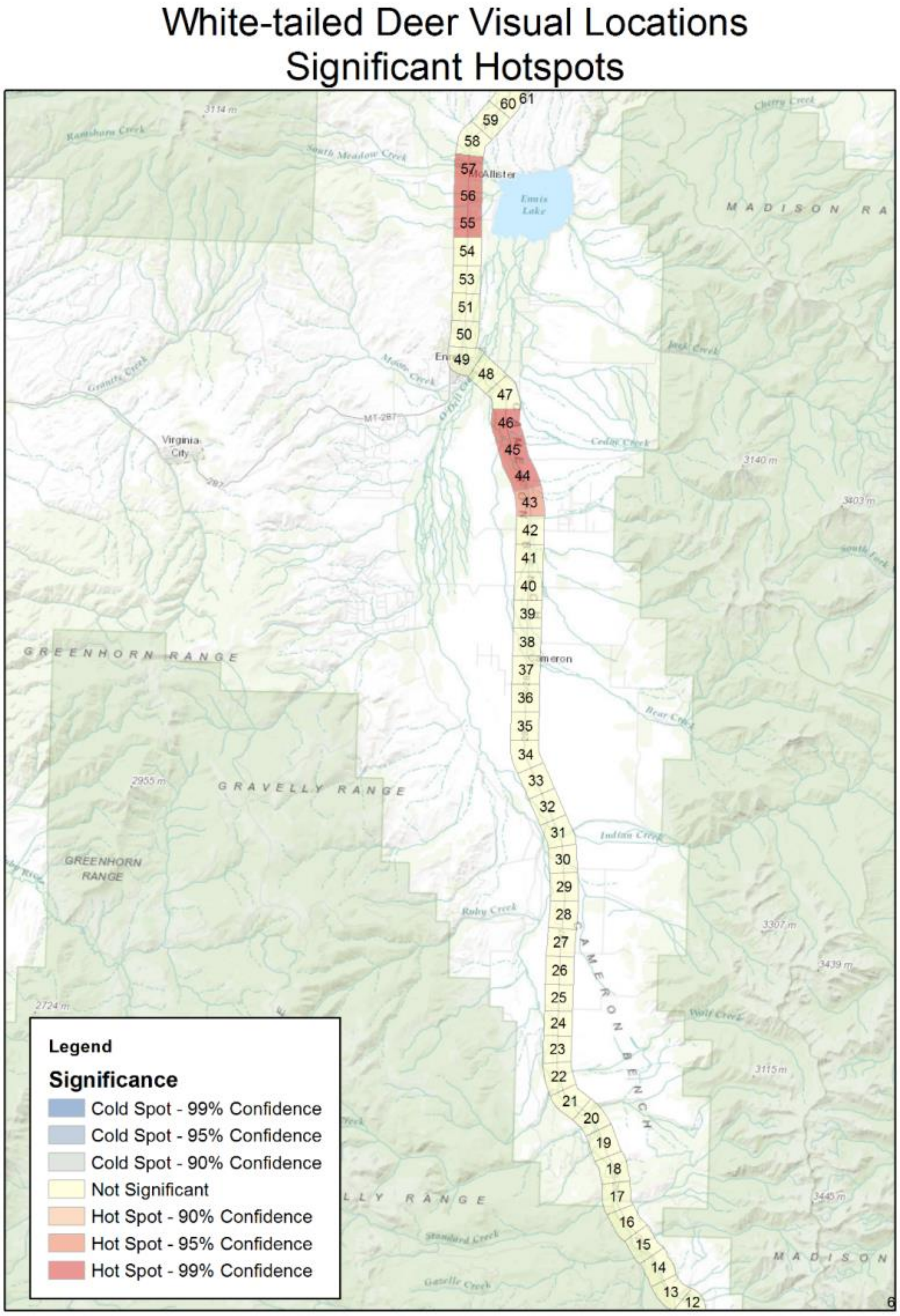


Figure 15. White-tailed deer visual locations.

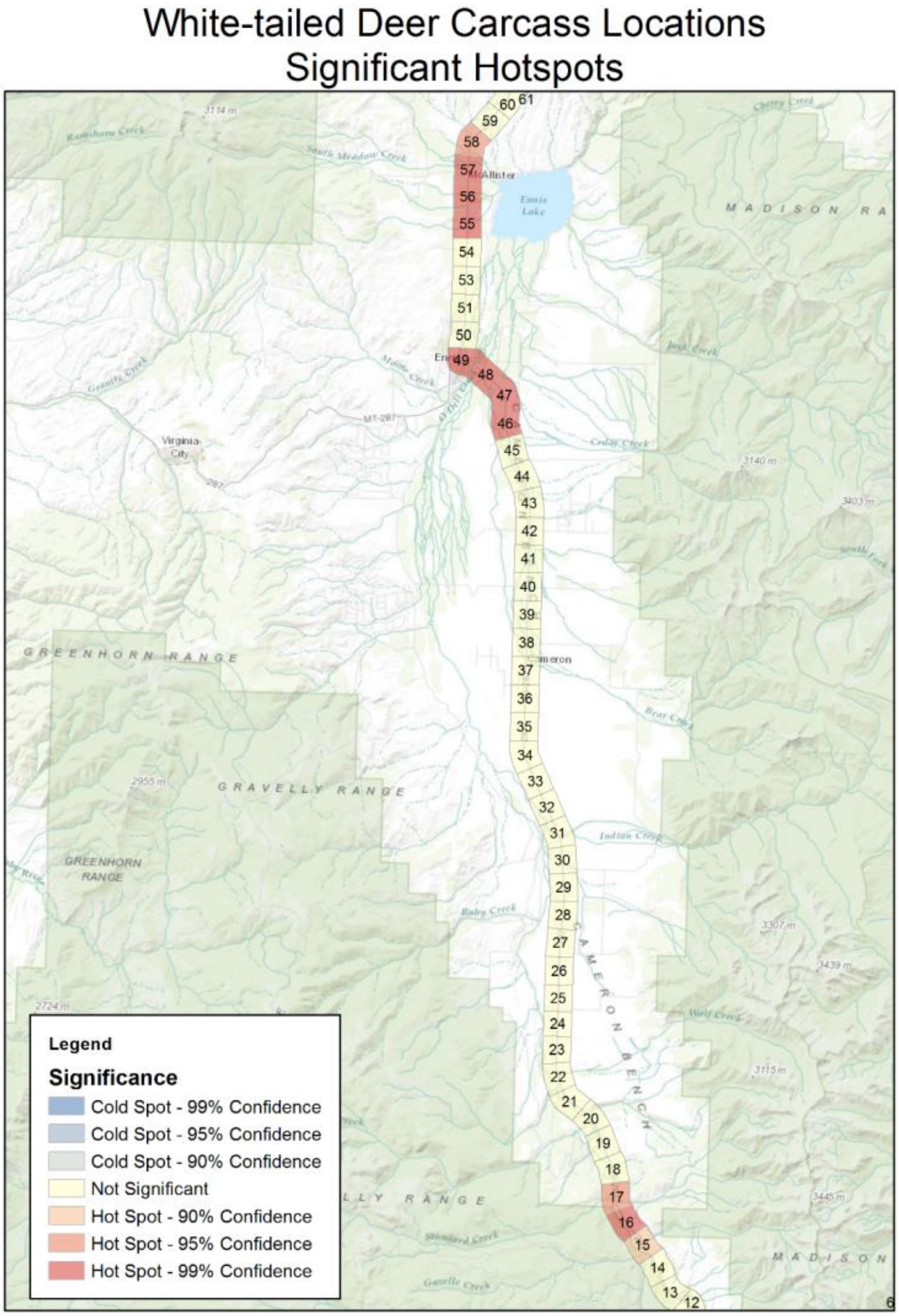


Figure 16. White-tailed deer carcass locations.

White-tailed deer carcasses were positively correlated with mean structure density and structure density and negatively correlated with WPCCD indicating that carcasses are more likely to occur near human development. They were positively correlated with distance to fence openings on one side of the road but negatively correlated with the interaction of fence openings on both sides of the road. Carcasses were also negatively correlated with distance to fence corners and mean visibility on axis (Table 7).

A visual comparison of observed white-tailed deer carcasses with model prediction values (Figure 17) indicates a reasonably good model fit.

Table 7. White-tailed deer carcass model summary.

	Estimate[1]	Std. Error	Adjusted SE	z value	Pr(>|z|)	
(Intercept)	2.921e+00	1.956e+00	1.985e+00	1.472	0.14107	
Distance to Fence Corner (One Side)	-1.928e-03	3.940e-04	4.006e-04	4.814	1.50e-06	***
Distance to Fence Opening (Side 1)	1.463e-03	3.102e-04	3.154e-04	4.640	3.50e-06	***
Distance to Fence Opening (Side 2)	1.105e-03	6.232e-04	6.334e-04	1.745	0.08094	.
factor(Fence Type (One Side))Buck and Rail	-2.272e+01	9.427e+03	9.584e+03	0.002	0.99811	
factor(Fence Type (One Side))Mesh	-4.902e+00	2.047e+00	2.079e+00	2.357	0.01841	*
factor(Fence Type (One Side))Mesh & Barbed Wire Mixed	-3.061e+00	1.852e+00	1.880e+00	1.629	0.10341	
factor(Fence Type (One Side))None	-3.477e+01	8.015e+00	8.131e+00	4.277	1.90e-05	**
factor(Fence Type (One Side))Smooth Wire	-1.688e+01	3.189e+03	3.242e+03	0.005	0.99585	
factor(Fence Type (One Side))Wood	-2.383e+01	9.427e+03	9.584e+03	0.002	0.99802	
Mean Structure Density	9.950e-02	1.346e-02	1.368e-02	7.273	< 2e-16	**
Number of Fence Strands (Side 2)	-1.276e+00	4.194e-01	4.257e-01	2.997	0.00273	*
Structure Density	5.296e-02	1.275e-02	1.294e-02	4.092	4.28e-05	**
Wild Planner Cumulative Current Density	-5.170e+02	1.746e+02	1.775e+02	2.913	0.00358	*
Distance to Fence Opening (Side 1): Distance to Fence Opening (Side 2)	-8.555e-07	4.813e-07	4.890e-07	1.749	0.08021	.
Mean Visibility Distance (On Axis)	-8.151e-04	1.969e-03	1.988e-03	0.410	0.68185	

[1] Positive estimate values indicate a positive relationship with carcasses increasing as the parameter value increases. Negative values indicate a negative response with carcasses decreasing with decreasing value. The magnitude of the estimate indicates the slope of the response with high values indicating a greater change in carcasses per increment change in a parameter value compared with smaller estimate values.

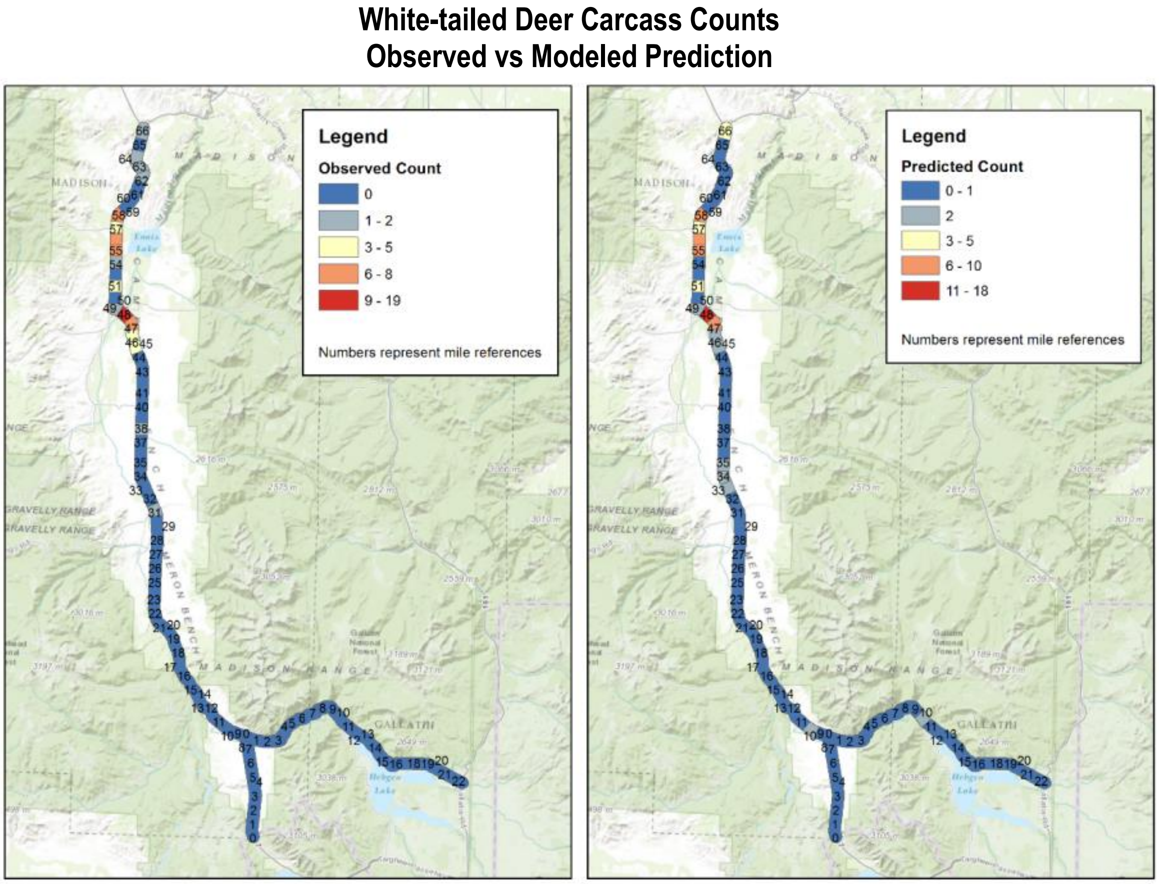


Figure 17. Comparison of observed white-tailed deer carcasses with model prediction.

5.2.4 Elk

Nearly all elk were observed between November and April each year (Figure 18). There were greater numbers of elk observed using the habitat surrounding the highway during the second winter (2013-2014) and they remained in this area in larger numbers through April. There were correspondingly larger numbers of carcasses observed during the second winter. (Note: The spikes above 4,000 elk observed in December 2013 and January 2014 may be due to differences in observers. However, the pattern of larger numbers of elk in the area during the second winter remains the same, even when accounting for this difference.)

The winter of 2013 had greater snowfall than the previous year. On several occasions thousands of elk could be seen from the highway. Many of the elk were several miles away in the foothills of the Gravelly or Madison ranges.

A total of 30 elk carcasses were recorded during this study (Appendix E: Carcass Observations by Species from April 4, 2012 to April 9, 2014. (9.5)). There were no carcasses recorded during the summer months (Figure 18) but the pattern varied slightly between years. The majority of carcasses were observed between November and April in both years.

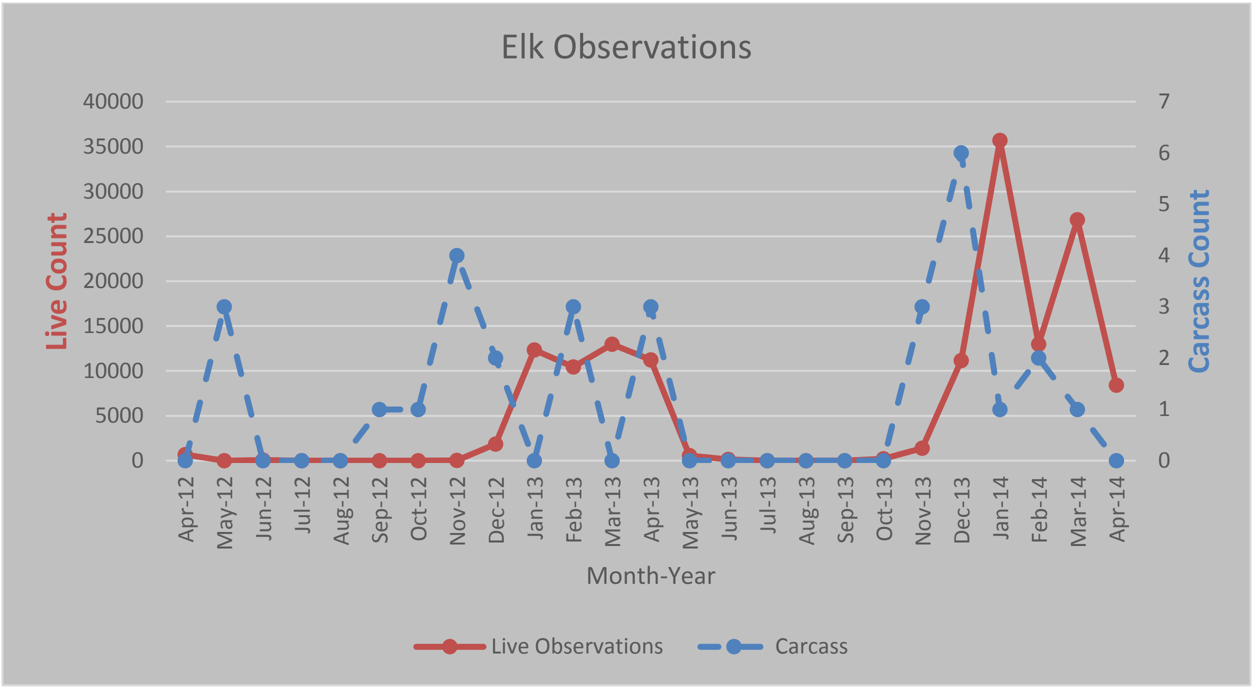
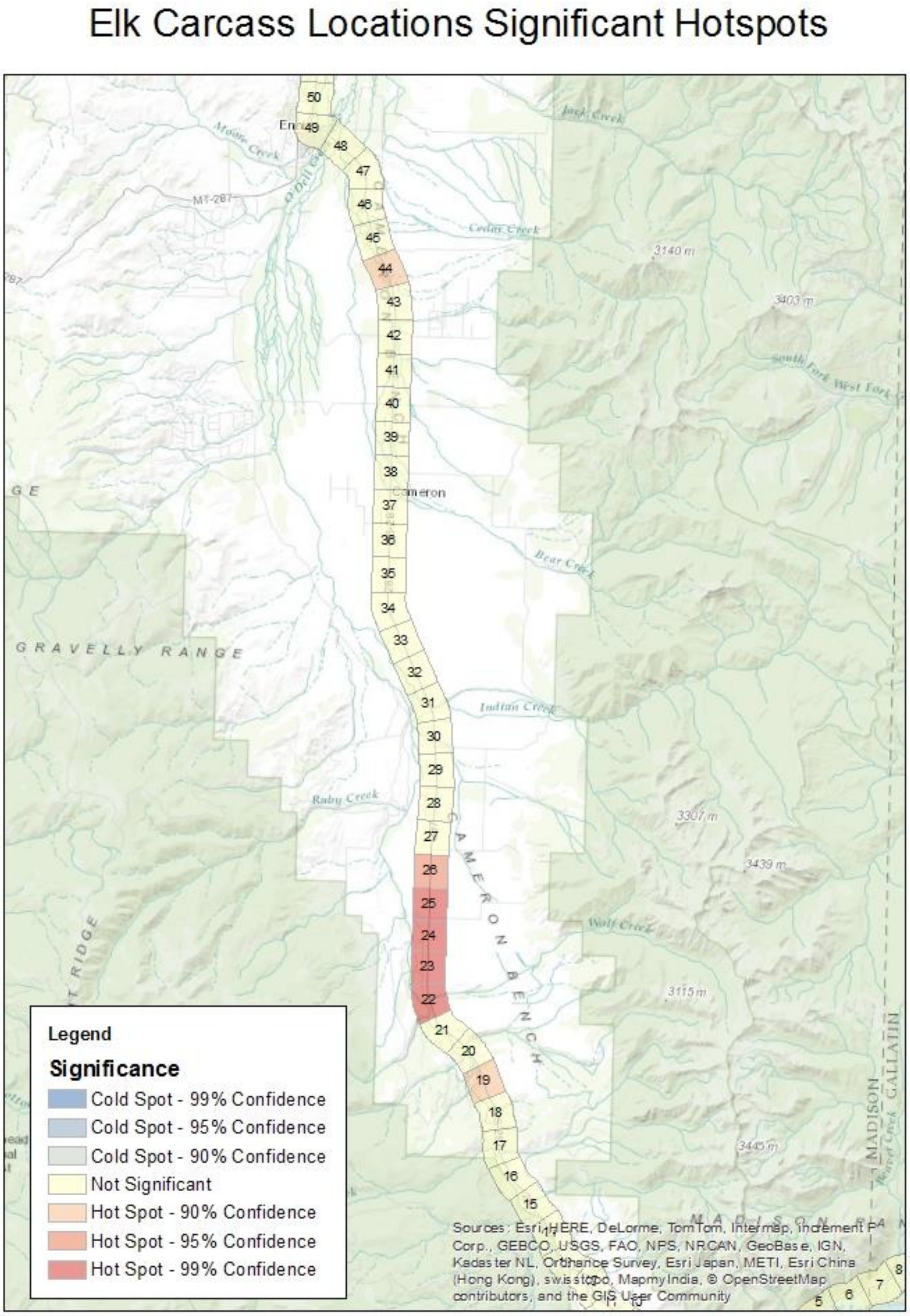


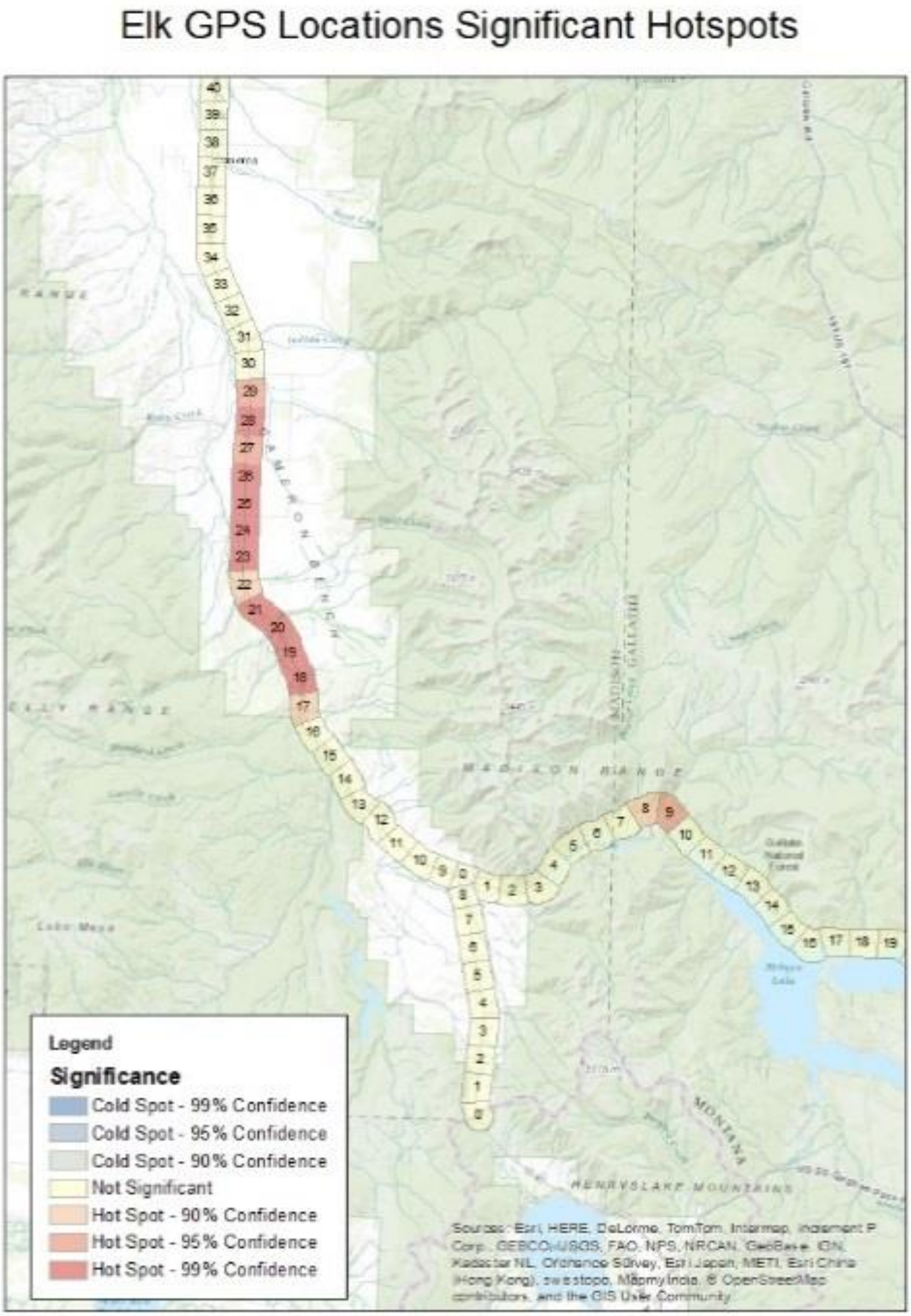
Figure 18. Elk observations (live and carcass) recorded by date.

Elk carcass hotspots are relatively concentrated at RP 22-26 near the Sun and Carroll Ranches, with additional hotspots at RP 19 and 44 (Figure 19). The carcass hotspots generally overlap with both the GPS location data and the live observations (Figure 20 and Figure 21) as well as with the track locations and successful crossing locations (Figure 22 and Figure 23). Elk carcasses and elk tracks were correlated ($R^2 = 0.91$), as were unsuccessful elk crossings when compared to elk successful crossings ($R^2 = 0.86$). However, elk visual observations were not correlated with elk tracks ($R^2 = 0.62$).



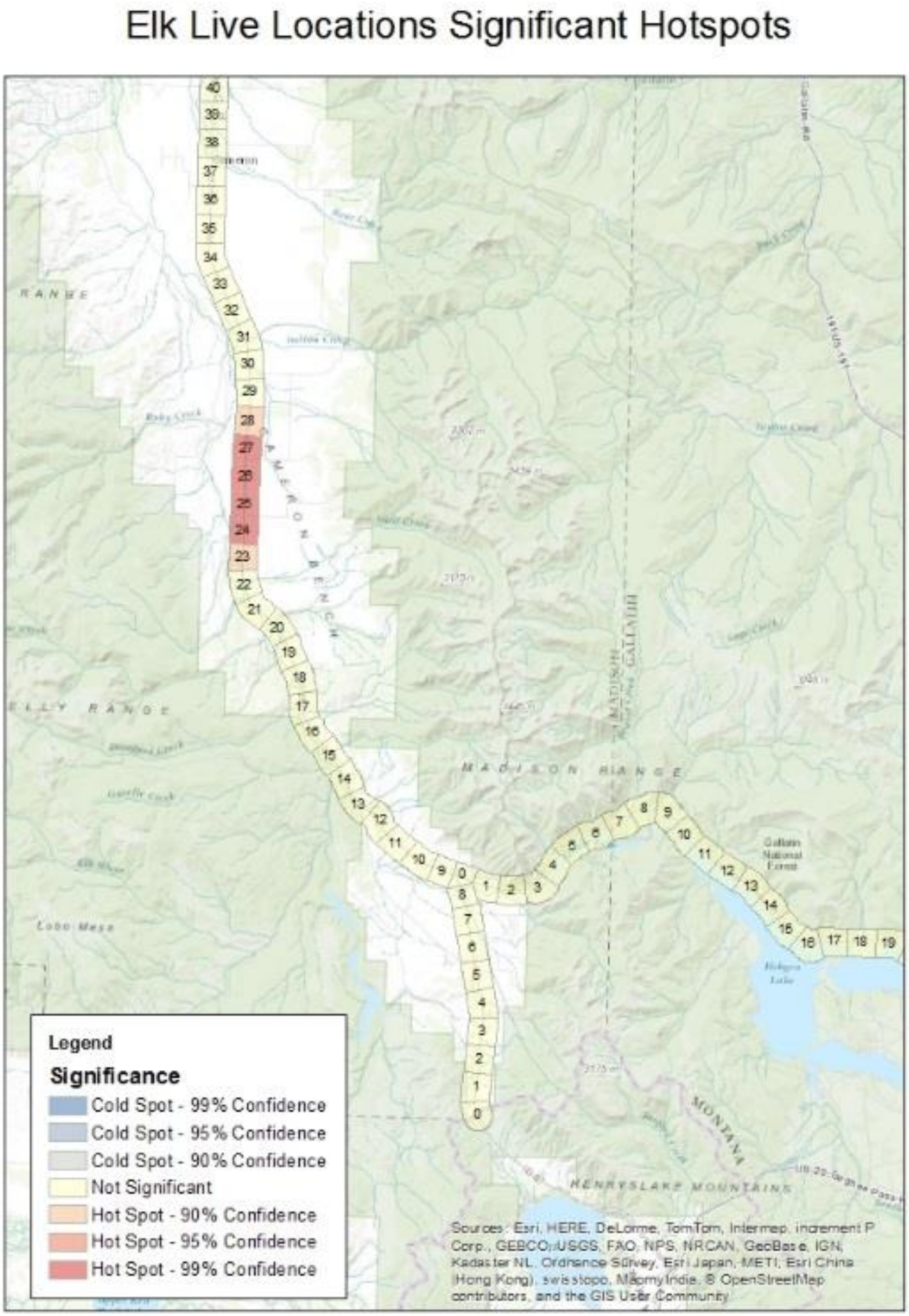
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 19. Elk carcass location hotspots.



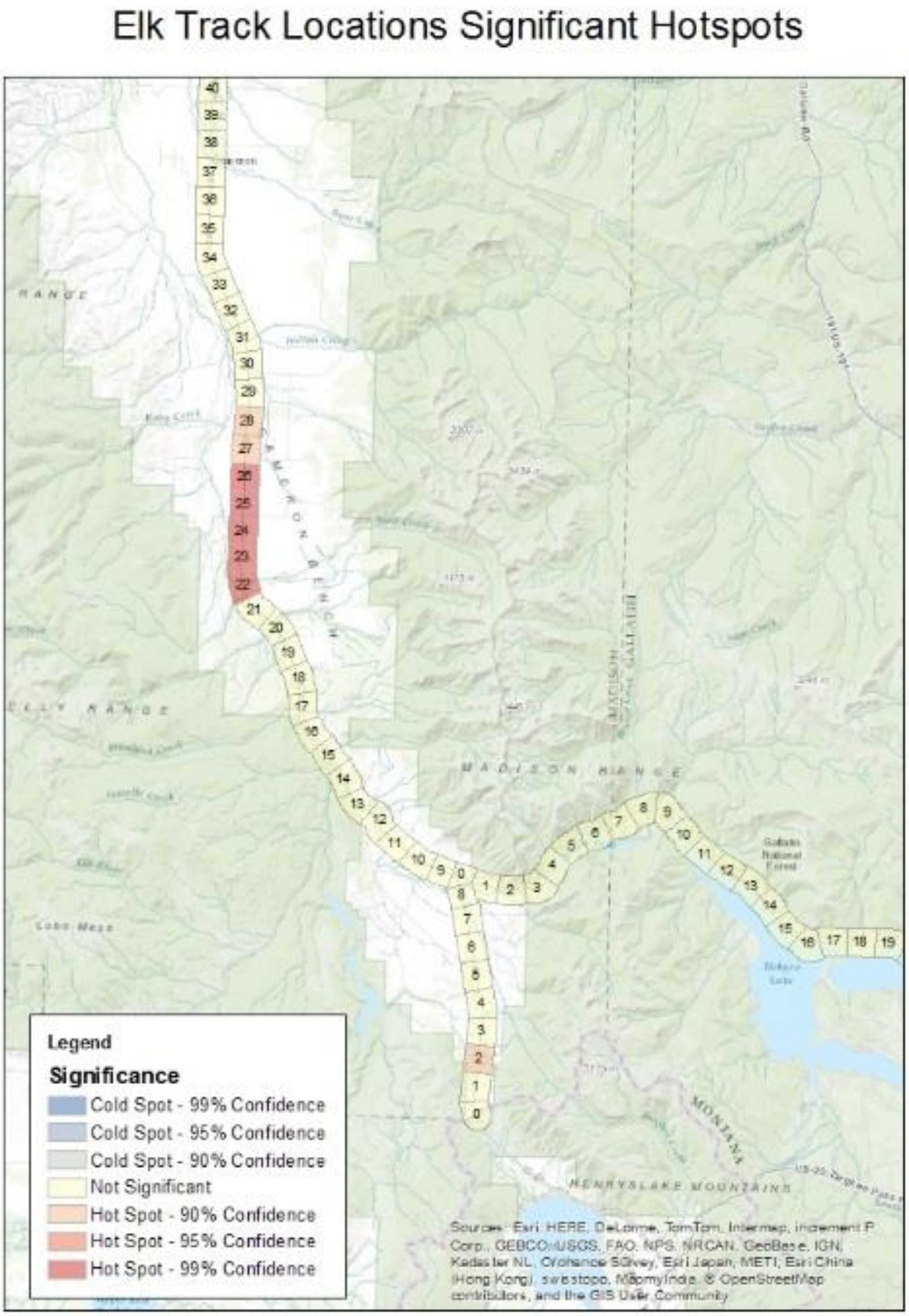
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, Mapmyindia, © OpenStreetMap contributors, and the GIS User Community

Figure 20. Elk GPS location hotspots.



Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 21. Elk live location hotpots.


Elk Track Locations Significant Hotspots

Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 22. Elk track location hotpots.

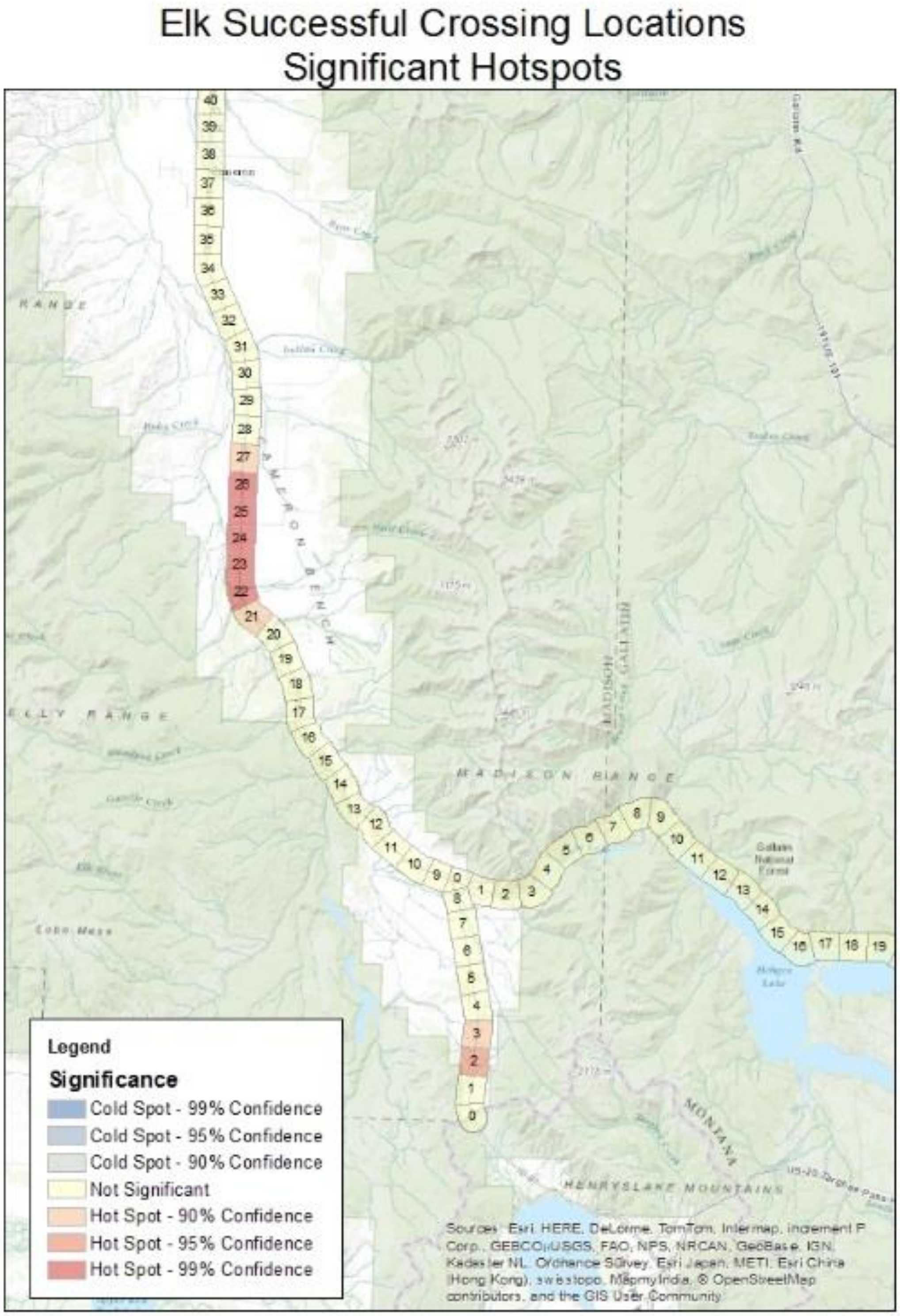


Figure 23. Elk successful crossing location hotpots.

While GPS track data for elk provided a wealth of information used for analysis, one factor that was not analyzed directly is the barrier effect of the highway. Figure 24 demonstrates this effect with GPS track data from three representative elk. Visual examinations of movement patterns of other elk in the GPS dataset fit one of these patterns, so these patterns are representative of elk in general. For two of the elk, the highway appears to serve as a complete or near complete barrier with very few or no crossings. The elk in the center map crossed the highway several times, remaining in the vicinity of the highway on both sides. Even though this animal successfully crossed the highway, the barrier effect is still clearly visible and the highway appears to be strongly influencing animal movement. Similarly, our observations indicate that many elk manage to cross the highway during winter, but it is likely that many others remain on one side or the other without crossing. These results indicate that the highway is not a complete barrier to elk movement but it appears to be a significant influence on elk movement and habitat use in the area.

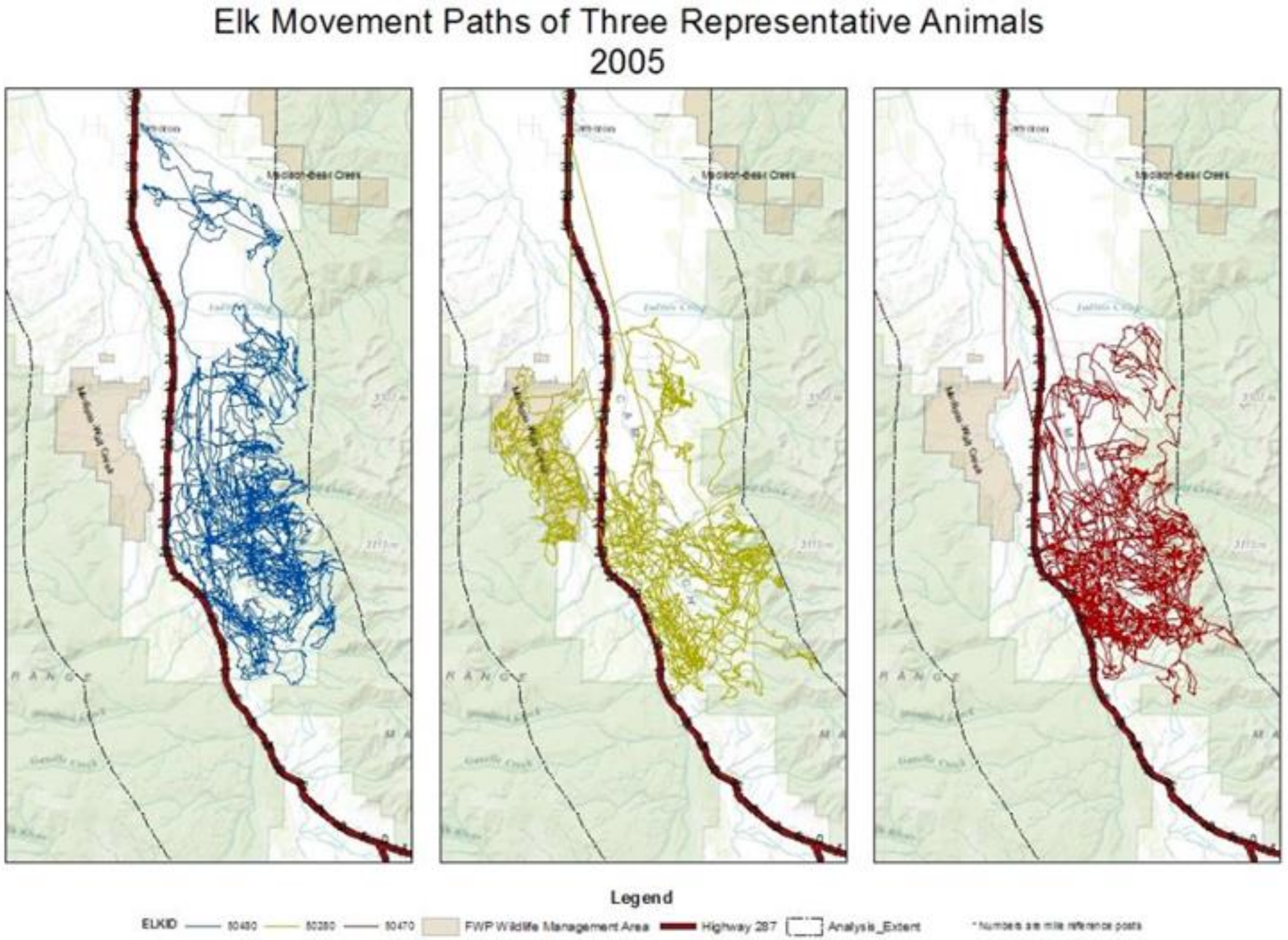


Figure 24. Movement pathways were derived from GPS collared animals in 2005. Three representative elk were chosen from visual examinations of movement patterns of 18 individual collared elk. The data illustrate the highway may be a barrier, with two elk appearing to cross zero or two times and a third elk crossing more often, but relatively few times compared to the number of times it was near the highway. (Data used to produce these figures were provided by Montana Fish, Wildlife and Parks.)

The final elk model contains eight variables (Table 8). Elk carcasses were positively correlated with WPCCD and negatively correlated with mean structure density, indicating that development patterns are likely influencing the location of carcasses. Elk carcasses were also positively correlated with grassland habitat and an absence of fencing on at least one side of the highway. Carcasses were also positively correlated with number of fence strands and occurred more frequently away from fence corners and near fence openings, although these last three parameters were the least important in the model.

A visual comparison of observed elk carcasses with model prediction values (Figure 25) indicates a reasonably good model fit.

Table 8. Elk carcass model summary.

Full model-averaged coefficients (with shrinkage):						
	Estimate[1]	Std. Error	Adjusted SE	z value	Pr(>|z|)	
(Intercept)	-2.262e+00	1.517e+00	1.532e+00	1.476	0.139878	
factor(Fence Type (One Side))Buck and Rail	-1.627e+01	3.468e+03	3.525e+03	0.005	0.996318	
factor(Fence Type (One Side))Mesh	-4.143e-01	1.383e+00	1.396e+00	0.297	0.766565	
factor(Fence Type (One Side))Mesh & Barbed Wire Mixed	-1.617e+01	1.495e+03	1.520e+03	0.011	0.991507	
factor(Fence Type (One Side))None	2.392e+00	1.290e+00	1.300e+00	1.840	0.065713	.
factor(Fence Type (One Side))Smooth Wire	-9.633e-01	1.111e+00	1.128e+00	0.854 0.	393211	
factor(Fence Type (One Side))Wood	-1.566e+01	3.468e+03	3.525e+03	0.004	0.996456	
factor(Majority Land Cover Class) Human Land Use	-1.282e+01	2.400e+03	2.440e+03	0.005	0.995808	
factor(Majority Land Cover Class) Forest and Woodland Systems	-3.146e-01	7.960e-01	8.089e-01	0.389	0.697332	
factor(Majority Land Cover Class) Shrubland, Steppe and Savanna Systems	-3.305e-01	9.026e-01	9.174e-01	0.360	0.718610	
factor(Majority Land Cover Class) Grassland Systems	1.015e+00	8.715e-01	8.859e-01	1.146	0.251911	
Mean Structure Density	-6.771e-02	3.363e-02	3.417e-02	1.981	0.047536	*
Number of Fence Strands (Side 1)	2.739e-01	1.127e-01	1.144e-01	2.395	0.016615	*
Wild Planner Cumulative Current Density	1.939e+02	5.114e+01	5.198e+01	3.731	0.000191	***
Number of Fence Strands (Side 2)	1.136e-01	2.616e-01	2.635e-01	0.431	0.666212	
Distance to Fence Corner (One Side)	2.987e-05	7.786e-05	7.843e-05	0.381	0.703294	
Distance to Fence Opening (Side 2)	-4.248e-05	1.482e-04	1.496e-04	0.284	0.776447	
Signif. codes:	0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					

[1] Positive estimate values indicate a positive relationship with carcasses increasing as the parameter value increases. Negative values indicate a negative response with carcasses decreasing with decreasing value. The magnitude of the estimate indicates the slope of the response with high values indicating a greater change in carcasses per increment change in a parameter value compared with smaller estimate values.

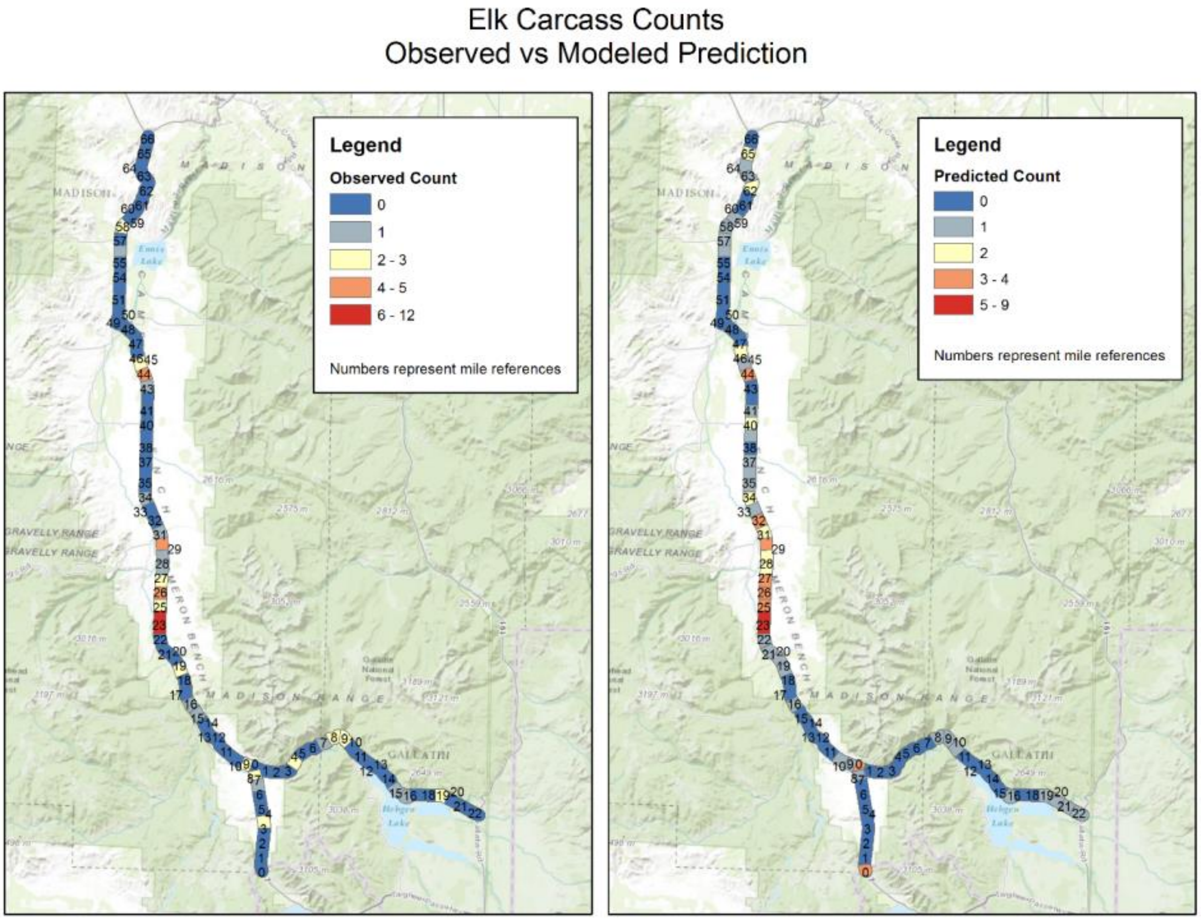


Figure 25. Comparison of observed elk carcasses with model prediction.

5.2.5 Pronghorn

Pronghorn were present throughout the year in the vicinity of the highway with notable increases during the winter months, and larger numbers that remained for a longer time during the second winter of 2013 (Figure 26).

A total of 16 pronghorn carcasses were recorded during the two years of the study (Appendix E: Carcass Observations by Species from April 4, 2012 to April 9, 2014. (9.5)). They generally occurred throughout the year, although the sample size is small (Figure 26).

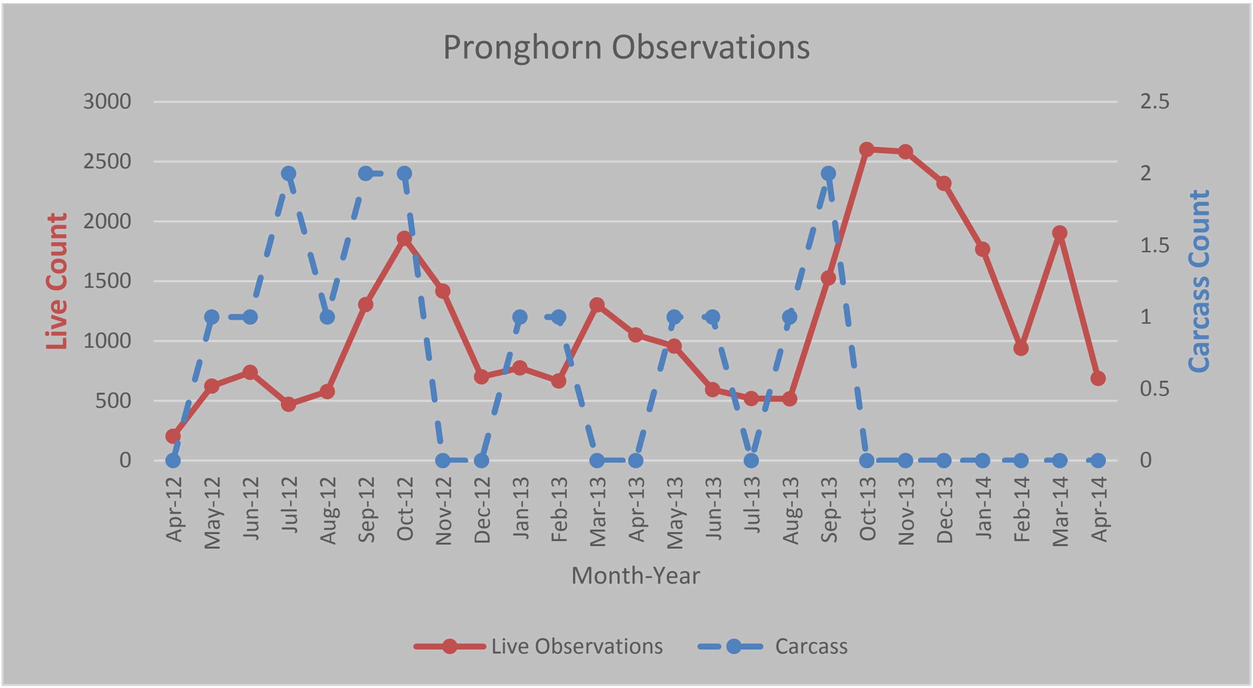
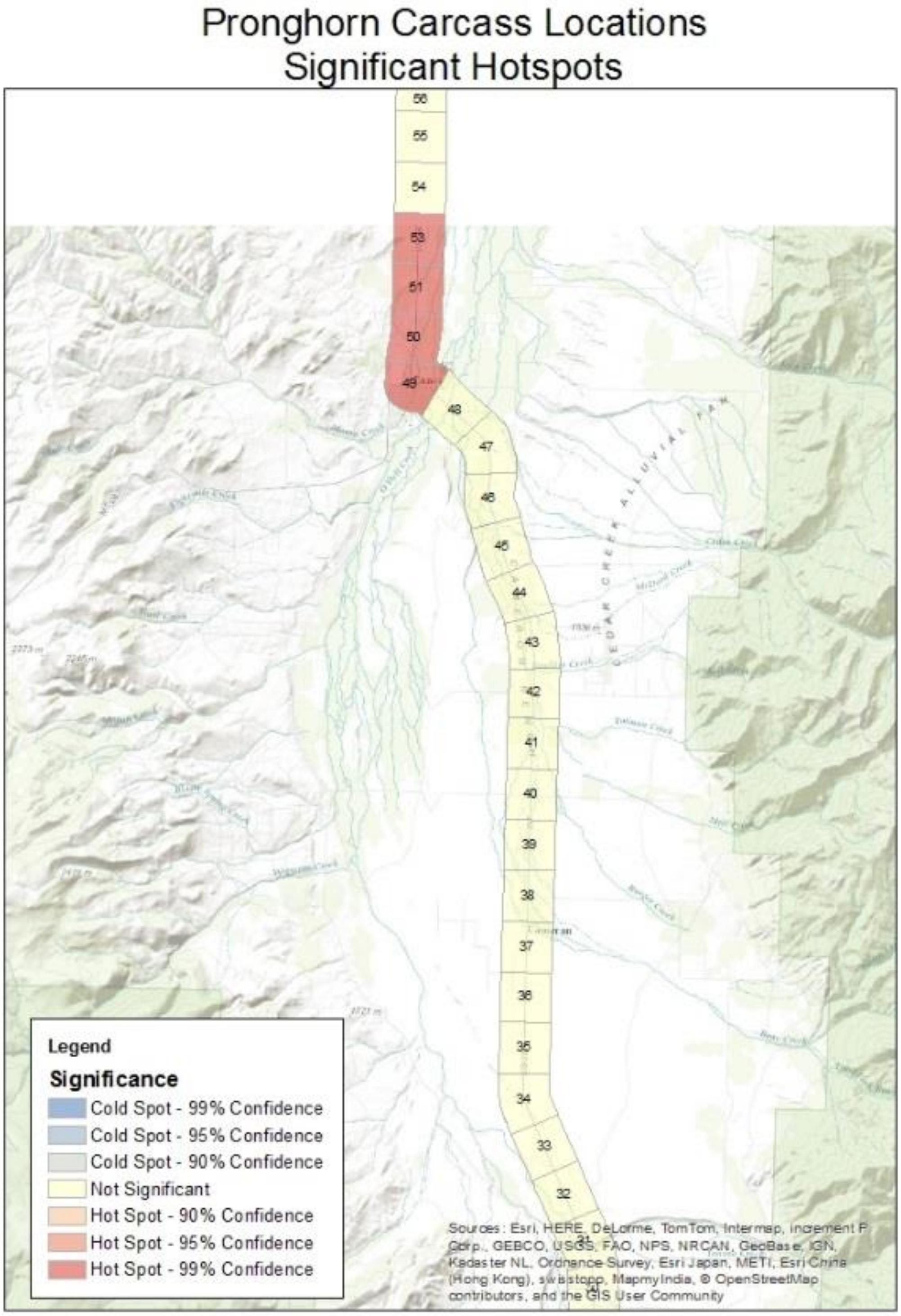


Figure 26. Pronghorn observations (live and carcass) recorded by date.

Pronghorn carcass locations are not spatially correlated with live pronghorn observations (R^2 = 0.36), but there is some overlap at RP 50-53 (Figure 27, Figure 28). Pronghorn successful crossings were not spatially correlated with pronghorn unsuccessful crossings (R^2 = 0.66).



Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 27. Pronghorn carcass hotspots.

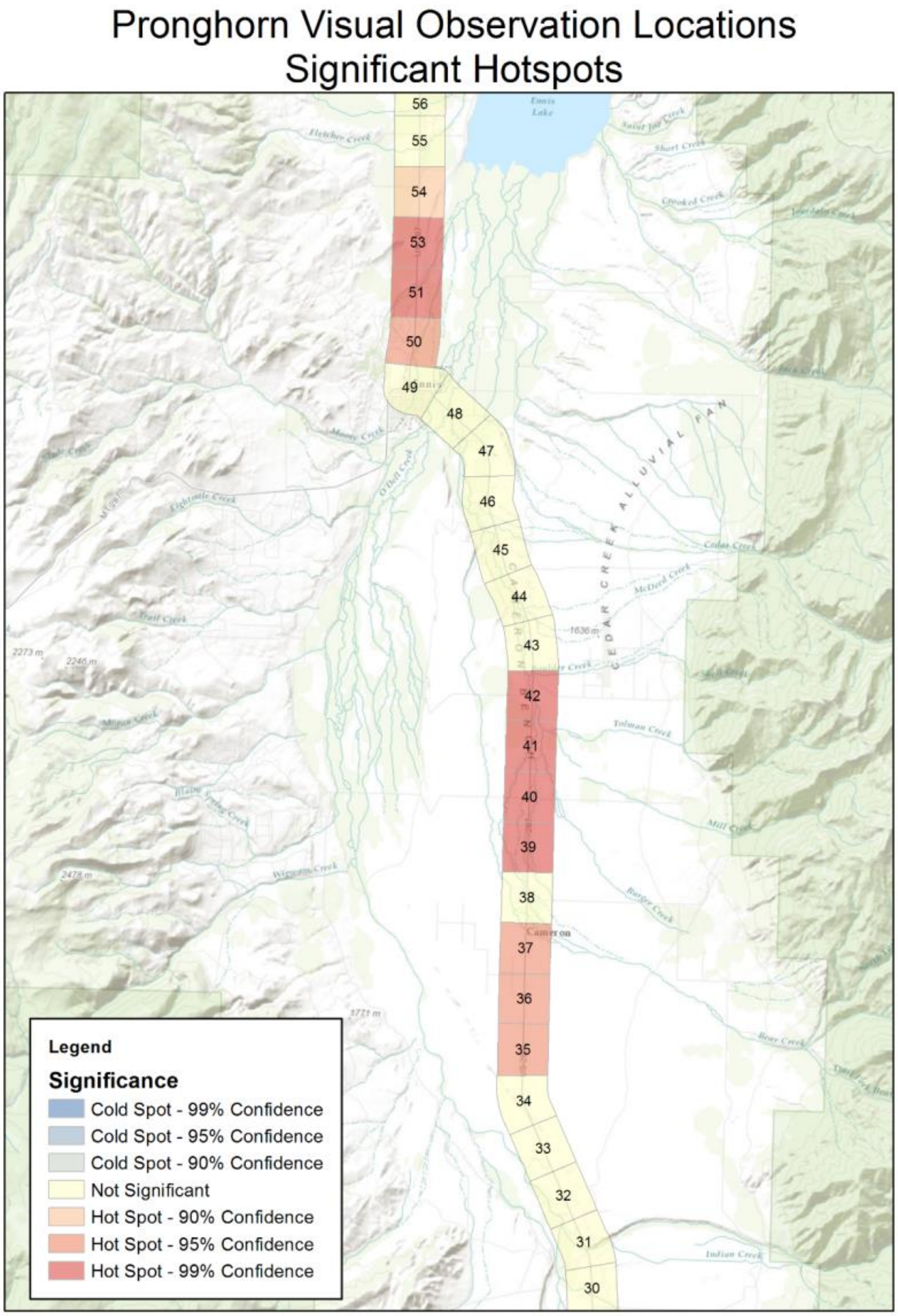


Figure 28. Pronghorn live observation hotspots.

Pronghorn carcasses were significantly correlated with distance to fence corners (positive), and mean visibility (negative). They were positively correlated with mean structure density, WPCCD, distance to fence opening, and mean visibility on axis, and negatively correlated with the distance to fence opening interaction term (Table 9).

Table 9. Pronghorn carcass model summary.

Full model-averaged coefficients (with shrinkage):						
	Estimate[1]	Std Error Adjusted	SE	z value	Pr(>|z|)	
(Intercept)	-1.719e+01	2.593e+03	2.634e+03	0.007	0.9948	
Distance to Fence Corner (One Side)	1.089e-03	4.609e-04	4.658e-04	2.339	0.0193	*
Distance to Fence Opening (Side 1)	5.169e-04	3.062e-04	3.085e-04	1.675	0.0939	.
Distance to Fence Opening (Side 2)	8.495e-04	5.844e-04	5.899e-04	1.440	0.1499	
factor(Majority Land Cover Class) Human Land Use -5.117e+00	5.561e+03	5.649e+03	0.001	0.9993		
factor(Majority Land Cover Class) Forest and Woodland Systems	8.397e+00	2.593e+03	2.634e+03	0.003	0.9975	
factor(Majority Land Cover Class) Shrubland, Steppe and Savanna Systems	1.522e+01	2.593e+03	2.634e+03	0.006	0.9954	
factor(Majority Land Cover Class) Grassland Systems	1.633e+01	2.593e+03	2.634e+03	0.006	0.9951	
Mean Structure Density	3.614e-02	3.398e-02	3.417e-02	1.058	0.2903	
Mean Visibility Distance (360°)	-6.221e-03	3.045e-03	3.079e-03	2.021	0.0433	*
Distance to Fence Opening (Side 1):Distance to Fence Opening (Side 2)	-1.593e-06	1.057e-06	1.066e-06	1.495	0.1350	
Mean Visibility Distance (On Axis)	3.322e-03	4.015e-03	4.040e-03	0.822	0.4108	
Wild Planner Cumulative Current Density	2.919e+01	6.314e+01	6.356e+01	0.459	0.6460	

[1] Positive estimate values indicate a positive relationship with carcasses increasing as the parameter value increases. Negative values indicate a negative response with carcasses decreasing with decreasing value. The magnitude of the estimate indicates the slope of the response with high values indicating a greater change in carcasses per increment change in a parameter value compared with smaller estimate values.

A visual comparison of observed pronghorn carcasses with model prediction values (Figure 29) indicates a reasonably good model fit.

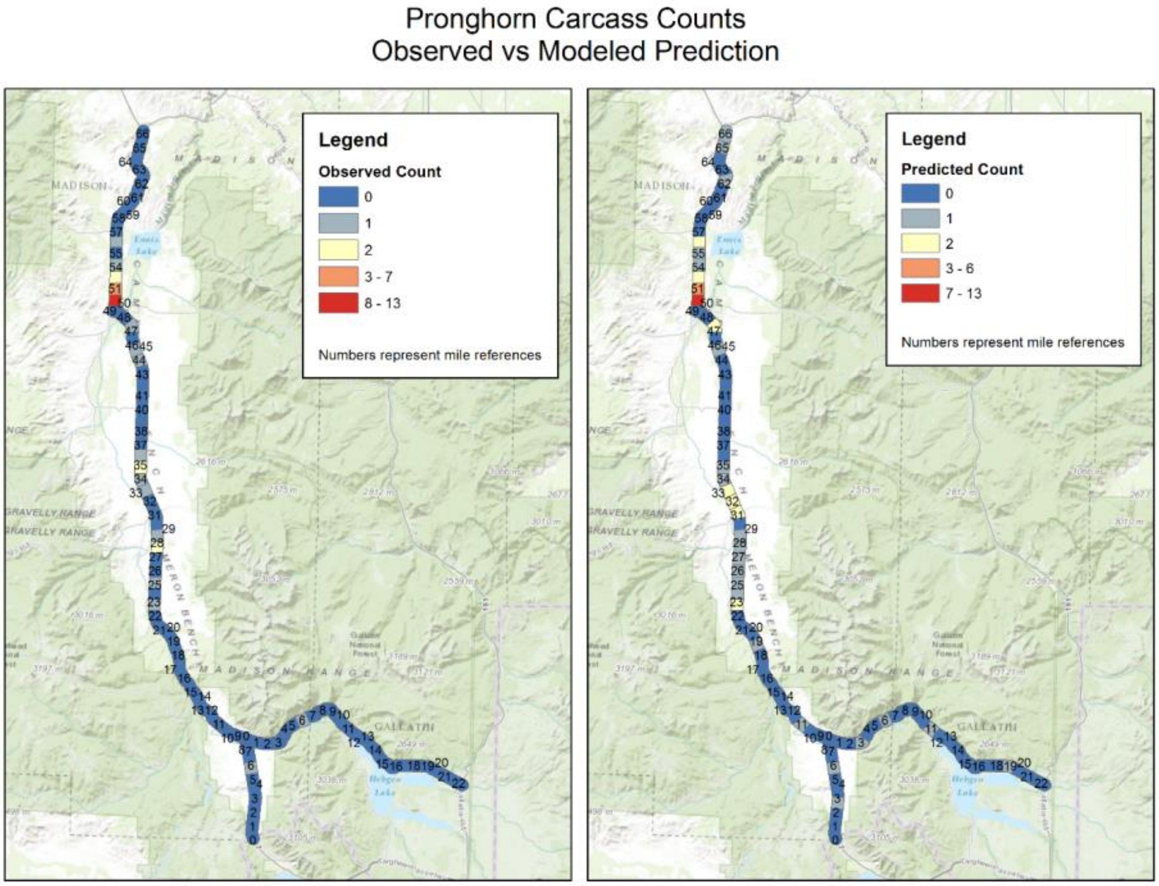


Figure 29. Comparison of observed pronghorn carcasses with model prediction.

5.2.6 Bighorn Sheep

A total of four bighorn sheep carcasses were observed during the two years of the study. These confirmed WVCs occurred during one incident in November 2013 in which a large group of sheep attempted to cross the highway.

There was a clear seasonal pattern of habitat use in the vicinity of the highway during winter (Figure 30). Larger groups of sheep were observed during the first winter (2012-2013). Live observation hotspots were just west of Quake Lake on US 287 at RP 0-6 and on MT 87, RP 8 (Figure 31). Bighorn sheep track hotspots were on US 287 at RP 0-7 and on MT 87, RP 8 (Figure 32).

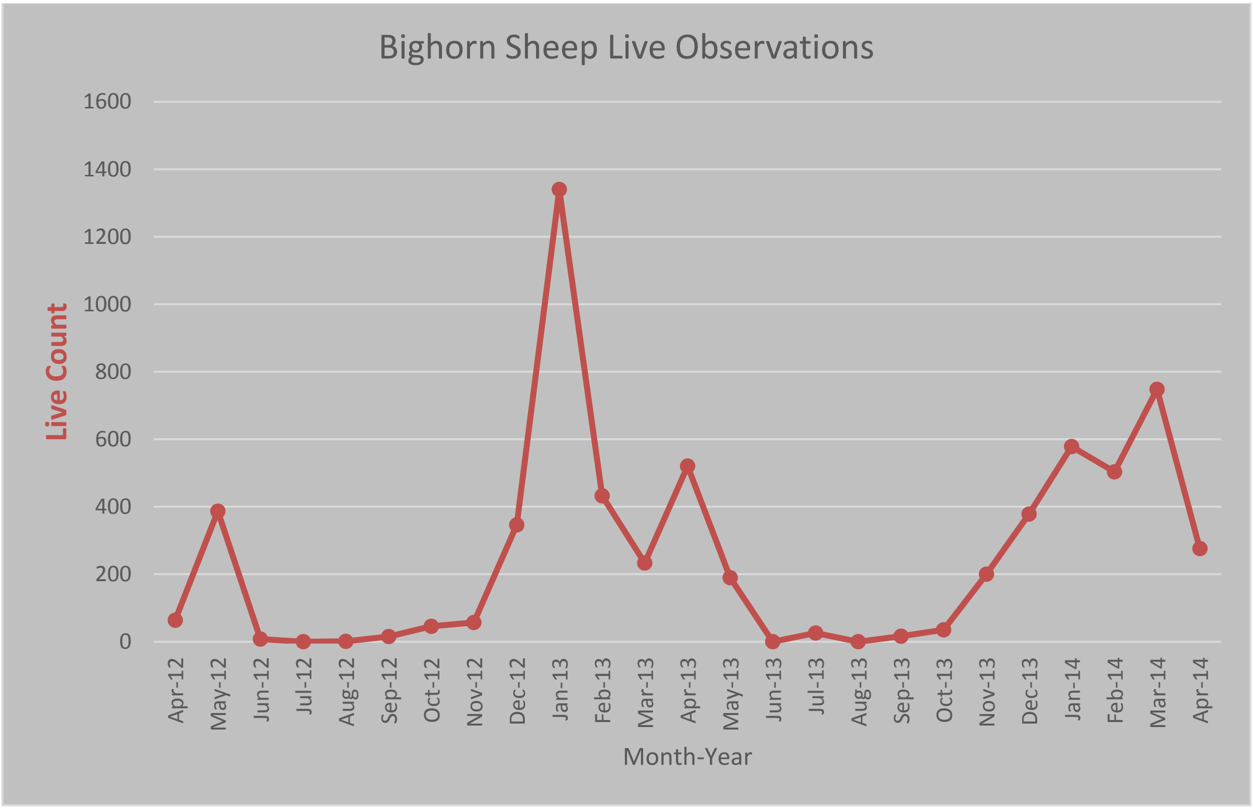
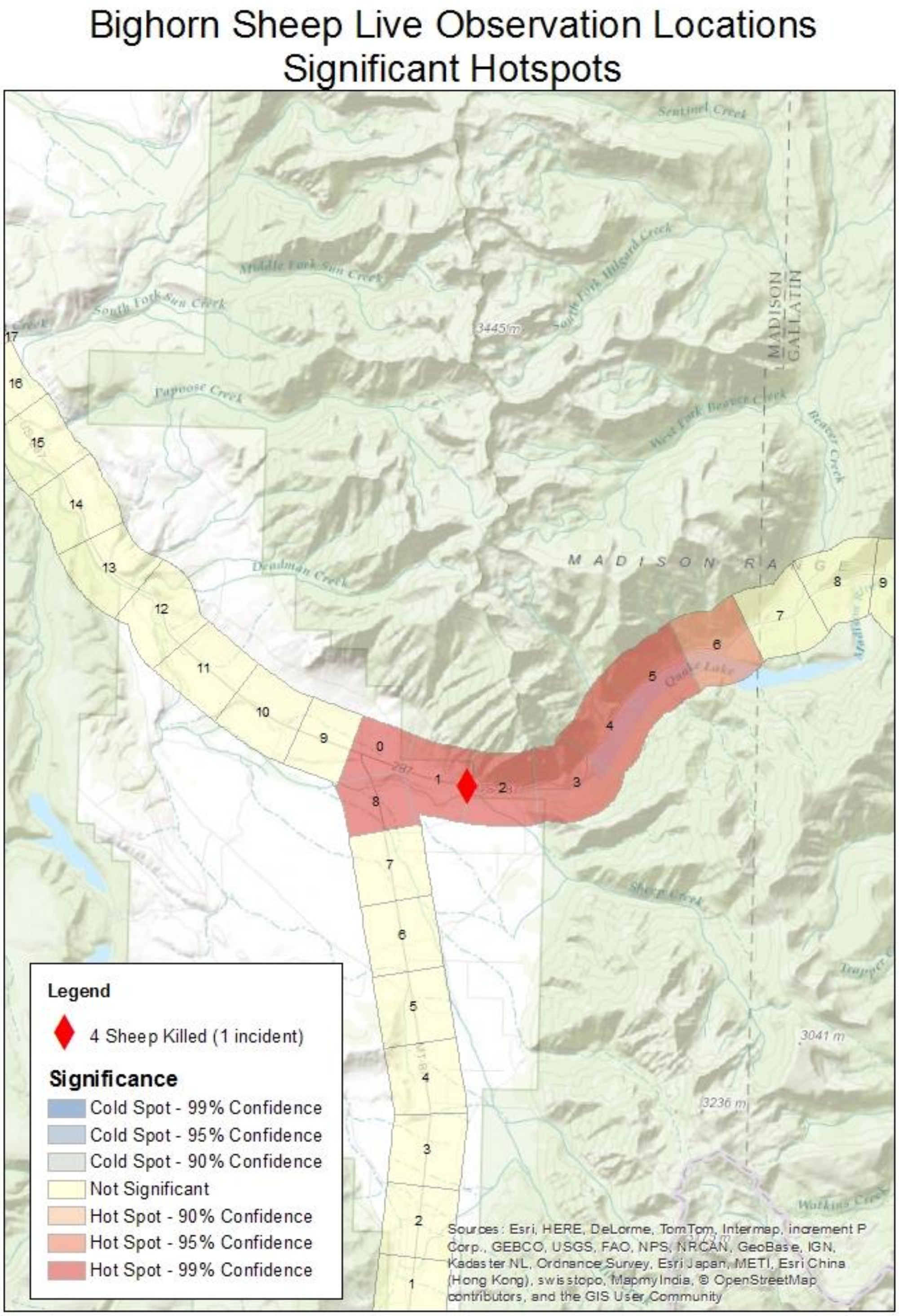
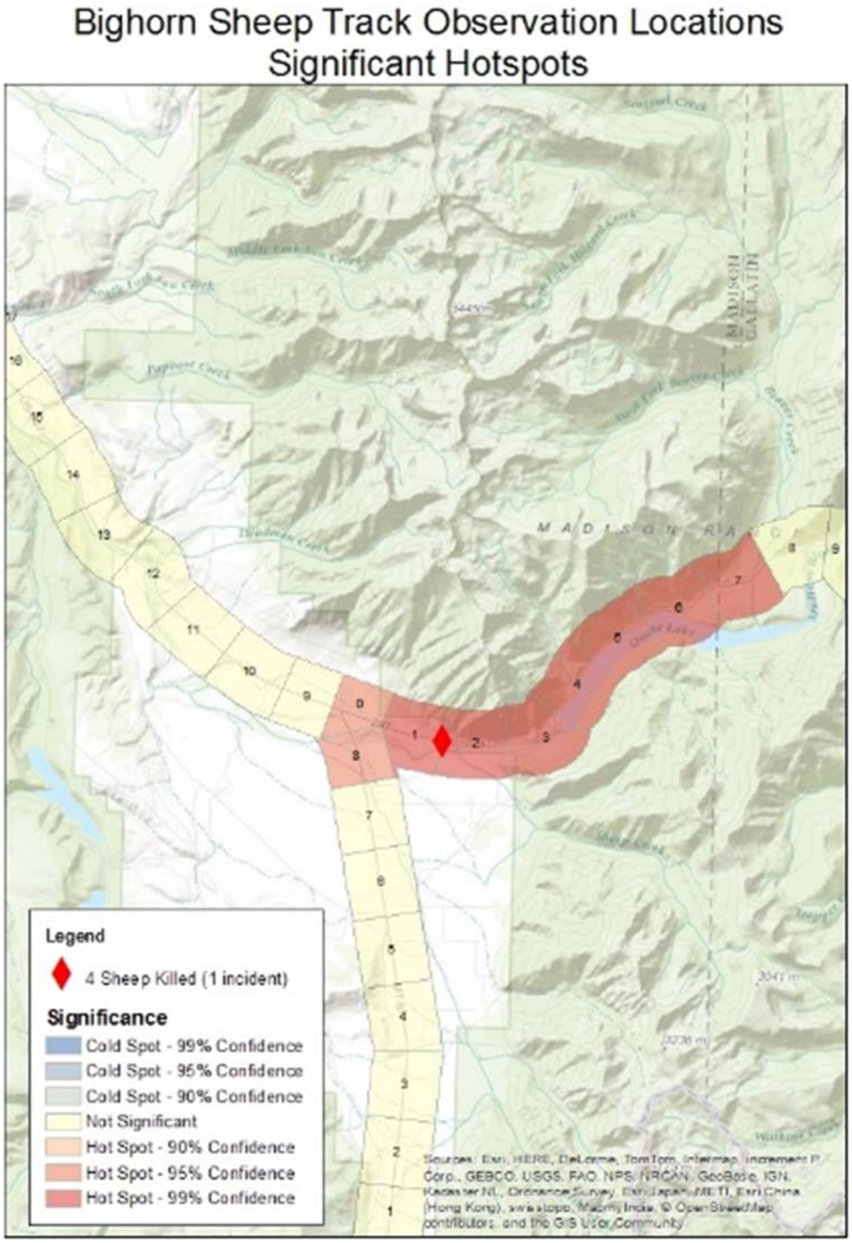


Figure 30. Bighorn sheep live observations recorded by date. (Monthly count represents the cumulative number of observations over the course of the month. An individual sheep may be observed multiple times in one month.)



Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 31. Bighorn sheep live observation hotspots and carcass location.



Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 32. Bighorn sheep track observation hotspots and carcass location.

5.2.7 Grizzly Bear

Grizzly bears were one of the species of concern for this project. There has been only one known WVC (confirmed) involving a grizzly bear along US 287. It occurred near Grayling Creek (RP 20.1) on August 30, 2013, and the bear was killed. No live grizzly bears were observed during the course of this study. Grizzly bear movement data from GPS collars for 2001-2012 were obtained from the Interagency Grizzly Bear Study Team (IGBST), which identified areas between likely locations where grizzly bears crossed US 287.

Data were collected in all, or in part, of 318 grizzly bear active seasons. They identified 54 highway crossings locations among the nine grizzly bears and 10 bear-collar combinations whose Minimum Convex Polygons intersected US 287 (Appendix I: Table 1, Figures 1 and 2). Specific information regarding date, time, and locations of US 287 grizzly bear crossings sites are contained within the accompanying spreadsheet (Appendix I, Table 2).

The nine grizzlies studied crossed US 287 primarily between RP 10-22, RP 18-22, and RP 3-9. Another grizzly bear crossing occurred near Raynolds Pass on MT 87 (RP 0) near the Idaho border. Individual bears often crossed repeatedly at or near the same location. None of the bears followed with GPS were involved in a WVC.

5.2.8 Other Species

There were some species for which hotspot and other analyses were not conducted because: 1) the sample size was too small (e.g., bears, wolves, moose) or 2) WVCs pose no threat to motorists or to the animal populations (e.g., rabbits, skunks, ground squirrels). Species of interest either from a highway safety (i.e., black bear, moose, mountain goat, wolf) or a wildlife conservation perspective (i.e., boreal toad, wolverine) are qualitatively summarized below.

Black Bear. During the course of this study, one live black bear was observed at RP 28, and there were no black bear carcasses recorded.

Boreal Toad. Boreal toads are a species of concern in the study area. Areas along the shore of Hebgen Lake are important habitat for boreal toads, especially during the spring mating season. No live boreal toads or carcasses were observed during the course of this study. However, it is possible that the field biologist and others conducting surveys were not able to observe wildlife as small as the boreal toad while driving at speeds up to 55 mph. In addition, small reptile and amphibian carcasses often do not persist on or near the road for long periods of time, making carcasses difficult to observe with the methods used in this study.

Moose. Four moose carcasses were reported during the study, all by either MDT or USGS. All were found from mid-June to September, 2012. Live observations occurred on five different days, with numbers of individuals observed each day varying between one and two.

Mountain Goat. While there were several observations of mountain goats high on a rock outcrop away from the road, there was only one observation of eight goats close to the road. No carcasses were recorded during the study.

Wolf. During this study, one wolf carcass was recorded on May 11, 2012 at RP 20.3 on US 287 near the Sun Ranch. Live wolves were also observed on six different days between January and March 2013, with numbers of individuals observed each day varying between one and three.

Wolverine. Wolverines are also a species of concern in the study area. There have been only two known WVCs involving wolverine along US 287. Both were males killed in March 2004. One WVC occurred along the shore of Hebgen Lake where the wolverine was feeding on a road-killed elk (-111.267756W 44.825169N). The other occurred north of Ennis near the Valley Garden

Ranch (-111.729706W, 45.402978N). No wolverines were observed during the course of this study.

5.3 Remote Camera Data for All Species

Because data from remote cameras are qualitatively different than other data, the findings have been summarized in narrative form here and in a table in Appendix F (9.6). In general the culverts were used by small to medium-sized mammals; occasionally birds were also observed. Larger structures such as bridges were also used by deer and moose, as well as smaller wildlife. Species using these structures varied greatly depending upon the habitat adjoining the structure.

Remote camera locations corresponded with carcass locations in two areas: the North Meadow Creek bridge at RP 57.5, and the underpass south of the Madison River bridge near Ennis at RP 48.4. Other remote camera locations were used frequently by wildlife without many carcasses on the highway nearby. Some interesting observations include: 23 records of moose and 404 records of mule deer using the Beaver Creek Bridge, 52 records of badger using the stock culvert south of the Madison River Bridge at Ennis at RP 48.4 on US 287, 68 records of humans using the Grayling Creek Bridge at RP 20 on US 287, 98 records of mule deer using the Indian Creek Bridge at RP 29.6 on US 287, 104 records of mule deer (and only 3 records of white-tailed deer) and 484 records of humans (typically floating and/or fishing) using the Madison River Bridge near Ennis at RP 48.5 on US 287. Finally, there were 3,328 records of humans with 310 records of dogs using the Madison River Bridge at RP 8.1 on US 287 in just one year; they were mostly fishermen from the nearby fishing access site.

6 CONCLUSIONS

6.1 Overview

This research project set out to investigate the effect of the major highways in the Madison Valley on wildlife mortality and movement patterns. Species of interest from a safety perspective were large-bodied animals: pronghorn (*Antilocapra americana*), bighorn sheep (*Ovis canadensis*), mountain goat (*Oreamnos americanus*), deer (*Odocoileus sp*.), elk (*Cervus canadensis*), moose (*Alces alces*) and bear (*Ursus sp.)*. The research team's investigation focused on systematically quantifying carcasses (i.e., carcass surveys, MDT carcass removal, MTFWP carcass and salvage data and opportunistic sightings) and assessing species presence and/or movements along and across the highway (i.e., photo monitoring, live animal observations, and a limited amount of snow tracking).

The results of the data analysis lead to several conclusions that are species specific. These conclusions reflect the fact that US 287 and MT 87 in the study area bisect important habitat, particularly during winter months, for many species included in this study. Some individuals of these species may spend the winter season or even live year-round in the vicinity of the highway. In addition, other individuals or groups of animals of the migratory species (elk, bighorn sheep, mule deer and pronghorn) may cross or attempt to cross the highways in the spring and in the fall as they move between winter and summer ranges.

Regression models were run to identify which factors may contribute to observed patterns of carcasses (e.g., fencing, visibility). These models are only preliminary and exploratory. They should not be used for prediction.

The research team ran several models for carcass data and one model for all observations of elk, because live observations and carcasses were known to correlate so well from previous analyses. Results indicate that animal carcass locations (and presumably movement patterns) are generally influenced by existing development patterns, vegetation cover, terrain, and potential barriers near roadways.

6.2 Conclusions by Species

6.2.1 Deer species combined

Deer carcass locations do not match track locations or successful crossing locations, indicating that deer carcasses are not just a function of where deer cross the highway and that some other environmental or road factor is involved.

Track locations do not match visual hotspots well, indicating there may be a bias in visual observations (deer are more easily observable in some areas, resulting in the visual hotspot). Deer of one or both species are successfully crossing the highway throughout the valley, which may be due to deer residency in the valley, familiarity with the highway, and traffic patterns that individuals learn over time.

White-tailed deer and mule deer seem to partition the habitat (either by avoidance of each other, displacement, or differences in habitat preference) to some extent, as indicated by the visual hotspot analyses. Both species have carcass hotspots around Ennis and near RP 56. These may be areas where highway characteristics or traffic patterns contribute to WVCs for either species of deer even if they are not more densely concentrated. In general for deer, it appears that they are not necessarily getting hit in areas that they use the most. It is possible that because there are resident deer throughout the year, they become habituated to traffic and perhaps learn how to cross the highway safely. The deer that are getting hit may be those that encounter the highway in unfamiliar conditions, perhaps when they move closer to Ennis in the winter or are migrating across the highway during seasonal movements.

6.2.2 Mule Deer

Mule deer are similar to elk in the sense that they also migrate between low elevation winter range and higher elevation summer range (Constan 1967, Martinka 1968, Mackie et al. 1976, 1982, Wood 1989, Chapman and Feldhammer 1982, Foresman 2001). Movements in the Madison Valley tend to be east-west. Small herds of mule deer may remain within the Madison Valley during summer. Mule deer herds are found throughout the valley in winter. Mule deer would be expected to cross highways in spring and in fall as they migrate, and throughout the year as they travel to find forage or avoid disturbance.

Although many mule deer migrate out of the valley during summer, there appear to be resident animals that stay in the vicinity of the highway throughout the year and are occasionally involved in WVCs. Mule deer observations and carcasses do not overlap clearly except at RP 46-51. This may be due to habituation of mule deer around the town of Ennis. The mule deer carcass hotspot at RP 12-13 is an area of greater topographic variation than further north and it is likely that deer cannot be seen as well from the highway; hence observers are not able to detect them if they do occur in greater concentrations here.

Model results indicate that mule deer carcass locations are influenced by visibility along and around the roadway and fencing, but more refinement of the model is needed to provide a clear interpretation.

6.2.3 White-tailed Deer

White-tailed deer can also be migratory and tend to spend their entire lives within relatively small home ranges where they can find food, water, shelter, and mates (Martinka 1968, Chapman and Feldhammer 1982, Foresman 2001). In Montana their summer and winter ranges are about 9-15 miles apart. White-tailed deer in the vicinity of the highway may need to cross it daily or less frequently to meet their needs. Other white-tailed deer may never cross a highway during their entire life.

White-tailed deer observations and carcass locations overlap at RP 55-57. There are also dove-tailed live and carcass location hotspots at RP 43-46 and RP 46-49, respectively. This indicates that, while the carcass locations are habitat driven, there are also likely other factors (e.g., road, environmental) involved. The carcass hotspot at RP 15-17 is similar to the mule deer carcass hotspot at RP 12-13: it is an area of greater topographic variation and it is likely that deer cannot be seen as well from the highway; hence observers are not able to detect them if they do occur in greater concentrations here.

Model results indicate that white-tailed deer carcasses are more prevalent in areas near human development. Therefore habituation of white-tailed deer to human presence may be an important factor influencing hazards to motorists and deer. The model also indicates that fencing near the highway may influence locations of carcasses, but more refinement of the model is needed to provide a clear interpretation.

6.2.4 Elk

Elk are the biggest concern in terms of motorist safety. They are the largest animals that are frequently hit by vehicles, and they occur in the greatest numbers in the vicinity of the highway in the Madison Valley. US 287 bisects important elk winter range, and elk prefer areas away from roads and other disturbance. However, snow conditions and other factors such as human and wolf activity can also influence their behavior, and elk do sometimes forage near and cross the highway.

Elk are highly migratory with distinct summer and winter ranges. They spend the summer at higher elevations where growing plants have higher nutritional content (Constan 1967, Chapman and Feldhammer 1982, Foresman 2001). Very few if any elk remain in the Madison Valley during summer. Movements in the Madison Valley tend to be east-west. Some elk may travel as far as Yellowstone National Park to reach summer range. As winter snow accumulates, elk move to lower elevations such as the Madison Valley where they forage on mostly dead plant material in areas of light snow cover. These movements are altered by disturbance, particularly by humans in fall during hunting season, and by predators such as wolves. However, elk would be expected to cross highways in the spring as they leave the lower elevation areas, and in fall as they return. They also may cross highways throughout the winter as they move around within their winter range to forage or avoid disturbance.

Elk exhibit strong herding behavior and move in compact groups when attempting to cross highways and roads. Once some animals of the herd cross, the others are likely to follow, regardless of other threats such as traffic. In a large herd, the lead animals can begin crossing when no traffic is detectable. However, some of the herd may still be approaching the highway as vehicles begin to arrive at the site, at which point collisions may occur.

The majority of elk carcasses occur in winter when large herds spend months in the vicinity of the highway and cross at varying times of the day or night. Data analyses (carcasses, visual, track, successful crossing, and GPS hotspots) have highlighted the same areas as highway crossing points where most carcasses occur. These results strongly indicate that carcass locations are largely a function of habitat use. The most important area appears to be from RP 22-26 on US 287. Secondary sites are found near RP 2 on MT 87 and RP 44 on US 287.

Development in these areas is unlikely to change in the future, because they are located adjacent to large ranches with conservation easements. GPS data provide the least biased indication of use and indicate a wider area of habitat use than carcasses and live animal observations. The GPS data of movement pathways used in this study indicate a barrier effect of Hwy 287. The data show that elk are bunching on the side of the highway with a lot of movement along the highway and few crossing events in relation to approaches. The data indicate that elk cross the road in a relatively narrow area compared with general habitat use. Successful crossing observations from this study support this. Most elk crossing activity occurs back and forth from Wall Creek Wildlife Management Area, with evidence that crossings have become more and more common in recent years (J. Cunningham, Pers. Comm.).

Model results for elk carcass locations indicate elk habitat use is influenced by landscape level development patterns; they prefer to stay in open areas away from buildings and roads and cross the highway away from buildings. Correlation with fence presence or type gave contradictory results on different sides of the highway. Making inferences about these variables is risky and needs to be explored in more detail. Lack of correlation with visibility in the model is interesting and indicates that topography/driver visibility do not play a significant role in carcass location.

6.2.5 Pronghorn

Pronghorn are migratory and most populations tend to remain at lower elevations throughout the year (Skinner 1922, Armstrup 1978, Bruns 1977, Cole and Wilkins 1958, Chapman and Feldhammer 1982, Foresman 2001). Movements in the Madison Valley tend to be north-south. In winter they move to find areas of better forage (including center pivot irrigation fields) and/or less snow such as windswept ridges (e.g. Norris Hill). Pronghorn do not generally jump fences although they are physically capable of doing so. Fences can become complete barriers to pronghorn movement if they are unable to get underneath the lower wire strands. Pronghorn would be expected to cross highways throughout the valley only in areas where fences are passable underneath or in areas where there are no fences such as open gates.

The research team expected pronghorn to be highly observable, so the visual observation hotspots are likely a good indicator of habitat use. Visual observation hotspots corresponded with carcass hotspots in one location (RP 50-53). However, observations did not match well with carcass hotspots outside that area, indicating that factors other than habitat use are contributing to carcass locations. Fences are a likely factor. Model results found that Distance to Corner, Distance to Opening (on one side) and Mean Visibility were significant factors. One likely explanation is that pronghorn only attempt to cross the road at certain spots where the fence is permeable, not where they spend most of their time. In addition, they may get through a fence on one side, but not the other, and be caught within the ROW where they travel along the highway, increasing their chance of being hit by vehicles.

6.2.6 Bighorn Sheep

Bighorn sheep are also migratory and spend the summers at high elevations near escape terrain (cliffs) (Beuchner 1960, Constan 1967, Oldemeyer, Barmore, and Gilbert 1971, Chapman and Feldhammer 1982, Foresman 2001). They currently spend the winter in a localized area, largely between RP 1-6, along Quake Lake and the Madison River as it leaves Quake Lake (Figure 33. Bighorn sheep are often on or near the road between reference posts 1 and 6 on US 287. As in this photo, sheep are often present in large numbers and are accustomed to being on the highway and near traffic (photo by Western Transportation Institute). They forage on south facing hillsides north of US 287 and along the highway ROW where they also lick minerals from the road surface, sometimes crossing to the south side of the highway. Not surprisingly, this area was the only hotspot for visual observations and was the location of the four carcasses that were a result of a single WVC. The sheep in this area are habituated to human disturbance, at least in winter, and this may become even more of a safety concern in the future.

Figure 33. Bighorn sheep are often on or near the road between reference posts 1 and 6 on US 287. As in this photo, sheep are often present in large numbers and are accustomed to being on the highway and near traffic (photo by Western Transportation Institute).

6.2.7 Grizzly Bear

Grizzly bears may experience some barrier effect due to the highway, but the GPS data indicate that they can learn to cross the highway safely at current traffic levels, and may often use the same, or close, crossing points each time. Crossing locations are in topographically mixed locations, often near some type of cover.

6.3 Remote Camera Data for All Species

Remote camera locations corresponded with carcass locations in two areas: the North Meadow Creek bridge at RP 57.5, and the underpass south of the Madison River bridge near Ennis at RP 48.4. The North Meadow Creek bridge area was a hotspot for white-tailed deer carcasses, but only one white-tailed deer was recorded using the bridge. This is probably because there is no bank along the stream under the bridge, and wildlife has to wade in the stream to pass under the bridge; the bottom is rocky and slippery.

The underpass south of the Madison River bridge near Ennis at RP 48.4 was used extensively by mule deer (575 records) and less so by white-tailed deer (68 records), mostly for resting in the shade, but also for crossing beneath the highway. Interestingly, this general area, RP 46-51, was a carcass hotspot for both species. One exception was at RP 48, above the underpass, which was not a hotspot for mule deer carcasses, perhaps because they used the underpass preferentially.

7 RECOMMENDATIONS

The following recommendations are based on quantitative wildlife carcass data; live (visual), track, and GPS (elk only) location data; and qualitative data from remote cameras. These data were analyzed within the context of motorist safety, land use, wildlife use, and habitat permeability of the valley. Recommendations are divided into three types: 1) Wildlife accommodation recommendations, 2) Recommendations for data collection and analysis, and 3) Other recommendations.

The data analysis for this project is related to motorist safety and was performed using patterns of carcass data collected throughout this study area. This study does not specifically address driver safety related to reported wildlife vehicle collisions. An in depth analysis of crash data as it relates to incidences and severity of wildlife related accidents was not completed for the purposes of this study. Any future implementation of the recommendations for wildlife accommodations put forth in this study must be evaluated further based on an in-depth analysis of both safety and connectivity considerations. The implementation of any wildlife accommodations within the Madison Valley are dependent on funding availability, cost-effectiveness, statewide transportation priorities, and the potential nomination and development of future highway projects within these highway corridors.

Based on the data analyzed for this study, there are specific road sections that stand out where wildlife accommodation measures would increase motorist safety and/or benefit wildlife. The importance of the Madison Valley as winter range for ungulates will remain the same or perhaps increase in the future given the permanent habitat protections that exist in the form of government lands and conservation easements on private lands. Traffic will likely increase in the future. Crossing structures of the appropriate type and size for the species and topography in the area, in combination with wildlife exclusion fencing, are investments that will benefit motorists, sportsmen, wildlife watchers, and the general public, as well as wildlife with the Madison Valley. Such accommodations would promote safe passage of wildlife across a highway that acts as a partial barrier to movement and which bisects critical winter range and increases the safety of the travelling public as it relates to the potential for wildlife-vehicle collisions.

7.1 Wildlife Accommodation Recommendations

7.1.1 Consider broad range of factors

The prioritized locations in this report are based on carcass locations, habitat usage and connectivity. The results are intended to provide a planning level prioritization and a starting point for the project development process. For solutions to be cost effective long-term, the exact location, type, size and design of a crossing structure (or other structure like fencing) needs to be determined by highway engineers, in consultation with biologists, considering topography, vegetation, road design, safety and cost.

In addition to sound project development and design, other elements are needed for long-term success. Funding for maintenance of crossing structures should be in place. Land use and ownership on either side of a crossing site needs to be considered; conservation easements or public ownership that can preclude development will help ensure that habitat linkages can be maintained for animals to access the crossing site. Agreements should be developed to ensure that any funneling of animal movements created by the crossing structure for wildlife does not become a target for opportunistic hunting. For example, it may be possible for FWP to establish and enforce regulations creating a buffer zone surrounding crossing structures in which hunting is not allowed.

7.1.2 Wildlife accommodation recommendations by location

To increase motorist safety, reduce WVCs and increase wildlife habitat connectivity in the Madison Valley, accommodation efforts will be most effective if they address winter conditions and focus primarily on elk. The most important area to address is the section of US 287 from about RP 22 to RP 26 (Table 10). This is a hotspot for elk, but crossing structures here would likely be effective for both elk and mule deer, and may also be used by species such as white-tailed deer, pronghorn, and wolves.

Crossing structures of the appropriate type and size, in combination with wildlife exclusionary fencing, would likely be used by thousands of elk every winter and may greatly reduce carcasses in that area. Accommodation measures in this area would also complement the substantial conservation investment in easements and the Wall Creek Wildlife Management Area by potentially reducing the barrier effect of the highway to ungulate movement.

Table 10. Researchers' priority sites for wildlife accommodation measures based on hotspot analyses and motorist safety concerns.

Priority	Location	Species of Interest[2]	Primary reasons for accommodation	Potential Accommodation Measures[3]	Cost Estimates[4]
1	RP 22-26, US 287	Elk	• **Motorist safety** • **Wildlife connectivity** The highway may be a partial barrier to elk movement; however, when elk do cross the road, they tend to cross in large numbers and often during low visibility conditions that make it difficult for motorists to avoid a collision	• Wildlife crossing structure(s) appropriate for these species, with accompanying exclusionary fencing, jump-outs, and wildlife guards as needed	• Overpass: $1- 4 million • Underpass Culvert: $100 – 400,000 • Underpass Bridge: $100 to $150 per square foot of structure • Wildlife Barrier Fencing: $7-10 per linear foot • Wildlife Friendly Fencing: $2 – 3 per linear foot • Jumpouts: $5,000 – 30,000 (depends on design)
2	RP 46-49, US 287	Mule deer, White-tailed deer	• **Motorist safety** The increased traffic near Ennis combined with possible wildlife habituation creates a safety concern	• Wildlife exclusionary fencing to guide wildlife to existing bridges, with jump-outs and wildlife guards as needed • Retrofit existing bridges to be more wildlife-friendly	• Wildlife Barrier Fencing: $7-10 per linear foot • Wildlife Friendly Fencing: $2 – 3 per linear foot

---

[2] Note: this column contains the species for which there was a carcass, live, track or GPS hotspot identified in analyses. However, it is likely in many cases that other species would also benefit from accommodation measures at this location.

[3] These recommendations are based on carcass data and not on wildlife vehicle collision data. These priority sites and potential accommodation recommendations will be considered if/when potential future projects are nominated and developed.

[4] Cost estimates are based on information compiled by MDT in 2016. Estimated cost ranges are listed, as costs can vary significantly depending on supply/demand, quantities, location, incidentals, material costs, haul, size, etc. These estimates include materials and installation costs, but do include long-term maintenance costs. Many factors will affect the long-term applicability of these estimates, in particular inflation factors.

Priority	Location	Species of Interest[2]	Primary reasons for accommodation	Potential Accommodation Measures[3]	Cost Estimates[4]
					• Jumpouts: $5,000 – 30,000 (depends on design)
3	RP 0-7, US 287	Bighorn sheep	• **Motorist safety** Sheep are often on the highway in large numbers in this area, presenting a hazard to both motorists and sheep	Though less effective than wildlife exclusionary fencing in combination with crossing structures, the following measures may be effective at this site to increase motorist safety: • reducing the speed limit in this area (combined with enforcement) • decreasing the attractiveness of the ROW and road to sheep (e.g. changing mowing schemes, vegetation, decreasing/eliminating salt usage on the road, intercept feeding) • educating locals to ensure that sheep are not attracted to the ROW Note: many of these options would require cooperation with other state and federal agencies • an animal detection system is another alternative that may be feasible at this site	• Static signage: $75 - $15,000 (signpost to VMS) • At-grade detection systems: $200,000 - $600,000 per mile (depends on system and components)

Priority	Location	Species of Interest[2]	Primary reasons for accommodation	Potential Accommodation Measures[3]	Cost Estimates[4]
4	RP 15-19, US 287	White-tailed deer Elk	- **Motorist safety** - **Wildlife conservation** This is a carcass hotspot for white-tailed deer and for elk to some extent; GPS data of elk movement indicate that elk frequently cross the highway in this area	- wildlife crossing structure(s) appropriate for these species, with accompanying exclusionary fencing, jump-outs, and wildlife guards as needed	- Overpass: $1- 4 million - Underpass Culvert: $100 – 400,000 - Underpass Bridge: $100 to $150 per square foot of structure - Wildlife Barrier Fencing: $7-10 per linear foot - Wildlife Friendly Fencing: $2 – 3 per linear foot - Jumpouts: $5,000 – 30,000 (depends on design)
5	RP 50-53, US 287	Pronghorn Mule deer	- **Motorist safety** Increased traffic near Ennis combined with possible wildlife habituation creates a safety concern	- wildlife crossing structure(s) appropriate for these species, with accompanying exclusionary fencing, jump-outs, and wildlife guards as needed	- Overpass: $1- 4 million - Underpass Culvert: $100 – 400,000 - Underpass Bridge: $100 - $150 per square foot of structure - Wildlife Barrier Fencing: $7-10 per linear foot - Wildlife Friendly Fencing: $2 – 3 per linear foot - Jumpouts: $5,000 – 30,000 (depends on design)

Other priority areas for accommodation measures are RP 46-49 and RP 50-53, on either side of Ennis. These are hotspots for mule deer and white-tailed deer, and pronghorn and mule deer, respectively. It should be noted that, due to their proximity to Ennis and neighboring developments, these areas may be challenging to address. For example, the El Western Motel near RP 48 has a large expanse of green lawns. This is an attractant that keeps deer near the highway in an area where vehicles begin to accelerate as they leave Ennis heading south, and where vehicles are still travelling fast as they approach Ennis from the south. Nevertheless, accommodation measures in these areas would benefit not only wildlife but also people by increasing highway safety. It may be possible to work with the landowner to construct a crossing structure in this area to reduce WVCs. Because it is near Ennis and wildlife habitat is already altered, this is an area where it may be possible to install wildlife exclusionary fencing with no crossing structures without adversely affecting wildlife connectivity. However, this is also an area where wildlife exclusionary fencing could be installed to guide wildlife to existing bridges and retrofitting the bridges to be more wildlife-friendly crossing structures. Any exclusionary fencing should also include jump-outs and wildlife guards as needed.

Another priority area is RP 0-7, where bighorn sheep are often present in large numbers on the highway, creating a potential hazard for motorists. Though wildlife exclusionary fencing in combination with crossing structures would be effective for this area, there are several less expensive options that should be considered for this location. One option is to lower the speed limit in the area. However, this would likely require regular enforcement to help ensure that motorists comply when sheep are not obviously present.

Another option is an animal detection system designed to warn motorists when wildlife are on or near the road. It should be noted, however, that any detection system chosen for installation at this site should be capable of detecting large herds of bighorn sheep that often congregate on or near the road.

Other options that may be considered for this area are aimed at reducing the attractiveness of the ROW and road to bighorn sheep. Some methods of accomplishing this include, but are not limited to, changing mowing schemes, changing vegetation, decreasing or eliminating salt (and other attractive mineral) usage on the road and intercept feeding. Also, it may be beneficial to educate locals to ensure that bighorn sheep are not attracted to the ROW.

Yet another priority area is RP 15-19, which is a hotspot for white-tailed deer and elk. This is an area of mixed topographic variation. Wildlife crossing structures appropriate for the target species and fitting of the topography, combined with wildlife exclusionary fencing, would likely be effective. Wildlife guards and jump-outs should also be considered as needed. Crossing structures in this area would also likely be used by grizzly and black bear, as well as other carnivores.

In addition to the five priority location recommendations, there are a few other areas that also stand out as potential sites for accommodation measures. RP 12-13, near Butte Creek and Curlew Creek, is a mule deer carcass hotspot. If a wildlife crossing structure were to be implemented, it would be used by mule deer, as well as grizzly, black bear and other carnivores, if of suitable type and size.

Other possible sites occur on US 287 near RP 39-42 (pronghorn), RP 44 (elk and white-tailed deer), RP 58 (white-tailed deer) and RP 63-64 (mule deer) and near RP 2 on MT 87 (elk and deer).

7.1.3 General accommodation types and considerations

There are many types of wildlife accommodation measures that may be considered and there are many resources available for guidance in implementing these measures. Many of these options have been discussed in this report (section 3.3.2), so below is a general summary of structures and considerations that may be relevant for the study area. This list is not intended to be an exhaustive set of options, nor is it intended to suggest that any or all of these options must be implemented. As stated above, every location is unique and there are multiple considerations that must be taken into account during the planning and implementation process. The following recommendations are intended as further guidance that may help MDT and other stakeholders select appropriate structures and strategies for the study area in general and for one or more of the focal species documented in this study.

NOTE regarding cost estimates: Cost estimates are based on information compiled by MDT in 2016. Estimated cost ranges are listed, as costs can vary significantly depending on supply/demand, quantities, location, incidentals, material costs, haul, size, etc. These estimates include materials and installation costs, but do include long-term maintenance costs. Many factors will affect the long-term applicability of these estimates, in particular inflation factors.

Wildlife Overpass

Safe crossing opportunities for wildlife should be designed with the target species in mind, including their physical capabilities (e.g., jump, climb, dig, push through fencing) and their choices for different types and dimensions of crossing structures. Due to the generally open and flat landscape, the most effective crossing structure for many locations within the study area would be a wide highway overpass that is not too steep (i.e. level with surrounding landscape), with wildlife exclusionary fencing on both sides of the road to direct animals to the overpass. For elk and pronghorn in open flat terrain it is much better to have overpasses (level with surrounding landscape) than underpasses (M. Huijser, Pers. Comm.). Estimated cost: $1 million - $4 million.

Wildlife Underpasses

Wildlife underpasses are effective for many species and have been added to existing highway designs along US 93 north of Missoula, in Banff National Park, Canada, and in many other areas. The location and design of underpasses is dependent upon the topography along the highway. In most areas of this study the highway is level with the surrounding terrain. To construct underpasses in these places, either the highway would have to be raised, or ground would need to be removed on both sides of the highway, or both. There is greater topographic relief in some areas where an underpass might be feasible, and there are locations where a high berm was built as the highway climbs from one river bench to a higher bench. An underpass might be constructed through berms with exclusionary fences to direct animals to the crossing. Estimated cost: Underpass culvert - $100,000 - $400,000; Underpass bridge - $100 - $150 per square foot of structure.

Animal Detection System or Electrified Mat Aided At-grade Crossing

An alternative structure would be a designated crosswalk, or at-grade crossing opportunity across the highway surface with wildlife exclusionary fencing on both sides of the road to direct animals to the crosswalk. Electrified mats bordering the crosswalk embedded in the highway surface would deter most animals from leaving the crosswalk and getting trapped on the ROW inside the fence. A high exclusionary fence would be more effective at directing animals to the crosswalk, but if animals managed to escape the crosswalk over the electrified mat (perhaps if panicked by traffic or other disturbance) they would be effectively trapped along the highway inside the ROW until they travelled to the end of the exclusionary fence.

The crosswalk could be painted on the road surface to make it visible to animals and to motorists, either at the crossing site or just prior to the crossing location. Signage could be employed to alert motorists to the upcoming crosswalk location. However, an at-grade crossing opportunity at a gap in fence is only about half as effective as fences combined with over/underpasses. An animal detection system could improve the effectiveness of an at-grade crossing opportunity.

An animal detection system is designed to alert motorists with flashing lights and messages when animals are detected near the crosswalk. This type of system would likely increase motorist safety. However, it should be noted that a crosswalk is not likely to remove any barrier effect of the highway, especially for elk movement given that a barrier effect exists despite the fact that sections of wildlife friendly fencing already exist along the elk hotspot. Estimated cost (for at-grade detection system): $200,000 - $600,000 per mile (depends on type of system and components).

Wildlife Exclusionary Fencing

Any crossing structure should include wildlife exclusionary fencing that extends the length of the particular hotspot and a buffer zone at the end of up to 1 km (0.6 miles) (M. Huijser, Pers. Comm.). Wildlife fencing should be designed with the target species in mind, including their physical capabilities. An exclusionary fence of woven wire about 8 feet high would be a substantial barrier for deer and elk and a near absolute barrier for pronghorn entering the ROW. Estimated cost: $7 - $10 per linear foot.

Wildlife Friendly Fencing

Fences are partial obstacles to deer, elk, and other species of concern. They can be absolute barriers to pronghorn in many cases. Fences appear to direct the movement of deer and certainly pronghorn and may be important factors in directing them to the highway where they attempt to cross. A collaborative effort with landowners by MDT and other agencies to install wildlife friendly fences in appropriate areas of the ranch to facilitate animal movement and exclusionary fencing near highways and crossing structures could help to make highway crossing points more predictable and could increase the effectiveness of any structures.

If requested by landowners, the entrances to crossing structures could be fenced with smooth wire fence to contain cattle and other livestock; a 3-strand fence with the bottom wire about 18” above the ground would allow pronghorn to easily pass underneath. If the top wire were 42” or less, and the center wire spaced 12” from the top and bottom, it would allow elk and deer to jump the top wire easily with little chance of getting legs tangled between the strands. Livestock fencing should be wildlife friendly and positioned a good distance away from the structure so that approaching animals (close to the road and the structure) can focus on moving across the structure without being hindered by livestock fencing (M. Huijser, Pers. Comm.). Estimated cost: $2 - $3 per linear foot.

Most of the installations described above will require complementary infrastructure, including:

- Jumpouts: estimated cost $5,000 - $30,000 each depending on design
- Static signage: estimated cost $75 (signpost) - $15,000 (variable message sign)

7.2 Recommendations for Data Collection and Analysis

In addition to the specific recommendations developed for the Madison Valley corridor, this project provided an opportunity to compile data and develop protocols that can be applied to future studies and other locations. This section summarizes recommendations and procedures that can facilitate the data collection and analysis tasks related to future, similar wildlife planning and accommodation projects.

7.2.1 Database (and Datasets)

One major deliverable of this project was the creation of a database that includes much of the data compiled through the course of this project. By the end of the project, the database contained more than 20 layers with the numerous types of wildlife data (previously available or collected during the course of the project), including:

- Wildlife movement/activity data
- GPS telemetry locations
- Habitats/winter ranges/nesting areas
- Species of concern
- Crash (WVC) data
- Carcass counts
- Animals observed on or near highways
- Snow tracks

There are many other data layers in the database containing relevant land and infrastructure information, including:

- Infrastructure locations (buildings, roads, fences, culverts)
- Aerial survey data
- Land ownership and status
- Topography

The database provides an archive of datasets and toolboxes used in the analyses described in this report and can be used to explore additional questions not addressed in this study. It can also be combined with similar studies in other locations to contribute to development of robust and transportable methodologies for wildlife and highway planning throughout the state. When used in conjunction with applications like ARC GIS, users can produce maps that display patterns or pinpoint key locations related to the analysis. For example, in this project, the analyses focused on three areas of investigation (location of carcasses, spatial patterns of wildlife habitat use in vicinity of roadway, and modeling factors), which were used to predict carcass locations and animal use. Each focus area has different data requirements but the foci are not independent.

Recommended Applications

Based on the available data layers and preliminary use of the database during this project, the research team recommends continued use of the database for future wildlife and/or transportation-related projects, such as:

- Evaluating impacts to wildlife of an existing road
- Evaluating potential impacts of a construction or road improvement project
- Identifying potential corridors to include in an ecosystem or habitat connectivity study

- Assessing wildlife accommodation options
- Analyzing data collected in other locations, using toolbox tools.

Recommended Enhancements

Several ArcGIS tools were created using Model Builder to simplify complex GIS processing workflows to allow GIS technicians to more easily replicate our procedures. These tools are contained in the US 287 Toolbox contained in the project database. However, Model Builder tools can be somewhat unstable and unpredictable when moved to a new computer location or applied to different data layers. This simply means that a GIS technician may need to edit input and output parameters for individual process steps or validate models from their own computer. This is easily accomplished by a moderately skilled GIS technician. Ideally, all of the model tools used in the analyses of this study would be coded in Python and converted to script tools that are much more stable and transportable. That conversion was beyond the scope of this project but could be accomplished relatively easily. Regardless of Model Builder instabilities, these tools still provide considerable time savings for replicating procedures.

7.2.2 Developing Predictive Models

Field-collected data for carcass and live animal locations were a crucial component of analyses for this project. However, this project also demonstrates the potential for identifying wildlife accommodation priority areas using a modeling approach. Therefore, the research team recommends that future projects be designed to build upon the preliminary modeling approach reported here.

Recommended Applications

Reliable models of wildlife habitat use and WVCs could be extrapolated to areas where field data are lacking and would drastically reduce costs of analyzing highway effects on wildlife by reducing or eliminating the need for site specific field collected data, which represent the majority of study costs.

Recommended Enhancements

The models created in this project need substantial refinement, but the results indicate this would be a worthwhile focus of future work. Reliable models predicting fine-scale habitat use and animal movement would allow information to be extrapolated to areas lacking detailed carcass and animal location data. In other words, data collection for a new study area could be reduced from months of field observation of carcass and animal locations to a few weeks of collecting site specific data to parameterize models. Project results indicate that animal carcass locations (and presumably movement patterns) are influenced by existing development patterns, vegetation cover, terrain, and potential barriers near roadways. Of these, only potential barriers require field-collected data in most areas.

Model refinement efforts should include developing standardized protocols for recording barrier features including fences, guardrails and other relevant structures, and cut/fill slopes. There was some confusion in this study about whether GIS layers for “as built” features existed for the study area. Ultimately, those features were not included in the preliminary models, but it is generally agreed that they should be. The suitably of existing data should be determined early in the study design and proposal phase, and field collection of the necessary data should be included if necessary. There are several options for including cut/fill features in model parameters. The best option is to use high spatial resolution elevation data with fine enough grain to capture cut/fill and other fine-scale topographic features. If available, LIDAR data would provide the highest resolution (usually sub-meter) data available and could incorporate vegetation height. This would capture all topographic features that could possibly obscure visibility of an animal. Ten meter (33 feet) resolution digital elevation models could provide another alternative. This resolution would likely capture topographic features most relevant to animal visibility. As a last resort, cut/fill information could be incorporated into lower resolution elevation data by resampling the elevation data to a finer resolution and then replacing values with the values of the cut/fill features. For this study, cut/fill data were not available and could not be developed within the project budget. Although some cut/fill features can be identified from aerial imagery, it is impossible to conduct a complete census from imagery alone because it is difficult or impossible to detect small features or features obscured by vegetation, and aerial detection alone does not provide information about the height and slope of the feature. The research team estimates it would require 80-160 man-hours to map and measure the elevation, length, height, and slope of cut/fill features in the study area plus another 24-56 man hours to process the data for inclusion in the models. Therefore, acquiring higher resolution elevation data would be the preferred option. However, higher resolution data comes at a cost of requiring increased computer power. As spatial resolution increases, the computing power needed for processing increases exponentially, which increases time and expense of processing data. Using 30m (100 feet) elevation data, researchers were able to calculate visibility indices on a moderately powerful computer in about one hour per index (this is only the cpu time required to process the data and does not include time to prepare the data and execute commands. Running the same index on 10m (33 feet) data would likely require days (up to a week) of processing time, and LIDAR data might require leasing time on a super computer to accomplish.

Recording fencing was another challenge in the present study. The research team recorded fencing information with a combination of quantitative (e.g. number of strands) and qualitative (e.g. fence type or fence condition) attributes. Recommended improvements to these methods include breaking fences into physical components and minimizing or eliminating qualitative attributes. Qualitative attributes are problematic because they enter models as class variables, which limit their utility. In addition, qualitative variables can be difficult to attribute. For example, researchers recorded fences composed of both wire mesh and barbed wire, which defy classification without creating a new class and create the risk that every fence will end up as the only representative of a unique class. A better approach might be to break the fence into quantifiable components that relate to an animal's ability to go over, under, or through a fence. Top height (distance from ground to top of the barrier), bottom height (distance from ground to bottom of barrier, and depth (planar distance from front to back of the barrier) are straightforward measurements for describing barrier dimensions. Attributing permeability and fence condition are more difficult because they require subjective measures, but perhaps could be combined into an ordinal index score to indicate the likely probability of animals moving through (not over or under) a barrier without becoming entangled. However, the best attributes to record would be determined by testing the effect of many different candidate parameters on model performance. Data recommendations are summarized in the following procedure and in Table 11.

7.2.3 Recommended Data Collection and Analysis Procedure

Based on the results of this study, as well as the tools and protocols developed for it, the research team has developed a recommended procedure for conducting a similar wildlife study in any location. The procedure consists of four basic phases: determine focal species, collect data, analyze data, and develop predictive models. However, this procedure also includes recommended subtasks for each phase to provide guidance to help DOT or resource agency personnel conduct a study that produces sufficient data and relevant, valuable results.

This section provides a description of the four phases, followed by a summary table, and specific protocols that can be applied to the recommended tasks.

Phase 1: Determine focal species

In order to properly scope and plan the study, the first step is to identify the species that will be counted, analyzed, and mapped. While one species may have provided the initial motivation for the study (based on mortalities, threatened status, or other factors), there may be other species experiencing similar impacts. Considerations include:

- Select species for which highways: pose a safety hazard to motorists, represent a significant mortality factor to species populations, or potentially create a barrier to movement.
- Choose species that occur in the area of analysis.
- Include all ungulates that live or pass through vicinity of highway.
- Consider inclusion of wide ranging species (e.g. carnivores).
- Consult with local biologists from Montana Fish, Wildlife, and Parks for recommendations on species to include.

Phase 2: Collect Data

There are several types of data that can be collected and analyzed for wildlife studies. Not all types will be applicable to every study. However, in most cases, studies will entail the collection and integration of data from multiple sources.

Existing Wildlife Data: in many cases, MDT, other agencies, or research organizations may have already documented wildlife data for a location of interest. However, the research team does not recommend gathering all wildlife data available for the area. Generally, georeferenced point locations of focal species are the only data useful for analyses.

- Live animal locations (recommend minimum buffer of 2 miles around highway. For this project, researchers used locations within ½ mile of the roadway for hotspot analysis but collecting live animal observations to 2 miles does not increase project costs and provides opportunity to adjust analysis buffers if needed.)

GPS/telemetry data locations (if available)

- MDT carcass reports

Field-collected Wildlife data: if feasible, collect current wildlife data at all locations of interest.

- Carcass locations (follow this study's protocol for road-killed animals; also consider collecting data on carcasses found in livestock or highway boundary fencing)
- Field-collected observations (especially tracking data)

- Remote camera data or sand tracking beds are useful at locations suspected or identified as potential wildlife crossings or as locations for crossing structures (e.g. bridges and culverts) to document current use of key locations and to provide a baseline for evaluating wildlife response to accommodation measures in the future. Track beds, while more expensive, have the advantage of allowing for sampling animal movements at greater frequency and year-round, which would increase the statistical power of survey methods. However, track beds can only practically be deployed along relatively few segments or roadways, so they do not provide an unbiased estimate of crossing hotspots as do snow tracking surveys. Therefore, track beds are probably best deployed at known wildlife crossings or potential accommodation locations where more accurate estimates of movement activity than can be obtained through snow tracking are desired.

Existing GIS Layers: layers needed to process and analyze animal location data (includes reference layers and explanatory variables).

- Mile reference post locations
- Roadway centerline
- Existing Structures – MT Structures Framework (downloadable from NRIS)
- Roadway “as built” features
    - Location and design of cut/fill (not necessary if high resolution elevation data are available – see discussion in text)
    - Location and design of guardrails and other barriers such as jersey barriers, etc.
    - Digital Elevation Model (prefer 10m/33ft resolution or better)
    - Landcover – MT Landcover 2013 (or most recent)

Field Collected GIS Layers

- Fence location and design (see notes in Table 11 and discussion under the Fence Type parameter of predictive model methods. Include gate locations.)
- Cut/fill features if dataset or high resolution elevation data not available. If field collected, should include georeferenced information about area, height, and slope.

It is difficult to recommend an ideal duration for a study like this because natural systems are dynamic. Animals respond to changes in their environment over short and long time scales and therefore habitat use can be unpredictable. Ungulates, for example, may migrate to the same winter range in most years but may drastically shift to different locations during unusually harsh or mild weather. Ungulates may also shift habitat use on shorter time scales in response to forage availability, hunting or predator pressure, current weather conditions, or other factors. Therefore, habitat use in the vicinity of highways is likely to shift over both short and long time scales, so the duration of studies should be designed to capture most of the variability. Three years is probably a minimum duration for a study in an area with relatively low inter-annual variation in habitat use. But sampling may need to be extended for areas that exhibit high inter-annual variability of habitat use or perhaps sampling should be repeated periodically to better capture the variability of the system being studied. Failure to adequately capture the variability of spatial patterns of wildlife movements and habitat use risks expending resources on accommodation measures in the wrong locations for the highest long term benefit.

Phase 3: Data Analysis

Data Preparation

- Observation Data
    - Combine field-collected and MDT carcass datasets. Error check data to make sure field codes are consistent. The most important fields are: Date, Animal_Type, Obs_Type, Sex, and Count. Also, check for consistent capitalization, spelling, and punctuation. This is important to insure that records get grouped into correct classes.
    - Filter combined data to remove duplicate records.
    - Add and calculate additional fields if needed (e.g. Ungulate, Live/Dead, etc.).
- GIS Layers
    - Create Clip layer. The research team used a ½ mile buffer around the highway centerline of the surveyed route but this can be adjusted as needed. Points within the clip layer are assigned to the nearest mile reference post for analysis.
    - Make sure all data layers are in same projection. A recommended resource is MT State Plane NAD83.

Hot Spot Analysis

- Create ArcGIS map document containing observation points, mileposts, and clip layer.
- Create selection query of observations to be included in analysis (eg. Animal_Type = “Elk” AND Obs_Type = “Carcass”
- Use ‘Hot Spot’ model tool in the US 287 toolbox to run the analysis
    - Adjust input parameters as needed

Phase 4: Predictive Models

The methods used to develop models are described in section 4.4.2 (Spatial Data Analysis) of this report. Model parameters and methods described are preliminary and will require considerable refinement before standardized methods can be recommended. Model refinement would include exploring improved or alternative parameters and testing against independent datasets in other locations. Robust and transportable models will likely require pooling data from different studies in different locations to create models that perform well across a range of conditions encountered in Montana. Model refinement will require the services of a competent modeler, preferably with enough background to understand potential interactions between model parameters and wildlife behavior.

7.2.4 Corresponding Methods

The following methods can be used to carry out and facilitate the data collection and analysis procedures.

Estimating locations of WVCs

The research team recommends replicating the methods from this study to map locations of wildlife carcasses as estimators of WVCs. Carcass survey methods are described in section 4.2.1 of this report, and calculation of statistical hotspots of carcass locations is straightforward using the ‘Hot Spot’ tool developed for this project.

Estimating Habitat Use

There are several types of data available to estimate habitat use. The research team developed the following recommendations and guidance for several types of data that can be used individually or in combination to estimate habitat use by wildlife.

- **Visual and Tracking Observations**. Visual and tracking observations of live animals can provide useful data if limitations are taken into account. Visual observations are biased by time of observation (e.g. does not capture nocturnal movement or habitat preferences of species and works best for species that prefer open habitat) and visibility imposed by terrain and vegetation, and is suitable only for relatively abundant and easily observable species. The research team found that visual observation worked well for bighorn sheep, elk and pronghorn but not for mule or white-tailed deer. Snow tracking data eliminates the bias of time of day of observation but can only be conducted immediately after snowfall; also, some species cannot be reliably distinguished by tracks. Researchers found that tracking data worked well for elk and bighorn sheep. It also apparently worked well for mule deer and white-tailed deer combined, but the species could not be distinguished reliably from each other or from pronghorn. Collection of live animal observations as part of study protocols is probably warranted but the data should be used with caution. For more detail on the methods used in this study, see section 4.2.2.
- **Aerial survey data**. Aerial survey data collected by MT FWP biologists were obtained but not used in the analyses. Aerial surveys are designed to census animal populations rather than determine movement or habitat use patterns, but they do provide point in time locations of animals surveyed. Their main limitation is the number of observation days. This limits their use for detecting animal habitat use near roadways.
- **GPS data**. GPS data provides the best data for analyzing effects of highways on wildlife. Since GPS can be programmed to record locations at regular intervals over the study period, they are not biased by time of observation. They also contain a much more detailed and accurate record of animal movements than can typically be derived from direct field observations, and they are not as limited by terrain and visibility except in severe cases where the ability to receive satellite signals is lost. The main limitation of GPS is the expense and consequently limited availability. The only species with GPS data available for the study area were elk and grizzly bear. Grizzly bear locations were provided as electronic maps, so there was no access to raw data. The elk data provided a form of “gold standard” for evaluating field-collected observations. Unfortunately the project budget did not permit a rigorous and detailed analysis of the elk GPS dataset but visual observation of GPS locations plotted on maps revealed a barrier effect of the highway that could not be captured by other methods. The research team also found anecdotal evidence of avoidance of areas near residential structures indicating this type of data could be instrumental in developing better predictive models.

Calculation of statistical hotspots of live animal locations is straightforward using the ‘Hot Spot’ tool developed for this project.

7.2.5 Corresponding Resources

The following resources can be used to carry out and facilitate data collection and analysis procedures.

Table 11. Data required for analysis.

Data	Source	Notes
Hot Spot Analysis (WVC)		
Carcass Locations (points)	Field-collected and MDT	Follow protocol described in this study
Mileposts (points)	MDT	The research team developed a layer of 0.1 mile reference posts. However, analysis to the resolution of 1 mile worked best.
Study Route Centerline (line)	Derived from GPS or clipped from existing highway layer	Used to create analysis area boundary.
Clip Layer (polygon)	Derived	Buffer around study route used to extract points to be associated with mile reference posts. The research team used a ½ mile buffer.
Hot Spot Analysis (Habitat Use)		
Live Animal Locations (points)	Field-collected but sources vary	GPS provides the best and least biased data for animal locations. Radio telemetry is also good but can be biased by the timing of data collection. Aerial survey data can also be useful. Visual observations collected during carcass surveys can be useful for species that use open habitats and are easily observed during the day but are biased by time of observation and visibility. Snow tracking data are limited by the time of year they can be collected, but are not biased by time of day of observations.
Mileposts (points)	MDT	The research team developed a layer of 0.1 mile reference posts. However, analysis to the resolution of 1 mile worked best.
Study Route Centerline (line)	Derived from GPS or clipped from existing highway layer	Used to create analysis area boundary
Clip Layer (polygon)	Derived	Buffer around study route used to extract points to be associated with mile reference posts. The research team used a ½ mile buffer.
Logistic Regression Models (methods need refinement)		
Animal/Carcass Locations (point)	Sources vary	See notes for hot spot analysis

Data	Source	Notes
Digital Elevation Model (DEM) (raster)	National Elevation Dataset	Recommend 10m (33 ft) resolution or better but make sure a computer with sufficient power for processing is available.
Land Cover (raster)	MT Landcover 2013 (available from NRIS)	GAP and National Landcover Dataset are also suitable.
Visibility (raster)	Derived	Derived from DEM using 'Road Visibility Index' tool contained in US 287 toolbox.
Fences	Field-collected	Recommend modifying collection protocol from this study. To the extent possible, fence attributes should be quantitative (continuous or ordinal) rather than qualitative. See section text for recommendations.
Structures (point)	MT Structures Framework (available from NRIS)	Used to calculate structure density and as input to WildPlanner
WildPlanner Output	Derived	Provides an index of human disturbance for estimating species avoidance or attraction to human modified landscapes.
Highway "As Built" Parameters (if available)	MDT	Suitable layers were not available for data analysis for this study. Locations of cut/fill and guardrails and barriers may be useful model predictors of WVC and crossing locations. High resolution elevation data are preferable to cut/fill mapping.

Table 12. US 287 Toolbox required inputs and function descriptions.

Tool Name	Data Inputs	Function Description
Batch Kernel Clip to Isopleth	Workspace containing kernel density rasters and isopleth layers. Kernel density names must match with the isopleths to be used for clipping except kernel density file names should be prepended with "kde" and isopleth file names prepended with "iso".	Facilitates clipping kernel density rasters to isopletsh generated using Geospatial Modeling Environment or other methods. (note: this tool uses a Python script to execute).
Fence Parameters	Fence attributes as points layer; Reference post layer.	Used to assign fence parameters to reference posts using fence data collected in this study.

		Suggested revised methods for collecting fence data may render this tool obsolete.
Field Check	Table Name; Field Name	Python script to provide a Boolean if/then operation in other toolbox models.
Hot Spot	Incident Points; Expression (to subset points analyzed); Mileposts; Clip Layer	Conducts hotpot analysis on a set of input points determined by an expression.
Normalize by ID	Animal observation points (ID field must represent unique individuals observed).	Used to normalize FWP elk GPS data so that each individual collared elk contributed equally to kernel density estimates. Can be used for any analysis to normalize unequal number of observations between individuals so that each individual contributes equally to statistical analysis.
Prep Fence	Fence Points; Expression; Track line; Search Radius; Point Type	Proprietary to this study. Included to document process steps used to prepare fencing data for model inputs.
Quantify by Mile	Incident Points; Expression; Reference Posts; Clip Layer	Used to summarize incident point counts by reference post.
Road Visibility Index	Reference Posts; Digital Elevation Model (filled); Survey Track; Search Distance	Calculates Mean Visibility, and Mean Visibility on Axis parameters used as model inputs for each reference post.

7.3 Other Recommendations

Research design for future work

There are several considerations for future research work. These can be grouped into two categories: 1) Use of existing data and methods, and 2) Future data collection.

Use of existing data and methods

This project has compiled a rich and detailed database for context-sensitive highway analysis. The results presented in this report represent an overview of initial considerations. The approaches that were examined, particularly regression analysis, should be analyzed in greater depth to tease out the landscape and highway features that may drive the habitat use and movement patterns of wildlife, and carcass locations.

As described in a previous section, the research team has made detailed recommendations on data collection and analysis. For consistency in future studies, it may be useful for MDT to build on this initial work and compile these procedure protocols into a desk manual.

Future Data Collection

The extensive data on elk GPS locations and movements provided by FWP offer a benchmark that is needed for other species, particularly pronghorn. A GPS tracking study of pronghorn in the Madison Valley is recommended.

Partnerships

One of the outcomes of this project is the formation of a very effective partnership among MDT, WTI, FWP, IGBST, USFS, and two NGOs (ChI, WCS) for purposes of data sharing. This group can continue to function for implementing recommendations and could expand to include local landowners, land trusts, the Rocky Mountain Elk Foundation, the Madison Valley Ranchlands Group, People and Carnivores, ARC Solutions, and others.

8 REFERENCES

This section contains the references used in the entire document except those used only in the Literature Cited section of the Literature Review Task. Those citations can be found in Appendix A (Section 9.1).

Armstrup, S., “Activities and habitat use of pronghorns on Montana-Wyoming coal lands.” Biennial Pronghorn Antelope Workshop, Proceedings Volume 8 (1978) pp. 270-306.

Barton, Kamil, MuMIn: Multi-model inference. R package version 1.10.5 (2014) http://CRAN.R-project.org/package=MuMIn.

Beckmann, J. P., A. P. Clevenger, M. P. Huijser, J. A. Hilty, editors, Safe passages. Highways, wildlife, and habitat connectivity. Island Press, Washington, D.C., USA (2010) 424 pp.

Beyer, H.L., *Geospatial Modelling Environment* (version 0.7.2.1) (software). Spatial Ecology LLC (2012). URL: http://www.spatialecology.com/gme.

Brock, B. L., E.C. Atkinson, C. Groves, A. Toivola, T. Olenicki and L. Craighead, “A wildlife conservation assessment of the Madison Valley, Montana.” *Unpublished Report*. Wildlife Conservation Society, Greater Yellowstone Program, Bozeman, MT (2006) 230pp. http://www.wcsnorthamerica.org/DesktopModules/Bring2mind/DMX/Download.aspx?EntryId=5581&PortalId=37&DownloadMethod=attachment.

Brock, B.L., Wild Planner: wildlife tools for land use planning. Craighead Institute. Bozeman, MT, USA (2011).

Brown, D. G., K. M. Johnson, T. R. Loveland, and D. M. Theobald, “Rural land-use trends in the conterminous United States, 1950–2000.” *Ecological Applications*, Vol. 15 (2005) pp. 1851–1863.

Bruns, E. H., “Winter behavior of pronghorns in relation to habitat.” *Journal of Wildlife Management*, Vol. 41 (1977) pp 560-571.

Buechner, H. K., “The bighorn sheep in the United States-its past, present and future.” *Wildlife Monograph* No. 4 (1960) 174pp.

Burnham, K. P. and D. R. Anderson, Model selection and multimodel inference: a practical information-theoretic approach (2nd edition). Springer-Verlag, New York (2002) 488 pp.

Chapman, J. A., and G. A. Feldhamer, editors, Wild mammals of North America: biology, management, and economics. Johns Hopkins University Press, Baltimore, Maryland (1982) 1168 pp.

Cleveland, S. M., “Human predation risk and elk behavior in heterogeneous landscapes.” Thesis, University of Montana (2010).

Cole, G. F. and B. T. Wilkins, “The pronghorn antelope, its range, use and food habits in central Montana with special reference to wheat.” *Montana Fish & Game Dept. Technical Bulletin 2* (1958).

Conover, M. R., W. C. Pitt, K. K. Kessler, T. J. DuBow, and W. A. Sanborn, “Review of human injuries, illnesses, and economic losses caused by wildlife in the United States.” *Wildlife Society Bulletin*, Vol. 23 (1995) pp 407–414.

Constan, K., “Food habits, range use and relationships of bighorn sheep to mule deer and elk in winter, Gallatin Canyon, Montana.” MS Thesis, Montana State University (1967) 43 pp.

Cunningham, J., email message to the author, July 23, 2015.

Foresman, K. R., “The wild mammals of Montana.” *American Society of Mammologists, Special Publication Number 12* (2001) 278 pp.

Forman, R. T. T., and L. E. Alexander, “Roads and their major ecological effects.” *Annual Review of Ecological Systems*, Vol. 29 (1998) pp 207–231.

Hansen, A. J., R. Rasker, B. Maxwell, J. J. Rotella, J. D. Johnson, A. W. Parmenter, L. Langner, W. B. Cohen, R. L. Lawrence, and M. P. V. Kraska, “Ecological causes and consequences of demographic change in the new west.” *BioScience*, Vol. 52, No. 2 (2002) pp. 151–162.

Hansen, A. J., and J. J. Rotella, “Biophysical factors, land use, and species viability in and around nature reserves.” *Conservation Biology*, Vol. 16 (2002) pp. 1–12.

Huijser, M. P., email message to the author, March 25, 2015.

Huijser, M. P., J. W. Duffield, A. P. Clevenger, R. J. Ament, and P. T. McGowen, “Cost–benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada: a decision support tool.” *Ecology and Society*, Vol. 14 (2009): http://www.ecologyandsociety.org/vol14/iss2/art15/. Accessed October 7, 2009.

Huijser, M. P., P. McGowen, J. Fuller, A. Hardy, A. Kociolek, A. P. Clevenger, D. Smith, and R. Ament, “Wildlife–vehicle collision reduction study.” *Report to Congress*. U.S. Department of Transportation, Federal Highway Administration, Washington, D.C. (2008). http://www.tfhrc.gov/safety/pubs/08034/index.htm. Accessed 3 Jan 2013.

Huijser, M. P., A. Kociolek, P. McGowen, A. Hardy, A. P. Clevenger and R. Ament, “Wildlife–Vehicle Collision and Crossing Mitigation Measures: A Toolbox for the Montana Department of Transportation.” *Report FHWA/MT-07-002/8117-34*, Montana Department of Transportation, Helena, MT (2007) 123 pp. http://www.mdt.mt.gov/other/research/external/docs/research_proj/wildlife_crossing_mitigation/final_report.pdf. Accessed June 6, 2012.

Khattak, A. J., “Human Fatalities in Animal-Related Highway Crashes.” *Transportation Research Board Annual Meeting Paper 03-2187* (2003) 17 pp. http://www.rexano.org/Statistics/animal_crash_highway.pdf. Accessed October 1, 2015.

Langley, R. L., “Animal-related injuries resulting in emergency department visits and hospitalizations in the United States, 2006–2008.” *Human-Wildlife Interactions*, Vol. 6 No. 1 (2012) pp. 123–136.

Mackie, R. J., K. L. Hamlin and D. F. Pac, “Mule deer.” *Wild mammals of North America*, Chapman, J. A. and G. A. Feldhamer (eds.), John Hopkins University Press, Baltimore (1982) pp. 862-877.

Mackie, R. J., K. L. Hamlin and J. G. Mundinger, “Habitat relationships of mule deer in the Bridger Mountains, Montana.” *Montana Fish and Game Department Job Project Report, Project W-120-R-6, Job No. BG-2.01* (supplement) (1976) 44 pp.

Madison County, “Madison County Growth Policy 2012: web-based version.” Adopted by Madison County, Montana in March 2013 (Amendment 11-2013) (2013) 142pp. http://madison.mt.gov/departments/plan/publications/GrowthPolicy/2012Final/2012GrowthPolicy.pdf. Accessed June 30, 2015.

Martinka, C. J., “Habitat relationships of white-tailed and mule deer in northern Montana.” *Journal of Wildlife Management*, Vol. 32 (1968) pp 558-565.

McRae, B.H., V.B. Shah, and T.K. Mohapatra, “Circuitscape 4 User Guide.” *The Nature Conservancy* (2013) http://www.circuitscape.org.

Montana Department of Transportation. “About MDT” (webpage). http://www.mdt.mt.gov/mdt/docs/about-mdt.pdf. Accessed June 25, 2015.

Montana Subdivision and Platting Act, Montana Code Annotated, sections 76-3-101 et seq. http://data.opi.mt.gov/bills/mca_toc/76.htm. Accessed October 5, 2012.

Oldemeyer, J. L., W. J. Barmore and D. L. Gilbert, “Winter ecology of bighorn sheep in Yellowstone National Park.” *Journal of Wildlife Management*, Volume 35-2 (1971) pp 257-269.

Polfus, J. L., “Literature review and synthesis on the effects of residential development on ungulate winter range in the Rocky Mountain West.” *Report prepared for Montana Fish, Wildlife & Parks*, Helena, MT (2011) 128 pp. http://fwp.mt.gov/fwpDoc.html?id=51645.

Polfus, J. L. and P. R. Krausman, “Impacts of residential development on ungulates in the Rocky Mountain West.” *Wildlife Society Bulletin*, Vol. 36, No. 4 (2012) pp. 647–657.

R Core Team, R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria (2014) URL http://www.R-project.org/.

Skinner, M. P., “The American antelope in Yellowstone National Park.” *Journal of Mammalogy*, Vol. 3(2) (1922) pp 1-32.

Sullivan, J. L., “Trends and Characteristics of Animal–Vehicle Collisions in the United States.” *Journal of Safety Research*, Vol. 42-1 (2011) pp. 9–16.

Wood, A.K., “Comparative distribution and habitat use by antelope and mule deer.” *Journal of Mammalogy* Vol. 70(2) (1989) 335-340.

9 APPENDICES

9.1 Appendix A: Literature Review

At the outset of the project in 2012, the research team consulted literature on various topics related to this project.

Information related to land use planning in the Madison Valley was crafted into a Literature Review. Subtopics included: *Subdivision Impacts on Wildlife*, with a special section on ungulates, and *Land Use Planning in the Madison Valley*. The Literature Cited section in this Appendix is separate and stands alone from the main References used in completing other tasks and sections of this report.

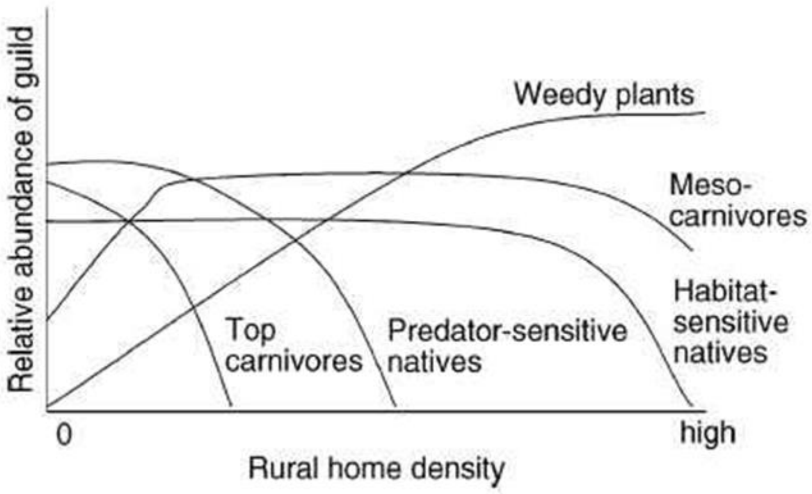
Literature related to the state of the practice of wildlife-highway accommodation measures was compiled into a bibliography, and follows as Appendix B. Land Use Planning in the Madison Valley: Literature Review.

9.1.1 Subdivision Impacts on Wildlife

Conversion of rural lands for human housing is the most pervasive form of land use change affecting wildlife habitat in the American West (Brown et al. 2005). Development pressures are particularly severe in natural and scenic areas adjacent to public lands as residents, freed from commuting to work by the information age, seek a high quality of life where natural scenery and wildlife abound (Hansen et al. 2002). Housing densities occur along a gradient that includes urban, high-density developments in cities and towns; suburban, somewhat-lower-density developments surrounding, and contiguous with, urban centers; exurban, very-low-density developments interspersed among rural landscapes; and rural, relatively undeveloped agricultural and natural areas (Nelson 1992).

Several studies have characterized the responses of wildlife along these gradients. A very concise summary of results of these studies can be found in Maestas (2007) and a more in-depth review of subdivision impacts on wildlife was provided by Glennon and Kretser (2005). Another excellent synthesis of impacts of exurban development on biodiversity with a discussion of possible mechanisms and research needs can be found in Hansen et al. (2005). In general, the relatively few studies conducted to date indicate that as housing densities increase, human-tolerant (e.g., black-billed magpie, American robin) and non-native (e.g., European starling, house sparrow) bird species increase, and native species of conservation concern decrease. Evidence also suggests that mammalian carnivores occur more frequently away from housing developments, while domestic predators like dogs and cats occur most frequently near housing developments and are largely undetectable in natural areas and ranches. Dogs and cats are known to have significant impacts on native wildlife. The influence of exurban development on plants is less studied, but one study found native plant species richness was higher on ranchlands than in exurban developments while non-native plants, including several noxious weeds, were most prevalent within exurban areas. In a synthesis of effects of exurban development on biodiversity, Hansen et al. (2005) summarized results of studies of six taxa (insects, bees, birds, lizards, butterflies, and plants) and found a general trend of decreasing species richness as housing density increased from wildland to urban. The one exception to this trend involved butterflies, which reached peak species richness in suburban parks.

Although native species often decrease with increasing housing density while non-natives increase, individual species responses are complex. Hansen et al. (2005) identified three general patterns of species abundance that emerge along the rural-to-urban gradient: decreases, increases, and nonlinear responses. Species that decrease are least abundant in areas with high human development and most abundant in wildlands, whereas the reverse is true for species that increase. Intermediate species exhibit peak abundances at intermediate levels of human development within the rural-to-urban gradient. Therefore, although rural development can have significant impacts on species abundances, it can be difficult to predict which species will win and which will lose. Hansen et al. (2005) proposed a guild-based hypothesis of species responses to increasing home density (Appendix A – Figure 1) whereby human-sensitive species like top order carnivores are eliminated at low housing densities and more human-tolerant species like meso-carnivores are able to persist until higher density thresholds are reached.



Appendix A – Figure 1. Hypothesized responses of various guilds of species to rural home density (from Hansen et al. 2005).

The impacts of rural development on wildlife can extend well beyond development footprints. For example, in a study that included the Madison Valley, reproductive success of yellow warblers was lower within 6 km (3.7 miles) of rural developments than nearby ranchlands (Hansen et al. 2002, Hansen and Rotella 2002), with the implication that reduced reproductive success in these "hot spots" could affect populations in adjacent nature preserves. Cleveland (2010) found that elk in Montana moved faster when they approached within 750 meters (1/2 mile) of houses and preferred areas 1600 meters (1 mile) from human development.

The mechanisms responsible for observed responses to rural development are less well understood, but Hansen et al. (2005) identified four general mechanisms that are likely responsible. These are:

- *Habitat alteration* – The result of the conversion of land cover (vegetation or geologic features) associated with development that can render areas unsuitable for many species and/or more suitable for human-adapted species. Even if the actual footprint of land cover conversion is small, overall development patterns increase habitat fragmentation leaving remaining patches of habitat unsuitable for many species. In addition, residential development can alter micro-climates, which further reduces the ability of the area to support its original native inhabitants.

- *Alteration of biotic interaction* – The indirect result of altering species abundances. For example, the increase of human-adapted native (e.g., raccoons or skunks) or domestic (e.g., dogs and cats) predators can result in increased predation rates on other species with subsequent population declines. Conversely, the loss of human-sensitive predators may disrupt natural predator–prey dynamics, resulting in population increases of prey species with subsequent declines in habitat quality and increased disease transmission.
- *Human disturbance* – Activities of humans and their pets may cause wildlife to avoid areas of frequent disturbance, thus abandoning otherwise suitable habitat. It may also increase stress, which could lead to increased mortality and reduced reproductive success.
- *Alteration of ecological processes* – Many ecosystems rely on natural disturbances to maintain a dynamic patchwork of habitats for sustaining native species. These processes are often disrupted or actively suppressed in rural developments. The most prevalent of these processes in Montana are fire, flooding, and grazing.

In summary, rural development significantly alters patterns of species abundance. Individual species responses may be increasing, decreasing, or non-linear, often with sharp thresholds of decline. Wildlife species differ in their tolerance of human development with the most sensitive species disappearing at lower densities of development than more tolerant or human-adapted species. These impacts extend well beyond the development footprint. Several mechanisms responsible for changes in species abundance have been identified but are poorly studied.

Impacts Specific to Ungulates

Because of the cultural and economic importance of ungulates in Montana, the potential impacts of subdivisions on these species have recently received considerable attention. In particular, there is concern over the effects of rural development on winter range, because these habitats occur predominantly on private lands in many areas of the state. Recent reviews and syntheses of information pertaining to the effects of rural development on ungulate winter range are provided in Polfus (2011) and Polfus and Krausman (2012). Specifically, they looked at five species: white-tailed deer, mule deer, elk, pronghorn, and bighorn sheep. After reviewing more than 100 articles, the authors found approximately 80 that were relevant to the effects of human development on ungulates. Only 25 dealt specifically with residential development. Most species exhibit at least short-term responses to human development, including increased vigilance, flight responses, and avoidance. Habituation of all species to human disturbance has also been documented, particularly in the absence of hunting and where human disturbance is predictable. Few studies link these responses to population-level consequences although recent studies associated with energy development indicate long-term demographic impacts may take many years to detect. However, energy expended through increased flight responses and vigilance or displacement from high quality habitat would presumably impact survival and reproductive rates. Developments within fawning/calving areas can be particularly detrimental as are developments across migration corridors, which impede the ability of animals to access seasonally important habitats. Roads can also form barriers to movement, with road densities often increasing within developed areas.

Habituated ungulates within subdivisions can be difficult to manage because hunting is often not feasible within developments and resident attitudes about hunting as a management tool can make it difficult to employ. The habituation of ungulates can lead to increased crop and property damage, habitat degradation, increased risk of human injury, increased vulnerability to vehicle collision, increased disease transmission, and reduction in migratory behaviors.

This is a generalized synopsis of the in-depth syntheses provided by Polfus (2011) and Polfus and Krausman (2012), but it can be deduced that subdivisions have the potential to alter ungulate movement patterns and road crossing behaviors in several ways. Because ungulates often avoid rural developments, movement patterns can be altered as their populations decline or they avoid formerly preferred habitats by moving elsewhere. If development blocks a migration path, then movement patterns may be significantly altered for many miles beyond development boundaries. Additionally, increased vigilance and flight associated with human developments could increase the frequency of panicked animals running into traffic. Finally, habituated ungulates in developed areas may cease migratory behavior and therefore alter road crossing patterns along the traditional migration route. Simultaneously, permanent concentrations of habituated ungulates near dwellings would likely create localized increases in ungulate road crossings and increase potential for animal–vehicle collisions.

9.1.2 Land Use Planning in the Madison Valley

Human development patterns influence patterns of wildlife habitat use and movement, and therefore, land use planning should be integrated into efforts to minimize the impacts of roads on wildlife and improve transportation safety. In recent years, significant progress has been made toward improving land use planning to protect wildlife resources.

The Montana Subdivision and Platting Act (76-3-608(3), MCA) requires counties to review subdivision applications based on a minimum of seven criteria including “(4) effect on wildlife” and “(5) effect on wildlife habitat.” The Madison County Growth Policy and Madison County Subdivision Regulations reflect these requirements. In 2007 the County adopted a *Revised Growth Management Action Plan for the Madison Valley* with the stated goal of incorporating the plan into the Madison County Growth Policy. The revised growth policy was submitted for public comment in October 2012 and adopted by the County in March 2013. A public review draft of the policy is available on the Madison County website. These documents reflect the County’s commitment to protect wildlife and wildlife habitat for its citizens. The draft Growth Policy emphasizes the need to protect wildlife resources under Goal 3, which reads as follows:

> **Goal 3. The Environment:** Protect the quality of our air, groundwater, surface waters, soils, vegetation, fish and wildlife habitat, scenic views, cultural and historic resources.
>
> Objectives:
>
> a. Promote best management practices by all land users.
>
> b. Encourage new development that is compatible with the environmental goals and objectives of this Plan.
>
> c. Support the establishment, expansion, and upgrading of community sewer/water systems.
>
> d. Review new development proposals for the full spectrum of potential and cumulative environmental impacts.
>
> e. Where necessary, more clearly define the resources we want to protect.

f. Promote noxious weed control.

Unless a subdivision application is exempted by the Montana Subdivision and Platting Act, developers must submit an environmental assessment with their application for subdivision. The County regulations require the environmental assessment to include the following wildlife provisions:

C. Wildlife

1. Identify any major species of fish and wildlife use [sic] the area to be affected by the proposed subdivision.

2. Locate on a copy of the preliminary plat, or on a plat overlay, any known important wildlife areas, such as big game winter range, waterfowl nesting areas, habitat for rare or endangered species, and wetlands.

3. Describe any proposed measures to protect wildlife habitat or to minimize degradation (e.g., keeping buildings and roads away from shorelines or setting aside marshland as undeveloped open space).

In addition, the regulations provide the following questions (as amended in the draft 2012 Growth Policy) as a guide for addressing the public interest criteria required by the Montana Subdivision and Platting Act previously discussed. “The subdivider must demonstrate, through the environmental assessment, that the proposed subdivision has been designed with consideration of these criteria”:

#4. Effect of proposed subdivision on wildlife and wildlife habitat:

- What types of wildlife are found (or likely to be found) in the habitat where this proposed subdivision is located? Consider both game species and non-game species of animals, birds, reptiles, amphibians, and fish. Consider both permanent and seasonal wildlife populations.
- Is the proposed subdivision located in big game winter range, an area of elk calving, and/or a wildlife migration corridor?
- Is the proposed subdivision located in a wildlife breeding area?
- Is the proposed subdivision located in habitat which supports threatened and/or endangered species?
- Is the proposed subdivision located in or adjacent to an area considered by wildlife specialists to be rich in wildlife resources?
- If the proposed subdivision is located in an area considered rich in wildlife resources, is the subdivision designed to minimize negative impacts on the wildlife?
  - o Development design measures could include clustering, reduced number of lots, buffer zones, access or use limitations, conservation easements, restrictive covenants, wildlife habitat enhancement projects, and wildlife habitat replacement areas.

  - Negative impacts could include wildlife harassment, displacement, endangerment, and either population loss or uncontrolled population increase.
- If the proposed subdivision is located adjacent to an area rich in wildlife resources, what measures are proposed to protect the adjacent habitat and wildlife population from being negatively impacted by the development?
- Is the proposed subdivision likely to put the immediate area close to, at, or over the limits of being able to sustain existing wildlife populations?
- Is the proposed subdivision likely to displace wildlife in a way that will create problems for adjacent landowners?

The Madison County Growth Policy recommends that, "wherever possible, new development should [...] include a land stewardship plan that addresses management responsibility for such things as noxious weed control, public access (where provided), wildlife, livestock grazing, other agricultural uses, recycling, and protection of water resources" and the Madison County Subdivision Regulations require submission of a land stewardship plan. This plan should address several major points including:

> **Wildlife.**
>
> Where a subdivision is proposed in an area rich in wildlife resources, what measures will be taken to avoid habituating the wildlife, harassing the wildlife, obstructing wildlife migration patterns, unnecessarily attracting dangerous wildlife, and/or causing game damage on adjoining properties? Remember that building and road location, fencing options, garbage containment, pets, landscaping choices, hunting policies, etc. may all impact wildlife. Suggested contacts: MT Dept. of Fish, Wildlife and Parks, County Extension Agent, Natural Resources Conservation Service, Local Conservation District.

Therefore, the County has emphasized the importance of protecting wildlife and wildlife habitat through stated goals, provided guidance for evaluating impacts on wildlife that recognizes the importance of movement habitat and wildlife corridors, and directed the County to consider cumulative impacts.

Implementation of the Madison County Growth Policy to protect wildlife and their habitats depends on good scientific information and appropriate tools to translate that information into sound land use decisions. The following studies are relevant to land use planning for wildlife in the Madison Valley. Full citations can be found in the Literature Cited section.

"A Multicriteria Assessment of the Irreplaceability and Vulnerability of Sites in the Greater Yellowstone Ecosystem" (Noss et al. 2002).

> This report highlights the regional importance of the Madison Valley and identifies several megasites containing portions of the Madison Valley as conservation priorities within the Greater Yellowstone Ecosystem.

"Montana's Comprehensive Fish and Wildlife Conservation Strategy" (Montana Fish, Wildlife & Parks 2005).

> Generically known as the State Wildlife Action Plan or "SWAP," this plan identifies habitat and species management priorities statewide.

"High-Quality Wildlife Connectivity Areas in the Madison Valley Watershed" (Groves, et al. 2005).

> A report summarizing analysis of wildlife connectivity in the Madison Valley and highlighting areas of conservation priority. This report is largely superseded by Brock et al. (2006).

"A Wildlife Conservation Assessment of the Madison Valley, Montana" (Brock et al. 2006).

> An analysis of conservation opportunities and priorities in the Madison Valley based on 15 focal species chosen to represent a full suite of species native to the valley. This report contains maps of modeled habitat and connectivity for focal species as well as compilation maps indicating conservation priority areas with management recommendations. Subsequent to release of this report, a series of workshops with area conservation stakeholders produced maps of conservation priority "zones" based on this assessment's results combined with expert revision.

"Establishing an Important Bird Area in the Madison Valley" (Marks and Kociolek 2006).

> A report describing the establishment of an Important Bird Area along the Madison River.

"Effects of Exurban Development on Wildlife" (Kretser and Glennon upubl.)

> An ongoing project by the Wildlife Conservation Society studying the effects of exurban development in the Madison Valley of Montana and in the Adirondack Mountains of New York. The current phase of the study explores the influence of landowner stewardship on native bird communities.

Recently, several tools have been developed that can assist land use planning decisions that avoid or minimize impacts to wildlife. These include: "Crucial Areas Planning System" *(*CAPS*)* (http://fwp.mt.gov/fishAndWildlife/conservationInAction/crucialAreas.html

> An online service developed by Montana Fish, Wildlife & Parks providing maps, site-specific management recommendations, and other information through an interactive website. The site contains crucial habitat areas for wildlife with connectivity layers currently under review. Users may request layers contained in CAPS in GIS format to use in their own analyses. Available layers are mapped at 1-mile-square resolution and are suitable for evaluating whether an area of interest (e.g., area of a proposed subdivision) falls within important wildlife habitat.

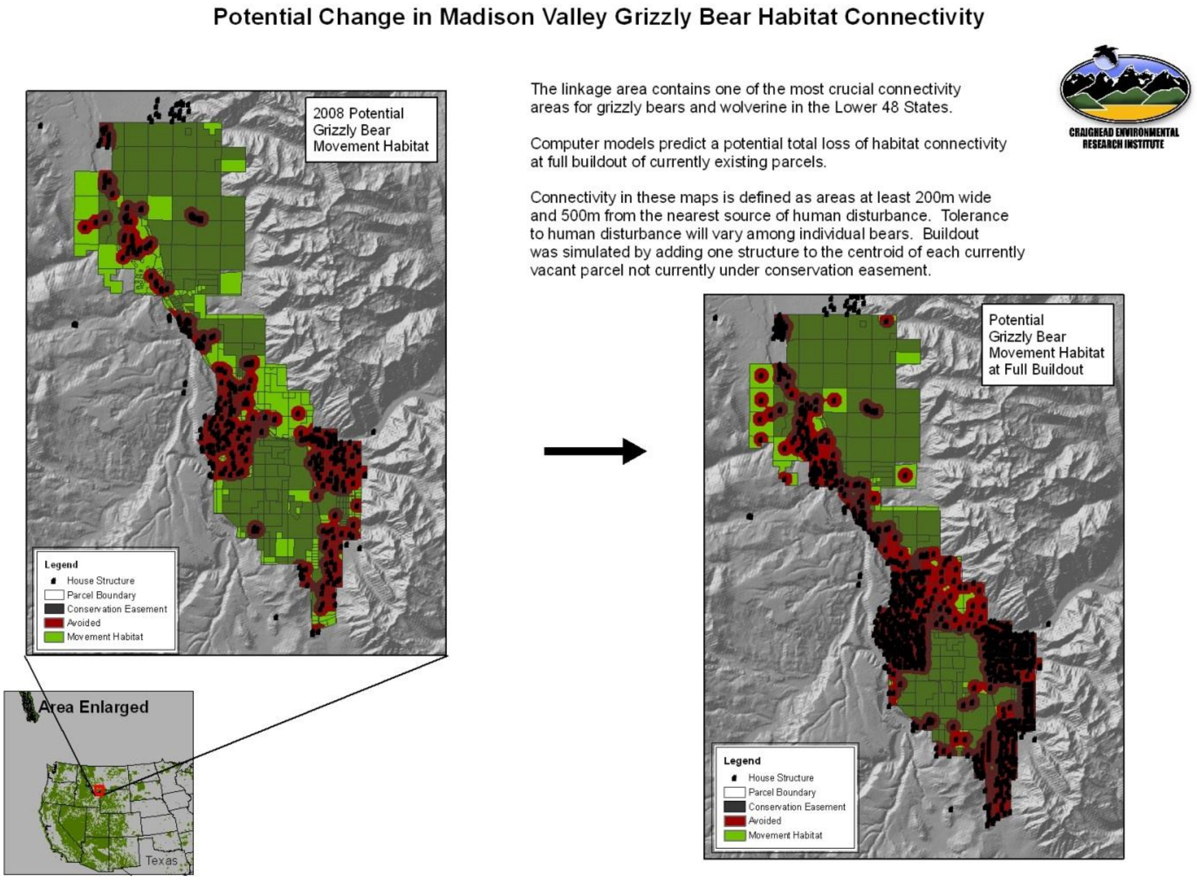
"Fish and Wildlife Recommendations for Subdivision Development in Montana" (Montana Fish, Wildlife & Parks).

> This document provides a set of development guidelines to minimize impacts to wildlife based on the best available science. This document also contains a wealth of scientific rationale for recommended guidelines and other information to help practitioners understand how best to implement them.

"WildPlanner: GIS-based tools for land use planning for wildlife" (The Craighead Institute).

> This tool was developed by the Craighead Institute to help evaluate the impacts of existing and future development on wildlife. The intent of these tools is to help

developers design projects that avoid negative impacts to wildlife and provide counties with tools to evaluate subdivision proposals for compliance with wildlife criteria. The tools model zones of influence around houses and roads to estimate the cumulative impacts of development on wildlife habitat and connectivity. The tools can be used to model potential development scenarios (Appendix A – Figure 2). Because land use patterns can influence wildlife movement, the tools can be used to make fine-scale predictions of likely movement pathways within wildlife corridors, including where wildlife may be most likely to attempt to cross roads.



Potential Change in Madison Valley Grizzly Bear Habitat Connectivity

The linkage area contains one of the most crucial connectivity areas for grizzly bears and wolverine in the Lower 48 States.

Computer models predict a potential total loss of habitat connectivity at full buildout of currently existing parcels.

Connectivity in these maps is defined as areas at least 200m wide and 500m from the nearest source of human disturbance. Tolerance to human disturbance will vary among individual bears. Buildout was simulated by adding one structure to the centroid of each currently vacant parcel not currently under conservation easement.

Appendix A – Figure 2. Example development scenario comparison generated by WildPlanner.

9.1.3 Literature Cited

Brown, D. G., K. M. Johnson, T. R. Loveland, and D. M. Theobald, "Rural land-use trends in the conterminous United States, 1950–2000." *Ecological Applications*, Vol. 15 (2005) pp. 1851–1863.

Brock, B. L., E.C. Atkinson, C. Groves, A. Toivola, T. Olenicki and L. Craighead, "A wildlife conservation assessment of the Madison Valley, Montana." *Unpublished report,* Wildlife Conservation Society, Greater Yellowstone Program, Bozeman, MT (2006) 230pp.

http://www.wcsnorthamerica.org/DesktopModules/Bring2mind/DMX/Download.aspx?EntryId=5581&PortalId=37&DownloadMethod=attachment

Cleveland, S. M., "Human predation risk and elk behavior in heterogeneous landscapes." *Thesis*, University of Montana, Missoula, Montana, USA (2010).

Glennon, M. and H. Kretser., "Impacts to Wildlife from Low Density, Exurban Development: Information and Considerations for the Adirondack Park." *Technical Paper No. 3* Wildlife Conservation Society: Adirondack Communities and Conservation Program, (2005) 65pp. http://www.wcsnorthamerica.org/DesktopModules/Bring2mind/DMX/Download.aspx?EntryId=5487&PortalId=37&DownloadMethod=attachment

Groves, C., B. Brock, and A. Toivola, "High-Quality Wildlife Connectivity Areas in the Madison Valley Watershed." *Unpublished report*, Wildlife Conservation Society, Greater Yellowstone Program (2005) 34 pp.

Hansen, A. J., R. Rasker, B. Maxwell, J. J. Rotella, J. D. Johnson, A. W. Parmenter, L. Langner, W. B. Cohen, R. L. Lawrence, and M. P. V. Kraska, "Ecological causes and consequences of demographic change in the new west." *BioScience*, Vol. 52 No. 2. (2002) pp. 151–162.

Hansen, A. J., and J. J. Rotella, "Biophysical factors, land use, and species viability in and around nature reserves." *Conservation Biology*, Vol. 16 (2002) pp. 1–12.

Hansen, A. J. and D. G. Brown, "Land-use change in rural America: Rates, drivers, and consequences." *Ecological Applications*, Vol. 15 No.6 (2005) pp. 1849–1850.

Madison County, "Madison County Growth Policy 2012: Updating the Madison County Growth Policy (last adopted 2006). *Public Review Draft (9/24/12)* (2012) 143pp. http://madison.mt.gov/departments/plan/current_proposals/GP2012PB1001.pdf Accessed October 4, 2012.

Maestas, J. D., "Effects of Exurban Development on Wildlife and Plant Communities." *U.S. Department of Agriculture, Natural Resources Conservation Service. Technical Note No. 75*, Washington, DC (2007) 6pp.

Marks, J., C. Putnam, and A. Kociolek, "Establishing an Important Bird Area in the Madison Valley, Montana." *Unpublished report*, Montana Audubon Society, Missoula (2006).

Montana Fish, Wildlife & Parks, "Montana's Comprehensive Fish and Wildlife Conservation Strategy." *Technical Report*, Montana Fish, Wildlife & Parks, 1420 East Sixth Avenue, Helena, MT 59620 (2005) 658pp. http://fwp.mt.gov/fishAndWildlife/conservationInAction/fullplan.html Accessed October 6, 2012.

Montana Fish, Wildlife & Parks, "Fish and Wildlife Recommendations for Subdivision Development in Montana: A Working Document." *Technical Report*, Montana Fish, Wildlife and Parks, Helena, Montana. (2012) 174 pp. http://fwp.mt.gov/fishAndWildlife/livingWithWildlife/buildingWithWildlife/subdivisionRecommendations/documents.html

Montana Subdivision and Platting Act, Montana Code Annotated, sections 76-3-101 et seq. http://data.opi.mt.gov/bills/mca_toc/76.htm. Accessed October 5, 2012.

Nelson, A. C., "Characterizing exurbia." *Journal of Planning Literature*, Vol. 6. (1992) pp. 350–368.

Noss, R. F., C. Carroll, K. Vance-Borland and G. Wuerthner, "A Multicriteria Assessment of the Irreplaceability and Vulnerability of Sites in the Greater Yellowstone Ecosystem." *Conservation Biology* Vol. 16, No. 4 (2002) pp. 895–908.

Polfus, J. L., "Literature review and synthesis on the effects of residential development on ungulate winter range in the Rocky Mountain West." *Report prepared for Montana Fish, Wildlife & Parks. Helena, MT* (2011) 128 pp. http://fwp.mt.gov/fwpDoc.html?id=51645

Polfus, J. L. and P. R. Krausman., "Impacts of residential development on ungulates in the Rocky Mountain West." *Wildlife Society Bulletin,* Vol. 36, No. 4 (2012) pp. 647–657.

9.2 Appendix B: Wildlife-Highway Accommodation Measures State of the Practice: Bibliography

Safety and wildlife habitat connectivity issues along highways can often be addressed with a variety of accommodation measures and conservation solutions. The following bibliography offers key resources from leaders in transportation ecology in the United States and abroad.

9.2.1 Overview of Issues and Solutions

The following resources provide a foundation for understanding how roads can impact wildlife. They include many examples that illustrate the need for a range of accommodation solutions.

ARC, "Animal Road Crossing," 2012, http://arc-solutions.org/ Accessed June 6, 2012.

> This website is a hub for new thinking, methods, materials and solutions for wildlife crossing structures.

Center for Environmental Excellence, American Association of State Highway and Transportation Officials (AASHTO), "Wildlife and Roads." *NCHRP 25-27* (2009). http://environment.transportation.org/environmental_issues/wildlife_roads/decision_guide/manual/ Accessed June 6, 2012.

> This website offers a decision guide to plan, implement and manage highway crossing structures and other accommodations for wildlife. It also houses the "Evaluation of the Use and Effectiveness of Wildlife Crossings" *NCHRP Report*, which includes a state-of-the-practice survey and research results.

International Conference on Ecology and Transportation (ICOET), Past ICOET Conferences (Proceedings). Center for Transportation and the Environment, http://www.icoet.net/links.asp Accessed June 5, 2012.

> This website maintains proceedings from ICOET conferences (a multi-disciplinary, inter-agency conference held every two years) dating back to 1996. Topics include a broad range of ecological issues related to surface transportation, including best practices to ameliorate negative effects to wildlife.

Iuell, B., G. J. Bekker, R. Cuperus, J. Dufek, G. Fry, C. Hicks, V. Hlaváč, V. Keller, C. Rosell, T. Sangwine, N. Tørsløv, and B. le Maire Wandall. (Eds.), "Wildlife and Traffic: A European Handbook for Identifying Conflicts and Designing Solutions." *Cooperation in the field of Scientific and Technical research (COST 341)*, Infra Eco Network Europe (2003) 21 pp., http://www.iene.info/cost341.php Accessed June 5, 2012.

> This handbook aims to enable practitioners and decision makers to reduce fragmentation and barrier effects of transportation infrastructure.

9.2.1.1 Supporting Information

While the following references do not address specific strategies and structures per se, they are included because of the wealth of supporting information they provide that can help build the case for wildlife accommodation in general.

Claar, J. J., N. Anderson, D. Boyd, M. Cherry, B. Conard, R. Hompesch, S. Miller, G. Olson, H. Ihsle, D. Pac, J. Waller, T. Wittinger, and H. Youmans, "Carnivores." Pages 7.1– 7.63 in Joslin, G. and H. Youmans, (coordinators). "Effects of Recreation on Rocky Mountain Wildlife: A Review for Montana." *Committee on Effects of Recreation on Wildlife. Montana Chapter of The Wildlife Society*. 307pp. (1999).

> This documentation of impacts includes the effects of roads and trails on wildlife but may understate the importance of habitat deterioration caused by recreational activities other than hunting and trapping. The authors conclude that research on recreational impacts is inadequate for most species. In addition to documented impacts, the authors have included some informed thought on probable impacts. In many landscapes, occurrence of habitats that fill the specialized habitat requirements of carnivores, particularly ursids and mustelids, has been reduced as a result of human developments (e.g., subdivisions, reservoirs, roads), logging practices (loss of old growth/structurally mature conifer stands with multiple canopies, snags, and downfall), and recreational use/developments in forest habitats and important landforms such as alpine cirques (e.g., ski resorts, snowmobile trails/play areas, heli-skiing, and extreme snowboarding).

Craighead, F. L., "Wildlife-related Road Impacts in the Yellowstone to Yukon Region." *Unpublished report*, prepared for Yukon to Yellowstone Conservation Initiative (1999) 14 pp.

> Roads, railroads, trails, and other linear developments that often reduce or eliminate animal movements and habitat connectivity are discussed. Literature references are cited according to key species discussed: grizzly bears, wolves, mountain lions, lynx, wolverine, fisher, elk, and mountain sheep.

Jalkotzy, M. G., P. I. Ross, and M. D. Nasserden, "The Effects of Linear Developments on Wildlife: A Review of Selected Scientific Literature." *Report,* prepared for the Canadian Association of Petroleum Producers (1997) 354 pp.

> This report, completed in 1997, is a review of the scientific literature describing the effects of linear developments on wildlife, especially large mammals. The authors reviewed 6,050 articles. Of particular interest were the types of roads and linear developments created by the oil and pipeline industries in western Canada. The effects of linear developments on wildlife are best understood in the context of regional and landscape ecology: the spatial arrangement of ecological processes on the land. The effects of development corridors on wildlife can be subdivided into six major categories: individual disruption, social disruption, habitat avoidance, habitat disruption or enhancement, direct and indirect mortality, and population effects. The presence or absence of any particular effect is dependent on the species of wildlife and the structure of the corridor. Of all disturbance corridors that humans create, roads probably have the greatest impact on wildlife populations. The most important effects are direct and indirect mortality and the loss of

habitat effectiveness as a result of habitat avoidance in the vicinity of disturbance corridors. The report comprises 120 pages and the literature review 234 pages.

Nietvelt, C. G., "The Effects of Roads on Wildlife: Bibliography." *Final Report*, prepared for U.S. Forest Service Bridger-Teton National Forest (2002) 77 pp.

Approximately 670 scientific papers, reports, articles and documents were reviewed with respect to the effects of roads on wildlife and the ecosystem. Links to web pages and online documents are also provided although many of these are no longer active. Articles are listed according to the taxa of wildlife discussed.

U.S. Forest Service, "Wildlife–Roadways Interaction Bibliography." *Unpublished report,* USFS Wenatchee Forestry Sciences Lab, Wenatchee, WA (1998) 97 pp.

An annotated bibliography of references related to wildlife and roadways.

9.2.2 Wildlife–Vehicle Collision Reduction

Huijser, M. P., P. McGowen, J. Fuller, A. Hardy, A. Kociolek, A. P. Clevenger, D. Smith and R. Ament, "Wildlife–Vehicle Collision Reduction Study." *Report to Congress,* U.S. Department of Transportation, Federal Highway Administration, Washington, DC (2007) 251 pp., http://www.westerntransportationinstitute.org/research/4W1096.aspx Accessed June 5, 2012.

This report estimates the magnitude and trend for wildlife–vehicle collisions (WVCs) in the United States, assesses causes and impacts of WVCs, and identifies solutions to this growing safety problem. This study was mandated by the U.S. SAFETEA-LU Congressional Bill of 2005.

Hesse, S. G., "Collisions with Wildlife: An Overview of Major Wildlife Vehicle Collision Data Collection Systems in British Columbia and Recommendations for the Future." *Wildlife Afield* 3 (2006) pp.1:3–7 (Supplement).

In this paper, it was estimated that three WVCs went undetected for every one that was recorded.

Huijser, M. P., A. Kociolek, P. McGowen, A. Hardy, A. P. Clevenger and R. Ament, "Wildlife–Vehicle Collision and Crossing Mitigation Measures: A Toolbox for the Montana Department of Transportation." *Report FHWA/MT-07-002/8117-34*, Montana Department of Transportation, Helena, MT (2007) 123 pp.

http://www.mdt.mt.gov/other/research/external/docs/research_proj/wildlife_crossing_mitigation/final_report.pdf Accessed June 6, 2012.

This report reviews the costs and benefits of 39 types of crossing structures and other accommodation measures for terrestrial mammals that may cause a safety risk (deer size and larger) and federally endangered or threatened species in Montana regardless of their size.

Huijser, M. P., P. McGowen, A. P. Clevenger, and R. Ament, "Wildlife–Vehicle Collision Reduction Study: Best Practices Manual." *Report to Congress,* U.S. Department of Transportation, Federal Highway Administration, Washington, DC (2008) 174 pp., http://www.westerntransportationinstitute.org/research/4W1096.aspx Accessed June 5, 2012.

This manual provides best practices to reduce WVCs. It includes guidelines for designing, implementing and monitoring the effectiveness of a variety of crossing structures and other strategies. . It also offers information on prioritizing, planning and fundraising.

Huijser, M. P., J. W. Duffield, A. P. Clevenger, R. J. Ament, and P. T. McGowen, "Cost–benefit Analyses of Mitigation Measures Aimed at Reducing Collisions with Large Ungulates in the United States and Canada: A Decision Support Tool." *Ecology and Society* 14: 2 (2009) 15. http://www.ecologyandsociety.org/viewissue.php?sf=41 Accessed October 16, 2012.

This decision-support tool is useful for determining when it makes economic sense to implement measures to reduce ungulate–vehicle collisions.

Sullivan, J. L., "Trends and Characteristics of Animal–Vehicle Collisions in the United States." *Journal of Safety Research* 42: 1 (2011) pp. 9–16.

This paper examines annual animal–vehicle collision (AVC) trends in the United States over a 19-year period, seasonal and diurnal patterns of AVC risk, the geographic distribution of crash risk by state, and the association between posted speed limit and AVC crash risk in darkness. AVCs represent a small but increasing share of crashes in the United States. Seasonal and daily variation in the pattern of AVCs seems to follow variation in deer exposure and ambient light level. Finally, the relative risk that a fatal and nonfatal AVC occurred in darkness is influenced by the posted speed limit, suggesting that a driver's limited forward vision at night plays a role in AVCs, as it does in pedestrian collisions. The association between speed limit and crash risk in darkness suggests that AVC risk might be reduced with countermeasures that improve a driver's forward view of the road.

9.2.3 Planning and Funding Wildlife Crossing Structures

National Park Service and U.S. Forest Service, "Wildlife Crossings Toolkit." *Resources* (2011) http://www.fs.fed.us/wildlifecrossings/resources/ Accessed June 6, 2012.

This website provides information for integrating conservation with large-scale/long-term transportation planning and funding opportunities. It also offers tools to assess when it is appropriate to retrofit existing structures for the benefit of wildlife. http://www.fs.fed.us/wildlifecrossings/resources/retrofitting-structures.php#Appropriateness.

U.S. Department of Agriculture, "Federal Surface Transportation Programs and Transportation Planning for Federal Land Management Agencies: A Guidebook." *Report 7700-Transportation Management 0777 1814-SDTDC*, U.S. Department of Transportation, Washington, DC (2007) 111 pp., http://www.fs.fed.us/eng/pubs/pdf/07771814.pdf Accessed June 6, 2012.

> This guidebook focuses on how to develop partnerships with federal land management agencies and to procure funding for surface transportation projects.

9.2.4 Placement, Design and Evaluation of Wildlife Crossing Structures

Wildlife crossing structures in combination with wildlife fencing are generally considered some of the most effective methods to reduce WVCs and to increase habitat connectivity. Proper placement and structural design are of utmost importance. To evaluate the conservation value of a given structure requires a proactive, systematic and scientific approach.

Clevenger, A. P., "Conservation Value of Wildlife Crossings: Measures of Performance and Research Directions." *GAIA*, Vol. 14, No. 2 (June, 2005) pp. 124–129, http://www.ingentaconnect.com/search/article?option2=author&value2=clevenger&sortDescending=true&sortField=default&pageSize=10&index=5 Accessed June 6, 2012.

> This review offers guiding principles for measuring the performance of wildlife crossing structures. It discusses the concept of assessing conservation value and how it depends on the intended purpose of the crossing and the biological or taxonomic level of organization of concern.

Clevenger, A. P. and M. P. Huijser, "Wildlife Crossing Structure Handbook: Design and Evaluation in North America." *Report FHWA-CFL/TD-11-003*, Federal Highway Administration, Washington, DC (2011) 224 pp., http://www.westerntransportationinstitute.org/research/425259.aspx Accessed June 6, 2012.

> This handbook provides transportation and natural resource management practitioners with technical design guidelines for wildlife crossing systems for North American species. Chapters reflect the practical sequence of project development.

Clevenger, A. P. and M. A. Sawaya, "Piloting a Non-invasive Genetic Sampling Method for Evaluating Population-level Benefits of Wildlife Crossing Structures." *Ecology and Society* Vol. 15, No. 1 (2010) Art. 7., http://www.ecologyandsociety.org/vol15/iss1/art7/ Accessed June 6, 2012.

> This article describes a pilot study that tests the feasibility of non-invasive genetic sampling to determine whether crossing structures have a population-level benefit.

Ford, A. T., A. P. Clevenger, M. P. Huijser and A. Dibb, "Planning and Prioritization Strategies for Phased Highway Mitigation Using Wildlife–Vehicle Collision Data." *Wildlife Biology* 17 (2011) pp. 253–265.

This paper presents several criteria that can be used to assist in prioritizing the location of wildlife-proof fencing. It analyzed data along a 94-km (58 mile) stretch of road in one of Canada's national parks. The authors considered temporal consistency of WVC occurrences, conservation value (i.e., reduction in WVC rates), economic benefits (i.e., cost of fencing vs. benefits in WVC reduction), and an approach to prioritize management actions. They found that longer fences best address conservation concerns, but all fencing sections, irrespective of length, rarely captured more than 50 percent of WVC locations. Shorter fences were more economically efficient, but also more variable in performance, than longer fences.

Gagnon, J. W., T. C. Theimer, N. L. Dodd, S. Boe, and R. E. Schweinsburg, "Traffic Volume Alters Elk Distribution and Highway Crossings in Arizona." *The Journal of Wildlife Management*, 71: 7 (2007) pp. 2318–2323.

Results from 38,709 fixes from 44 elk (Cervus elaphus) fitted with Global Positioning System collars and hourly traffic data recorded along 27 km (17 miles) of highway in central Arizona indicate that 1) managers assessing habitat quality for elk in areas with high traffic-volume highways should consider that habitat near highways may be utilized at low traffic volumes; 2) in areas where highways potentially act as barriers to elk movement, increasing traffic volume decreases the probability of highway crossings, but the magnitude of this effect depends on both season and proximity of important resources; and 3) because some highway crossings still occurred at the high traffic volumes recorded, increasing traffic alone will not prevent elk–vehicle collisions. Managers concerned with elk–vehicle collisions could increase the effectiveness of wildlife crossing structures by placing them near important resources, such as riparian meadow habitat.

Hardy A., A. P. Clevenger, M. Huijser, and G. Neale, "An Overview of Methods and Approaches for Evaluating the Effectiveness of Wildlife Crossing Structures: Emphasizing the Science in Applied Science." 2003 International Conference on Ecology and Transportation, Raleigh, NC, Proceedings (2004) pp. 319–330, http://www.icoet.net/downloads/03MonitoringofStructures.pdf Accessed June 6, 2012.

This conference presentation is a review that examines pre- and post- study designs of wildlife crossing structures. It encourages rigorous scientific evaluations to answer the question "Do wildlife crossing structures work?"

Kindall, J. L., and F. T. van Manen, "Identifying Habitat Linkages for American Black Bears in North Carolina, USA." *Journal of Wildlife Management* 71 (2007) pp. 487–495.

The authors use weights-of-evidence, a discrete multivariate technique for combining spatial data, to make predictions about bear habitat use from 1,771 telemetry locations on two study areas in North Carolina. The models clearly identified two of the three sites previously recommended for wildlife underpasses on a new four-lane highway in the study area. This approach yielded insights into how landscape metrics can be integrated to identify linkages suitable as habitat and dispersal routes.

Kintsch, J., and P. Cramer, "Permeability of Existing Structures for Wildlife: A Passage Assessment System." *Final Report No. WA-RD 777.1*, Washington Department of Transportation (2011) 187 pp.

A Passage Assessment System (PAS) was developed to help the Washington Department of Transportation (WSDOT) evaluate existing transportation infrastructure for its ability to facilitate terrestrial wildlife movement from one side of a roadway to the other. The PAS is intended as an evaluation tool to ensure that biologists ask the right questions in the field and fully document the conditions that may affect passage functionality for the diversity of target species. It offers potential cost savings and minimized project delays by identifying passage modifications that may be significantly less costly than new infrastructure. Where existing culverts and bridges can be shown to pass wildlife, it would help to reduce future construction costs for wildlife crossings in those areas and help to prioritize areas that are lacking in potential crossings and need additional accommodation measures.

McCollister, M. F., and F. T. van Manen, "Effectiveness of Wildlife Underpasses and Fencing to Reduce Wildlife–Vehicle Collisions." *Journal of Wildlife Management* 74 (2010) pp. 1722–1731.

The authors used camera and track surveys to evaluate wildlife use before and after construction of three wildlife underpasses and associated fencing on a new section of US 64 in North Carolina. This section experienced approximately 58 percent fewer wildlife mortalities (primarily white-tailed deer), suggesting underpasses and fencing reduced the number of deer–vehicle collisions. However, more mortalities were documented in fenced areas compared with unfenced areas. With greater distance from an underpass, animals with smaller home ranges seemed less likely to reach the underpass and instead attempted to climb over or crawl under fencing.

Van Manen, F., M. F. McCollister, J. M. Nicholson, L. M. Thompson, J. L. Kindall, and M. D. Jones, "Short-term Impacts of a Four-lane Highway on American Black Bears in Eastern North Carolina." *Wildlife Monographs* 181 (2012) pp. 1–35.

The authors assessed the short-term impacts of a new highway on spatial ecology, population size, survival, occupancy, and gene flow of black bears using a before-after control-impact (BACI) study design. They captured and radiocollared 57 bears and collected 5,775 hourly locations and 4,998 daily locations. They concluded that impacts of the new highway on resident black bears occurred at the population level, rather than the individual or genetic level, but that the impact was smaller than hunting harvest mortality. Effectiveness of wildlife underpasses to reduce mortality of black bears may be enhanced if the installations include continuous fencing between crossing structures. For small, isolated populations of threatened or endangered large mammals, the potential demographic impacts of highways are an essential consideration in the transportation planning process.

9.2.5 Roadside Animal Detection Systems

Roadside animal detection systems (RADS) aim to reduce wildlife–vehicle collisions and allow animals to move across a road at-grade. Warning signals alert drivers of an animal on or near the road so they may reduce their speed and stopping distance. RADS installation, operation and maintenance remain under review.

Huijser, M. P., T. D. Holland, M. Blank, M. C. Greenwood, P. T. McGowen, B. Hubbard, and S. Wang, "The Comparison of Animal Detection Systems in a Test-Bed: A Quantitative Comparison of System Reliability and Experiences with Operation and Maintenance." *Final report* FHWA/MT-09-002/5048, Federal Highway Administration, Washington, DC, and Montana Department of Transportation, Helena, MT (2009) 123 pp., http://www.westerntransportationinstitute.org/research/4W0049.aspx Accessed June 5, 2012.

> This report compares the reliability of nine different animal detection systems in a controlled environment using domestic animals as surrogates for wildlife species.

Huijser, M. P., Ph.D.; C. Haas, M.Sc.; K. R. Crooks, Ph.D., "The Reliability and Effectiveness of an Electromagnetic Animal Detection and Driver Warning System." *Final Report* CDOT-2012-2. Colorado Department of Transportation, Denver, USA (2012) 68 pp., http://www.coloradodot.info/programs/research/pdfs/2012/avc/view Accessed October 16, 2012.

> This report describes an animal detection system study conducted on US 160 in Colorado using horses, llamas and sheep as models for wild ungulates. Data were limited so no strong conclusions were made on the potential effectiveness of the system; however, the report discusses important factors when considering electromagnetic technology.

Huijser, M. P., M. C. Greenwood and L. Hayden, "Evaluation of the Reliability and Effectiveness of an Animal Detection System in a Test-Bed and along Hwy 3 near Ft. Jones, CA." *Final Report*. California PATH Program, U.C. Berkeley, CA (2012) 88 pp.

> This report describes an animal detection system project in northern California and a summary of driver opinions on the system. It concludes with a series of recommendations.

9.2.6 Simple Strategies to Reduce Road Impacts to Wildlife and the Environment

Federal Highway Administration, "Keeping it Simple: Easy Ways to Help Wildlife Along Roads." *Environment*, http://www.fhwa.dot.gov/environment/wildlifeprotection/ Accessed June 6, 2012.

> This website showcases state-level projects along or near roads that employ simple ways to reduce impacts to wildlife and the environment.

9.2.7 Habitat Conservation, Corridor Design and Context-Sensitive Solutions

The effectiveness of wildlife crossing infrastructure relies heavily on the availability of habitat to support wildlife. These resources address the need for habitat conservation and wildlife corridor linkages.

Beier, P., D. Majka, S. Newell, E. Garding, "Best Management Practices for Wildlife Corridors." *Unpublished report*, Northern Arizona University (2008). Available online http://corridordesign.org/dl/docs/corridordesign.org_BMPs_for_Corridors.pdf Accessed October 5, 2012.

> A review of best management practices for identifying and maintaining wildlife movement corridors. The report contains an extensive bibliography.

Corridor Design, 2012, http://www.corridordesign.org/ Accessed October 5, 2012.

> This website offers news and opinions on wildlife corridors and connectivity.

Craighead, F. L., and C. L. Convis, Jr. (Eds.), "Conservation Planning: Shaping the Future." Esri Press (2013). 440 pp. www.esri.com/conservationbook Accessed October 5, 2012.

> This book provides an introduction and guide for landscape conservation planning. The goal of a conservation plan is to maintain or enhance biodiversity, ecosystem function, and ecosystem structure, while accommodating human-oriented land uses that may be detrimental to that goal. At its simplest, creating a plan requires the conservation planner to make decisions about the most appropriate land use for a given site at a given time. To make these decisions correctly requires the best available information about the natural systems being conserved, particularly the biological processes that comprise the system. The effects of roads on wildlife habitat quality are addressed in several chapters.

Environmental Law Institute, "Conservation Thresholds for Land Use Planners – Essential Bibliography." *Environmental Law Institute*. (2007). Available online http://www.eli.org/pdf/research/thresholds/bibliography.pdf Accessed October 5, 2012.

> This bibliography was prepared from a conference in 2007 and includes papers relating to wildlife and planning.

Fields, K., D. M. Theobald, and M. Soulé, "Modeling Potential Broad-scale Wildlife Movement Pathways within the Continental United States." *Research white paper*, Colorado State University and Wildlands Network (2010). http://rewilding.org/rewildit/images/Wild-LifeLines_Wildlands-Network_White-Paper_low-res-copy.pdf Accessed October 5, 2012.

> This paper discusses a connectivity modeling project called Wild LifeLines™, which depicts potential movement pathways in the United States between the Mexican and Canadian borders that emphasize the least human modification and highest extant connectivity for wildlife. These pathways are the result of a novel modeling approach that

is based on a map of natural landscapes built from layers of land cover types, distance to roads, traffic volume and housing density, and then identifies the least fragmented connections between remaining natural areas. Roads are a key component in determining barriers to wildlife movement.

Leinwand, I. I. F, D. M. Theobald, J. Mitchell, and R. L. Knight, "Land-use Dynamics at the Public–Private Interface: A Case Study in Colorado." *Landscape and Urban Planning* 97(3): 182-193 (2010).

Using fine-grain land use data collected from high resolution aerial photographs, the authors quantify human land use composition, patterns, and trends at the interface of public and private land in the Southern Rocky Mountain Ecoregion (SRE) of Colorado. Two metrics were developed for assessing land use impacts. The first quantifies the amount of land cover modified by human land use and the second estimates the amount of wildlife habitat that is functionally modified. This research demonstrates how fine-scale land cover data can be used to examine land use patterns and composition as well as track land use changes.

Magle, S. B., D. M. Theobald, and K. R. Crooks, "A Comparison of Metrics Predicting Landscape Connectivity for a Highly Interactive Species along an Urban Gradient in Colorado, USA." *Landscape Ecology* 24 (2009) pp. 267–280.

This article provides guidance in modeling connectivity. The authors compared 12 connectivity metrics of varying degrees of complexity to determine which metric best predicts the distribution of prairie dog colonies along an urban gradient.

McGowen, P. and J. Johnson, "Habitat Connectivity and Rural Context-Sensitive Design: A Synthesis of Practice." *Final Report* No. FHWA/MT/06-012/8117-31 prepared for the Montana Department of Transportation (2007).

This report attempts to investigate how other states have incorporated Context Sensitive Design (CSD)/Context Sensitive Solutions (CSS) into their planning and design, including specific innovative examples of CSD/CSS, and statewide guidelines or standards that are used to prioritize and optimize habitat connectivity, roadside aesthetics and land use planning.

Stamatiadis, N., A. Kirk, D. Hartman, T. Hopwood, J. Pigman, "Quantifying the Benefits of Context Sensitive Solutions." *National Cooperative Highway Research Program Report 642, Transportation Research Board,* American Association of State Highway and Transportation Officials in cooperation with the Federal Highway Administration (2009) 168 pp.

This report discusses the concept and current status of Context Sensitive Solutions and includes a literature synthesis in Chapter 2. "Context Sensitive Design" and "Thinking Beyond the Pavement" were the early terminology used to define the context sensitive approach, because emphasis was placed on roadway design. To address the wider spectrum of context sensitive issues that exist from planning through construction (and beyond), the terminology has evolved into Context Sensitive Solutions. The report comprises 43 pages with 5 appendices and a section on guidelines for quantifying the benefits of CSS.

Theobald, D. M., J. M. Miller and N. T. Hobbs, "Estimating the Cumulative Effects of Development on Wildlife Habitat." *Landscape and Urban Planning,* 39(1) (1997) pp 25–36.

> The authors outline an approach based on a functional relationship between effect on habitat and distance from development. Within this building-effect distance, habitat is assumed to be degraded, producing a disturbance zone. They sum the total area within the disturbance zone and track how it changes over time and in response to different land use planning actions. This method is sensitive to both housing density and spatial pattern, so that the relative effects of clustered development can be evaluated. Two factors are important in understanding how development can degrade habitat: alteration of habitat near buildings and roads, and landscape fragmentation. Results show clustered development reduces the negative impacts on wildlife habitat.

Theobald, D. M., K. R. Crooks, and J. B. Norman, "Assessing Effects of Land Use on Landscape Connectivity: Loss and Fragmentation of Western U.S. Forests." *Ecological Applications* 21(7) (2011) pp. 2445–2458.

> This paper develops an approach that provides comprehensive, quantitative estimates of the effects of land-use change on landscape connectivity and illustrates its use on a broad, regional expanse of the western United States. The authors quantified loss of habitat and landscape connectivity for western forested systems due to land uses associated with residential development, roads, and highway traffic. They examined how these land-use changes likely increase the resistance to movement of forest species in non-forested land cover types and, therefore, reduce the connectivity among forested habitat patches. This approach can be readily modified to examine connectivity for other habitats/ecological systems and for other geographic areas, as well as to address more specific requirements for particular conservation planning applications.

9.3 Appendix C: Listing of Existing Datasets

During preliminary data collection activities, the team identified a variety of relevant existing datasets pertaining to wildlife, connectivity, highway characteristics, and county planning. A description listing is included in the following table.

Existing datasets identified for this study.

Data Name	Type	Owner	Contact	Description and Comments	Updates
Pronghorn	GIS shapefile	MTFWP	Julie Cunningham, FWP Region 3 Wildlife Biologist	Aerial Surveys on both sides of US 287, 2x per year, winter and summer. 1/4-1/3 of population migratory.	
Elk/mule deer	GIS shapefile	MTFWP	Julie Cunningham, FWP Region 3 Wildlife Biologist, Howard Burt, FWP Region 3 Wildlife Biologist	Aerial surveys on both sides of US 287 east of river. Feb-Mar.	
Elk	GPS	MTFWP	Julie Cunningham, FWP Region 3 Wildlife Biologist	2005-2006 43 elk gps-collared, kernelized estimates.	
Bighorn sheep		MTFWP	Julie Cunningham, FWP Region 3 Wildlife Biologist	Some collars and yearly spring counts.	
Bald eagle	GIS geodatabase	MTFWP	Kristi Dubois, FWP State Nongame Biologist. Claire Gower, FWP Region 3 Nongame Biologist	Activity and change from census. In NHP's nest locations database.	Never received and deemed unnecessary.
Bald eagle	GIS geodatabase	USFS	Courtney Frost	MTNHP's nest locations database. (Scavenging an issue with roads.)	Never received and deemed unnecessary.
Osprey	GIS geodatabase	USFS	Courtney Frost	MTNHP's nest locations database. (Maybe not an issue with roads.)	Never received and deemed unnecessary.
Peregrine	GIS geodatabase	Montana Peregrine Institute	Jay Sumner, Director Montana Peregrine Fund		Never received and deemed unnecessary.
Wolverine	Telemetry/Models	WCS	Bob Inman, independent wolverine biologist	Models outputs. (Raw telemetry data unavailable.)	
Connectivity Models from Madison Wildlife Assessment	GIS	WCS/Craighead	Brent Brock, Landscape Ecologist Craighead Institute and HoloScene Wildlife Services	Includes: elk, pronghorn, moose, western toad, grizzly bear, wolverine.	
Species of Concern	GIS Points and Polygons	MTNHP	Online Data Request		
Road Characteristics ("As Builts")		MDT	Jim Davies, MDT Butte District Road Design Supervisor.		

Data Name	Type	Owner	Contact	Description and Comments	Updates
Important Bird Areas	GIS shapefile	Montana Audubon	Available Online	Two IBAs are located in the Madison Valley.	
Montana Land cover 2010 (ReGAP)	GIS Raster	NRIS	Available Online	Vegetative land cover produced by GAP Analysis Program.	
Montana Conservation Stewardship	GIS shapefile	NRIS	Available Online	Includes public and private conservation easements.	
Montana Wildlife Management Areas	GIS shapefile	MTFWP	Available Online		
Infrastructure (roads, buildings)	GIS shapefiles	NRIS	Available Online		
Infrastructure (transmission lines, pipelines)	GIS shapefiles	Proprietary	Unavailable	These layers are proprietary and their distribution is regulated by Homeland Security.	
Streams and lakes	GIS shapefile	NRIS	Available Online		
Animal movements (IGBST grizzly movement images)	Raster Images	IGBST	Mark Haroldson		
Topography (30 meter DEM)	Raster	USGS	Available Online		
Vegetation (wetland data) from National Wetlands Inventory	GIS shapefile	NRIS	Available Online		
Wildlife habitat and winter range (FWP range maps)	GIS shapefile	MTFWP	Available Online		
FWP Critical Areas Planning System data layers	Online Data Service	MTFWP	Available Online	Layers may be requested by contacting MTFWP.	
Wildlife Vehicle Collisions data	Table of RP locations	MDT	Was requested from MDT maintenance bi-annually	Two week turnaround for data requests	
Vehicle Crash Data	Table of crashes and causes	MHP	Was requested from MHP maintenance bi-annually	May be included in MDT data	

Abbreviations used: IGBST = Interagency Grizzly Bear Study Team; MTFWP = Montana Fish Wildlife and Parks; USFS = United States Forest Service; WCS = Wildlife Conservation Society; MTNHP = Montana Natural Heritage Program; MDT = Montana Department of Transportation; MHP = Montana Highway Patrol; NRIS = Natural Resource Information System; USGS = United States Geological Survey.

9.4 Appendix D: Comparison of Reference Posts with Odometer Readings.

MT 87/US 287 RP number	**Distance in 1/10 mile**	**Comments**
0 (MT 87)	**Raynolds Pass**	end point at Targhee NF sign
	10	culvert at 0.6 RP
1 (MT 87)		missing RP signpost
	10	culverts at 1.5 and 1.95 RP
2 (MT 87)		
	10	culvert at 2.6 RP
3 (MT 87)		
	10	culvert at 3.4 RP
4 (MT 87)		
	10	
5 (MT 87)		culvert at 5.0 RP
	10	culvert at 5.2 RP
6 (MT 87)		culvert at 6.0 RP
	10	culvert at 6.7 RP
7 (MT 87)		
	10	culverts at 7.4 and 7.9 RP
8 (MT 87)		Madison River at 8.1 RP
	10	Intersection MT 87 and US 287 at 8.6 RP
9		
	10	
10		
	10	
11		
	10	
12		
	10	
13		
	10	
14		Vigilante Pub
	10	
15		
	10	Papoose Creek Road at 15.45 RP
16		
	10	Squaw Creek at 16.8 RP
17		

MT 87/US 287 RP number	Distance in 1/10 mile	Comments
	9; *9-9.5*	
18		
	10	
19		
	10	
20		
	9; *9.1*	Sun Ranch road at 20.4 RP
21		
	9; *10*	
22		Wolf Creek at 22 RP
	10	
23		
	9	
24		
	9; *8.5-9.1*	
25		
	10	
26		
	10	
27		
	10	
28		
	10	
29		
	10	Indian Creek Road at 29.6 RP
30		
	9; *9.8-9.9*	Very close to 1 mile apart RP
31		Indian Creek at 30.8
	10	
32		
	10	
33		
	10	
34		
	10	
35		
	10	

MT 87/US 287 RP number	Distance in 1/10 mile	Comments
36		
	10	
37		
	10	
38		Weigh Station at 38.6 RP
	10	
39		
	10	
40		Gravelley Range road at 40 RP
	10	
41		
	10	Airport road at 41.35 RP
42		
	10	
43		
	10	
44		
	10	
45		
	10	
46		
	10	
47		
	10	
48		Large underpasses at 48.2, 48.3, 48.4 RP
	10	Madison River at 48.5 RP
49		Ennis
	10	Ennis
50		Ennis
	10	
51		
	10	
52		
	10	
53		
	10	
54		

MT 87/US 287 RP number	Distance in 1/10 mile	Comments
	10	
55		
	9	
56		
	10	North Meadow Creek at 56.5 RP
57		
	10	
58		
	9	RP 59 was present during the first measurements but missing by the second visit
59		
	10	
60		
	10	
61		
	9; *9.5-10*	
62		
	10	
63		
	10	
64		
	10	
65		
65.4		End point at 65.4 RP; Norris, junction with MT 87
US 287 from junction of MT 87 to US 191		
0		
	10	
1		
	10	
2		
	10	
3		
	10	
4		
	10	
5		

MT 87/US 287 RP number	Distance in 1/10 mile	Comments
	10	
6		
	10	
7		Beaver Creek bridge RP 7.3
	10	
8		
	9; *9.8-9.9*	Very close to 1 mile apart
9		
	10	Hebgen Dam at 9.3 RP
10		
	10	
11		
	10	subdivision
12		
	10	
13		
	10	
14		
	10	subdivision
15		
	10	
16		
	9; *9.5-10*	
17		
	10	Campground road intersection
18		
	10	
19		
	9; *9.5-10*	
20		Grayling Creek bridge at RP 20.0
	10	
21		
	10	
22		
22.4		end point of US 287, junction US 191

In column 2, Distance in 1/10th mile, numbers in **bold** represent agreement during both surveys, normal font indicates distance measured by the Toyota Tundra (digital counter) and *italicized font* indicates distance measured by the rental vehicle (digital counter).

9.5 Appendix E: Carcass Observations by Species from April 4, 2012 to April 9, 2014.

Species	Date	Lat	Long	Milepost	Highway	Total
Bighorn sheep						**4**
Bighorn sheep	25-Nov-13	44.827	-111.458	1.6	287	
Bighorn sheep	25-Nov-13	44.827	-111.458	1.6	287	
Bighorn sheep	25-Nov-13	44.827	-111.458	1.6	287	
Bighorn sheep	25-Nov-13	44.827	-111.458	1.6	287	
Moose[1]	28-Sep-12	45.444	-111.732	56.7	287	**1**
Elk						**30**
Elk	2-May-12	45.308	-111.695	45.3	287	
Elk	21-May-12	44.835	-111.499	9.1	287	
Elk*[2]	21-May-12	45.292	-111.687	44.1	287	
Elk	28-Sep-12	44.804	-111.178	18.9	287	
Elk	3-Oct-12	44.804	-111.178	18.9	287	
Elk	12-Nov-12	45.291	-111.686	44.1	287	
Elk	26-Nov-12	44.806	-111.479	6.7	87	
Elk	28-Nov-12	44.941	-111.611	18.7	287	
Elk	30-Nov-12	44.963	-111.63	20.6	287	
Elk	14-Dec-12	44.821	-111.482	7.7	87	
Elk	17-Dec-12	44.82	-111.482	7.7	87	
Elk	6-Feb-13	44.987	-111.648	22.6	287	
Elk	6-Feb-13	44.987	-111.648	22.6	287	
Elk*[3]	6-Feb-13	44.987	-111.648	22.6	287	
Elk[2]	3-Apr-13	45.027	-111.648	25.5	287	
Elk	29-Apr-13	45.026	-111.648	25.5	287	
Elk	29-Apr-13	44.836	-111.503	9.3	287	
Elk[4]	3-Nov-13	44.955	-111.62	19.8	287	
Elk	4-Nov-13	45.457	-111.731	57.6	287	
Elk	13-Nov-13	44.938	-111.609	18.5	287	
Elk	6-Dec-13	44.997	-111.648	23.3	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Elk	6-Dec-13	44.991	-111.648	22.8	287	
Elk	13-Dec-13	45.012	-111.648	24.4	287	
Elk	21-Dec-13	44.993	-111.648	23	287	
Elk	21-Dec-13	45.013	-111.648	24.5	287	
Elk	30-Dec-13	44.991	-111.648	22.8	287	
Elk	1-Jan-14	45.048	-111.648	27	287	
Elk	10-Feb-14	45.074	-111.646	28.8	287	
Elk[5]	18-Feb-14	44.984	-111.648	22.4	287	
Elk	12-Mar-14	44.956	-111.621	19.9	287	
Pronghorn						**16**
Pronghorn	2-May-12	45.437	-111.731	56.2	287	
Pronghorn	25-Jun-12	44.817	-111.481	7.4	87	
Pronghorn[6]	9-Jul-12	45.175	-111.679	36	287	
Pronghorn	30-Jul-12	45.126	-111.665	32.5	287	
Pronghorn	22-Aug-12	44.739	-111.469	2	87	
Pronghorn	10-Sep-12	45.018	-111.648	24.9	287	
Pronghorn	14-Sep-12	45.077	-111.647	29	287	
Pronghorn	5-Oct-12	44.815	-111.481	7.3	87	
Pronghorn	15-Oct-12	45.06	-111.647	27.8	287	
Pronghorn	16-Jan-13	45.145	-111.678	34	287	
Pronghorn	25-Feb-13	45.366	-111.731	50.2	287	
Pronghorn	27-May-13	45.154	-111.679	34.6	287	
Pronghorn	10-Jun-13	44.797	-111.476	6	87	
Pronghorn	7-Aug-13	45.371	-111.731	50.6	287	
Pronghorn	9-Sep-13	44.999	-111.648	23.4	287	
Pronghorn	9-Sep-13	45.333	-111.701	47.1	287	
Mule deer						**27**
Mule deer	2-May-12	44.921	-111.602	17.2	287	
Mule deer	30-May-12	44.864	-111.55	12.4	287	
Mule deer	9-Jul-12	44.862	-111.331	9.5	287	
Mule deer	8-Aug-12	44.80986	-111.251	15	287	
Mule deer	17-Aug-12	44.855	-111.394	5.7	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Mule deer	22-Aug-12	45.344	-111.718	48.2	287	
Mule deer	3-Sep-12	44.864	-111.334	9.3	287	
Mule deer	12-Oct-12	44.925	-111.603	17.5	287	
Mule deer	19-Oct-12	45.521	-111.692	62.8	287	
Mule deer	22-Oct-12	45.522	-111.694	62.9	287	
Mule deer	26-Nov-12	44.869	-111.561	13.1	287	
Mule deer	1-Feb-13	45.368	-111.731	50.4	287	
Mule deer	6-May-13	44.829	-111.475	0.6	287	
Mule deer	21-Jun-13	45.319	-111.699	46.1	287	
Mule deer	8-Jul-13	44.835	-111.497	9	287	
Mule deer	31-Aug-13	44.862	-111.546	12.2	287	
Mule deer	12-Oct-13	44.853	-111.4	5.4	287	
Mule deer	16-Oct-13	45.534	-111.7	63.9	287	
Mule deer	18-Oct-13	45.46	-111.731	57.8	287	
Mule deer	21-Oct-13	45.533	-111.7	63.8	287	
Mule deer	1-Jan-14	44.953	-111.618	19.6	287	
Mule deer	15-Jan-14	45.312	-111.697	45.6	287	
Mule deer	22-Feb-14	45.52	-111.69	62.7	287	
Mule deer	14-Mar-14	45.363	-111.731	50	287	
Mule deer	19-Mar-14	45.368	-111.731	50.4	287	
Mule deer	24-Mar-14	45.53	-111.699	63.6	287	
Mule deer	7-Apr-14	45.099	-111.649	30.5	287	
White-tailed deer						**32**
White-tailed deer	20-Apr-12	45.337	-111.707	47.5	287	
White-tailed deer	22-Apr-12	45.459	-111.73	57.7	287	
White-tailed deer	23-Jun-12	45.336	-111.704	47.3	287	
White-tailed deer	9-Jul-12	45.517	-111.687	62.5	287	
White-tailed deer	1-Aug-12	45.57	-111.691	66.4	287	
White-tailed deer	8-Aug-12	45.448	-111.732	57	287	
White-tailed deer	22-Oct-12	45.297	-111.691	44.5	287	
White-tailed deer	29-Oct-12	45.459	-111.731	57.7	287	
White-tailed deer	7-Nov-12	45.427	-111.731	55.4	287	

Species	Date	Lat	Long	Milepost	Highway	Total
White-tailed deer	7-Nov-12	44.9	-111.589	15.6	287	
White-tailed deer	19-Nov-12	44.959	-111.625	20.2	287	
White-tailed deer	19-Nov-12	44.914	-111.602	16.8	287	
White-tailed deer	30-Nov-12	44.915	-111.602	16.8	287	
White-tailed deer	12-Apr-13	45.304	-111.694	45	287	
White-tailed deer	12-Jun-13	44.918	-111.602	17	287	
White-tailed deer	24-Jun-13	45.336	-111.704	47.3	287	
White-tailed deer	26-Jun-13	44.963	-111.631	20.6	287	
White-tailed deer	24-Jul-13	44.897	-111.585	15.3	287	
White-tailed deer	21-Aug-13	45.457	-111.731	57.6	287	
White-tailed deer	4-Oct-13	45.377	-111.731	51	287	
White-tailed deer	14-Oct-13	45.34	-111.71	47.7	287	
White-tailed deer[6]	15-Oct-13	44.927	-111.603	17.7	287	
White-tailed deer	25-Oct-13	44.898	-111.586	15.4	287	
White-tailed deer	11-Nov-13	45.313	-111.697	45.7	287	
White-tailed deer	16-Dec-13	45.105	-111.652	31	287	
White-tailed deer	23-Dec-13	45.46	-111.73	57.8	287	
White-tailed deer	6-Jan-14	44.887	-111.576	14.5	287	
White-tailed deer	6-Jan-14	44.91	-111.599	16.5	287	
White-tailed deer	13-Jan-14	45.342	-111.715	48	287	
White-tailed deer	29-Jan-14	44.979	-111.647	22	287	
White-tailed deer	17-Feb-14	45.433	-111.732	55.9	287	
White-tailed deer	22-Feb-14	45.433	-111.731	55.9	287	
Deer sp.						**8**
Deer sp.	5-Nov-12	45.569	-111.69	66.3	287	
Deer sp.	25-Feb-13	45.378	-111.731	51.1	287	
Deer sp.	24-Apr-13	45.554	-111.694	65.3	287	
Deer sp.	24-Jun-13	44.888	-111.577	14.6	287	
Deer sp.	4-Sep-13	44.872	-111.564	13.3	287	
Deer sp.	20-Sep-13	45.441	-111.732	56.5	287	
Deer sp.	4-Oct-13	45.342	-111.715	48	287	
Deer sp.	20-Nov-13	45.291	-111.685	44	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Ungulate						**9**
Ungulate	2-Jun-12	45.46	-111.73	57.8	287	
Ungulate	22-Mar-13	44.98	-111.647	22.1	287	
Ungulate	24-Apr-13	45.094	-111.648	30.2	287	
Ungulate	26-Apr-13	45.014	-111.648	24.6	287	
Ungulate	3-Jun-13	45.52	-111.689	62.7	287	
Ungulate	21-Oct-13	44.938	-111.609	18.5	287	
Ungulate	4-Nov-13	45.023	-111.648	25.2	287	
Ungulate	29-Nov-13	45.012	-111.648	24.4	287	
Ungulate	24-Feb-14	45.202	-111.679	37.9	287	
Grizzly bear[7]	30-Aug-13	44.798	-111.156	20.1	287	**1**
Wolf**	11-May-12	44.96	-111.626	20.3	287	**1**
Coyote						**7**
Coyote	7-Jul-12	45.199	-111.679	37.7	287	
Coyote	4-Feb-13	45.533	-111.7	63.8	287	
Coyote	10-Mar-13	45.516	-111.687	62.4	287	
Coyote	18-Mar-13	44.893	-111.582	15	287	
Coyote	27-Mar-13	44.867	-111.559	12.9	287	
Coyote	30-Sep-13	45.433	-111.732	55.9	287	
Coyote	4-Dec-13	45.115	-111.658	31.7	287	
Fox						**3**
Fox	13-Jul-12	44.841	-111.299	11.7	287	
Fox	27-Aug-12	44.802	-111.237	15.9	287	
Fox	19-Nov-12	44.914	-111.602	16.8	287	
Domestic cat						**5**
Domestic cat	30-May-12	45.3	-111.692	44.7	287	
Domestic cat	8-Aug-12	45.373	-111.731	50.7	287	
Domestic cat	31-Aug-12	45.337	-111.706	47.5	287	
Domestic cat	3-Oct-12	45.428	-111.731	55.5	287	
Domestic cat	2-Sep-13	45.571	-111.69	66.4	287	
Felid	22-Jul-13	45.566	-111.691	66.1	287	**1**
Badger						**11**
Badger	7-Jul-12	45.197	-111.679	37.5	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Badger	14-Sep-12	44.821	-111.483	7.7	87	
Badger	12-Oct-12	45.41	-111.731	54.3	287	
Badger	11-May-13	45.381	-111.731	51.3	287	
Badger	14-May-13	44.74	-111.469	2	87	
Badger	24-Jun-13	44.767	-111.468	3.9	87	
Badger	17-Jul-13	45.394	-111.731	53.2	287	
Badger	29-Jul-13	45.189	-111.679	37	287	
Badger	31-Jul-13	45.292	-111.687	44.1	287	
Badger	9-Aug-13	44.846	-111.526	10.6	287	
Badger	21-Aug-13	44.811	-111.48	7	87	
Marten	21-Dec-13	45.2	-111.679	37.7	287	**1**
Mink	23-Jun-12	44.98	-111.647	22.1	287	**1**
Long-tailed Weasel						**2**
Long-tailed weasel	11-Jul-12	44.855	-111.389	6	287	
Long-tailed weasel	26-Jun-13	45.42	-111.731	55	287	
Marmot				0	0	**4**
Marmot	18-Jun-12	44.855	-111.396	5.6	287	
Marmot	20-Jun-12	44.848	-111.41	4.8	287	
Marmot	5-Jul-12	44.855	-111.396	5.6	287	
Marmot	25-Jul-12	44.847	-111.412	4.7	287	
Porcupine						**8**
Porcupine	6-Aug-12	45.453	-111.731	57.3	287	
Porcupine	29-Aug-12	44.829	-111.486	8.3	87	
Porcupine	3-Sep-12	45.298	-111.691	44.6	287	
Porcupine	3-Sep-12	44.959	-111.625	20.2	287	
Porcupine	17-Sep-12	44.831	-111.276	13	287	
Porcupine	12-Oct-12	45.292	-111.686	44.1	287	
Porcupine	12-Jul-13	45.28	-111.68	43.3	287	
Porcupine	5-Aug-13	45.46	-111.73	57.8	287	
Skunk						**28**
Skunk	30-Jun-12	45.447	-111.732	56.9	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Skunk	11-Jul-12	44.914	-111.601	16.8	287	
Skunk	1-Aug-12	45.337	-111.707	47.5	287	
Skunk	3-Aug-12	45.337	-111.707	47.5	287	
Skunk	13-Aug-12	44.978	-111.646	21.9	287	
Skunk	20-Aug-12	45.415	-111.731	54.6	287	
Skunk	3-Sep-12	45.435	-111.732	56	287	
Skunk	7-Sep-12	45.453	-111.731	57.3	287	
Skunk	7-Sep-12	44.87	-111.562	13.1	287	
Skunk	5-Oct-12	44.954	-111.618	19.7	287	
Skunk	26-Oct-12	45.314	-111.698	45.8	287	
Skunk	28-Nov-12	45.211	-111.679	38.5	287	
Skunk	18-Mar-13	44.863	-111.547	12.2	287	
Skunk	10-Jul-13	44.861	-111.546	12.1	287	
Skunk	12-Jul-13	45.192	-111.679	37.2	287	
Skunk	19-Jul-13	45.452	-111.732	57.3	287	
Skunk	9-Aug-13	44.979	-111.647	22	287	
Skunk	28-Aug-13	45.568	-111.691	66.2	287	
Skunk	31-Aug-13	45.338	-111.707	47.5	287	
Skunk	4-Sep-13	45.213	-111.679	38.6	287	
Skunk	9-Sep-13	45.452	-111.731	57.3	287	
Skunk	11-Sep-13	45.333	-111.701	47.1	287	
Skunk	9-Oct-13	45.371	-111.731	50.6	287	
Skunk	1-Nov-13	45.458	-111.731	57.6	287	
Skunk	13-Nov-13	44.881	-111.57	14	287	
Skunk	29-Nov-13	45.145	-111.677	34	287	
Skunk	8-Jan-14	45.145	-111.678	34	287	
Skunk	19-Mar-14	45.348	-111.724	48.7	287	
Raccoon						**19**
Raccoon	13-Jun-12	44.803	-111.238	15.8	287	
Raccoon	13-Jun-12	44.837	-111.289	12.3	287	
Raccoon	5-Jul-12	44.888	-111.577	14.6	287	
Raccoon	13-Jul-12	45.336	-111.704	47.3	287	
Raccoon	20-Jul-12	45.337	-111.706	47.5	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Raccoon	20-Jul-12	45.337	-111.706	47.5	287	
Raccoon	22-Aug-12	45.335	-111.703	47.3	287	
Raccoon	3-Sep-12	45.337	-111.706	47.5	287	
Raccoon	5-Sep-12	45.276	-111.68	43	287	
Raccoon	5-Sep-12	44.964	-111.633	20.7	287	
Raccoon	26-Oct-12	45.237	-111.679	40.3	287	
Raccoon	9-Sep-13	44.952	-111.617	19.5	287	
Raccoon	11-Sep-13	44.826	-111.485	8.1	87	
Raccoon	14-Sep-13	44.886	-111.574	14.4	287	
Raccoon	18-Sep-13	45.416	-111.731	54.7	287	
Raccoon	12-Oct-13	44.886	-111.574	14.4	287	
Raccoon	11-Nov-13	45.385	-111.731	51.6	287	
Raccoon	11-Dec-13	45.385	-111.731	51.6	287	
Raccoon	19-Mar-14	45.434	-111.732	55.9	287	
Hare/rabbit						**151**
Hare/rabbit	18-Apr-12	45.154	-111.679	34.6	287	
Hare/rabbit	2-May-12	44.976	-111.645	21.8	287	
Hare/rabbit	7-May-12	45.465	-111.729	58.1	287	
Hare/rabbit	7-May-12	45.466	-111.727	58.2	287	
Hare/rabbit	11-May-12	45.258	-111.679	41.7	287	
Hare/rabbit	30-May-12	44.951	-111.617	19.5	287	
Hare/rabbit	4-Jun-12	45.558	-111.693	65.5	287	
Hare/rabbit	6-Jun-12	45.226	-111.679	39.5	287	
Hare/rabbit	9-Jun-12	45.472	-111.72	58.8	287	
Hare/rabbit	9-Jun-12	44.843	-111.522	10.4	287	
Hare/rabbit	13-Jun-12	45.148	-111.678	34.2	287	
Hare/rabbit	20-Jun-12	45.014	-111.648	24.6	287	
Hare/rabbit	20-Jun-12	44.848	-111.53	10.9	287	
Hare/rabbit	23-Jun-12	45.222	-111.679	39.2	287	
Hare/rabbit	25-Jun-12	45.006	-111.648	24	287	
Hare/rabbit	28-Jun-12	45.568	-111.691	66.2	287	
Hare/rabbit	30-Jun-12	45.178	-111.679	36.2	287	
Hare/rabbit	30-Jun-12	45.167	-111.679	35.5	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Hare/rabbit	30-Jun-12	44.936	-111.608	18.4	287	
Hare/rabbit	3-Jul-12	45.472	-111.72	58.8	287	
Hare/rabbit	3-Jul-12	44.802	-111.477	6.4	87	
Hare/rabbit	9-Jul-12	45.186	-111.679	36.8	287	
Hare/rabbit	9-Jul-12	45.057	-111.647	27.6	287	
Hare/rabbit	9-Jul-12	44.768	-111.468	4	87	
Hare/rabbit	9-Jul-12	45.277	-111.68	43	287	
Hare/rabbit	13-Jul-12	45.144	-111.677	33.9	287	
Hare/rabbit	16-Jul-12	45.209	-111.679	38.3	287	
Hare/rabbit	16-Jul-12	44.935	-111.606	18.2	287	
Hare/rabbit	20-Jul-12	44.942	-111.611	18.8	287	
Hare/rabbit	23-Jul-12	45.139	-111.674	33.5	287	
Hare/rabbit	25-Jul-12	45.008	-111.648	24.1	287	
Hare/rabbit	25-Jul-12	44.848	-111.53	10.9	287	
Hare/rabbit	27-Jul-12	45.08	-111.647	29.2	287	
Hare/rabbit	30-Jul-12	45.25	-111.679	41.2	287	
Hare/rabbit	30-Jul-12	44.784	-111.472	5.1	87	
Hare/rabbit	30-Jul-12	44.792	-111.475	5.7	87	
Hare/rabbit	1-Aug-12	45.539	-111.7	64.2	287	
Hare/rabbit	3-Aug-12	44.792	-111.475	5.7	87	
Hare/rabbit	6-Aug-12	45.481	-111.709	59.6	287	
Hare/rabbit	8-Aug-12	45.481	-111.709	59.6	287	
Hare/rabbit	8-Aug-12	45.226	-111.679	39.5	287	
Hare/rabbit	10-Aug-12	45.271	-111.679	42.6	287	
Hare/rabbit	10-Aug-12	45.226	-111.679	39.5	287	
Hare/rabbit	13-Aug-12	45.272	-111.679	42.7	287	
Hare/rabbit	13-Aug-12	44.784	-111.472	5.1	87	
Hare/rabbit	15-Aug-12	45.094	-111.648	30.2	287	
Hare/rabbit	15-Aug-12	44.829	-111.486	8.3	87	
Hare/rabbit	17-Aug-12	45.218	-111.679	39	287	
Hare/rabbit	20-Aug-12	45.245	-111.679	40.8	287	
Hare/rabbit	22-Aug-12	45.159	-111.679	34.9	287	
Hare/rabbit	27-Aug-12	45.088	-111.648	29.7	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Hare/rabbit	29-Aug-12	44.942	-111.611	18.8	287	
Hare/rabbit	29-Aug-12	44.774	-111.47	4.4	87	
Hare/rabbit	31-Aug-12	45.138	-111.673	33.5	287	
Hare/rabbit	7-Sep-12	45.321	-111.699	46.2	287	
Hare/rabbit	17-Sep-12	45.294	-111.689	44.3	287	
Hare/rabbit	17-Sep-12	45.208	-111.679	38.3	287	
Hare/rabbit	19-Sep-12	45.294	-111.689	44.3	287	
Hare/rabbit	21-Sep-12	45.564	-111.691	65.9	287	
Hare/rabbit	21-Sep-12	45.392	-111.731	53.1	287	
Hare/rabbit	24-Sep-12	45.291	-111.686	44.1	287	
Hare/rabbit	24-Sep-12	45.263	-111.679	42.1	287	
Hare/rabbit	24-Sep-12	45.193	-111.679	37.3	287	
Hare/rabbit	24-Sep-12	44.946	-111.613	19.1	287	
Hare/rabbit	26-Sep-12	45.294	-111.689	44.3	287	
Hare/rabbit	26-Sep-12	45.291	-111.686	44.1	287	
Hare/rabbit	26-Sep-12	45.247	-111.679	41	287	
Hare/rabbit	10-Oct-12	44.848	-111.531	10.9	287	
Hare/rabbit	15-Oct-12	44.781	-111.472	4.9	87	
Hare/rabbit	22-Oct-12	44.947	-111.614	19.2	287	
Hare/rabbit	26-Oct-12	45.211	-111.679	38.5	287	
Hare/rabbit	29-Oct-12	45.536	-111.7	64	287	
Hare/rabbit	14-Nov-12	45.25	-111.679	41.2	287	
Hare/rabbit	26-Nov-12	45.317	-111.699	46	287	
Hare/rabbit	28-Nov-12	45.538	-111.7	64.1	287	
Hare/rabbit	19-Dec-12	45.507	-111.693	61.7	287	
Hare/rabbit	21-Jan-13	44.824	-111.483	7.9	87	
Hare/rabbit	21-Jan-13	44.785	-111.473	5.2	87	
Hare/rabbit	25-Jan-13	45.557	-111.693	65.5	287	
Hare/rabbit	6-Mar-13	45.28	-111.681	43.3	287	
Hare/rabbit	8-Mar-13	45.532	-111.7	63.7	287	
Hare/rabbit	8-Mar-13	45.469	-111.722	58.5	287	
Hare/rabbit	12-Mar-13	45.509	-111.692	61.8	287	
Hare/rabbit	20-Mar-13	44.939	-111.61	18.6	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Hare/rabbit	25-Mar-13	45.14	-111.674	33.6	287	
Hare/rabbit	1-Apr-13	45.413	-111.731	54.5	287	
Hare/rabbit	1-Apr-13	45.155	-111.679	34.6	287	
Hare/rabbit	10-Apr-13	45.283	-111.682	43.5	287	
Hare/rabbit	17-Apr-13	45.477	-111.714	59.2	287	
Hare/rabbit	24-Apr-13	45.469	-111.723	58.5	287	
Hare/rabbit	24-Apr-13	45.223	-111.679	39.3	287	
Hare/rabbit	1-May-13	45.555	-111.694	65.3	287	
Hare/rabbit	11-May-13	44.843	-111.52	10.3	287	
Hare/rabbit	24-May-13	44.803	-111.477	6.4	87	
Hare/rabbit	3-Jun-13	44.792	-111.475	5.7	87	
Hare/rabbit	7-Jun-13	45.281	-111.681	43.3	287	
Hare/rabbit	7-Jun-13	45.102	-111.65	30.8	287	
Hare/rabbit	10-Jun-13	45.042	-111.648	26.6	287	
Hare/rabbit	24-Jun-13	45.231	-111.679	39.9	287	
Hare/rabbit	3-Jul-13	45.188	-111.679	36.9	287	
Hare/rabbit	5-Jul-13	44.843	-111.52	10.3	287	
Hare/rabbit	10-Jul-13	45.189	-111.679	37	287	
Hare/rabbit	17-Jul-13	45.241	-111.679	40.6	287	
Hare/rabbit	22-Jul-13	45.282	-111.681	43.4	287	
Hare/rabbit	24-Jul-13	45.341	-111.713	47.9	287	
Hare/rabbit	24-Jul-13	44.936	-111.607	18.3	287	
Hare/rabbit	31-Jul-13	45.286	-111.683	43.7	287	
Hare/rabbit	31-Jul-13	45.076	-111.646	28.9	287	
Hare/rabbit	2-Aug-13	45.364	-111.731	50.1	287	
Hare/rabbit	7-Aug-13	45.388	-111.731	51.8	287	
Hare/rabbit	12-Aug-13	45.222	-111.679	39.2	287	
Hare/rabbit	12-Aug-13	44.853	-111.539	11.4	287	
Hare/rabbit	14-Aug-13	44.819	-111.482	7.6	87	
Hare/rabbit	17-Aug-13	45.561	-111.692	65.7	287	
Hare/rabbit	19-Aug-13	45.145	-111.678	34	287	
Hare/rabbit	21-Aug-13	45.273	-111.679	42.8	287	
Hare/rabbit	21-Aug-13	45.256	-111.679	41.6	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Hare/rabbit	21-Aug-13	45.246	-111.679	40.9	287	
Hare/rabbit	26-Aug-13	45.476	-111.715	59.1	287	
Hare/rabbit	28-Aug-13	45.478	-111.713	59.3	287	
Hare/rabbit	28-Aug-13	45.155	-111.679	34.6	287	
Hare/rabbit	28-Aug-13	45.123	-111.664	32.3	287	
Hare/rabbit	16-Sep-13	45.473	-111.718	58.9	287	
Hare/rabbit	18-Sep-13	45.16	-111.679	35	287	
Hare/rabbit	27-Sep-13	45.477	-111.713	59.3	287	
Hare/rabbit	27-Sep-13	45.261	-111.679	41.9	287	
Hare/rabbit	9-Oct-13	45.303	-111.693	45	287	
Hare/rabbit	9-Oct-13	44.945	-111.613	19	287	
Hare/rabbit	12-Oct-13	45.043	-111.648	26.6	287	
Hare/rabbit	12-Oct-13	45.035	-111.648	26.1	287	
Hare/rabbit	16-Oct-13	45.002	-111.648	23.7	287	
Hare/rabbit	21-Oct-13	44.828	-111.486	8.2	87	
Hare/rabbit	13-Nov-13	45.157	-111.679	34.8	287	
Hare/rabbit	15-Nov-13	45.558	-111.693	65.5	287	
Hare/rabbit	22-Nov-13	45.539	-111.699	64.2	287	
Hare/rabbit	22-Nov-13	44.836	-111.504	9.4	287	
Hare/rabbit	25-Nov-13	45.525	-111.698	63.2	287	
Hare/rabbit	29-Nov-13	45.187	-111.679	36.8	287	
Hare/rabbit	11-Dec-13	44.811	-111.48	7	87	
Hare/rabbit	21-Dec-13	45.2	-111.679	37.7	287	
Hare/rabbit	25-Dec-13	45.47	-111.722	58.6	287	
Hare/rabbit	1-Jan-14	45.299	-111.692	44.7	287	
Hare/rabbit	6-Jan-14	44.719	-111.471	0.6	87	
Hare/rabbit	20-Jan-14	44.823	-111.483	7.9	87	
Hare/rabbit	29-Jan-14	45.175	-111.679	36	287	
Hare/rabbit	5-Feb-14	45.138	-111.673	33.5	287	
Hare/rabbit	10-Mar-14	45.091	-111.648	29.9	287	
Hare/rabbit	12-Mar-14	45.359	-111.732	49.7	287	
Hare/rabbit	24-Mar-14	45.515	-111.687	62.3	287	
Hare/rabbit	28-Mar-14	44.976	-111.645	21.8	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Hare/rabbit	7-Apr-14	45.559	-111.693	65.6	287	
Medium mammal	30-Nov-12	45.361	-111.731	49.9	287	**1**
Red squirrel						**5**
Red squirrel	2-Jun-12	44.864	-111.366	7.3	287	
Red squirrel	17-Aug-12	44.864	-111.366	7.3	287	
Red squirrel	17-Aug-12	44.862	-111.373	6.9	287	
Red squirrel	5-Aug-13	44.86	-111.381	6.5	287	
Red squirrel	21-Oct-13	44.899	-111.588	15.5	287	
Golden-mantled ground squirrel	29-May-13	44.827	-111.451	1.9	287	**1**
Ground squirrel						**67**
Ground squirrel	7-May-12	44.737	-111.469	1.8	87	
Ground squirrel	16-May-12	44.734	-111.47	1.6	87	
Ground squirrel	30-May-12	44.723	-111.471	0.8	87	
Ground squirrel	30-May-12	45.055	-111.647	27.5	287	
Ground squirrel	2-Jun-12	44.789	-111.134	21.3	287	
Ground squirrel	11-Jun-12	44.736	-111.469	1.7	87	
Ground squirrel	11-Jun-12	44.831	-111.48	0.3	287	
Ground squirrel	16-Jun-12	45.198	-111.679	37.6	287	
Ground squirrel	16-Jun-12	45.431	-111.731	55.7	287	
Ground squirrel	18-Jun-12	45.429	-111.731	55.6	287	
Ground squirrel	18-Jun-12	45.049	-111.648	27	287	
Ground squirrel	18-Jun-12	45.05	-111.648	27.1	287	
Ground squirrel	18-Jun-12	45.022	-111.648	25.2	287	
Ground squirrel	18-Jun-12	44.805	-111.478	6.6	87	
Ground squirrel	20-Jun-12	44.831	-111.482	0.2	287	
Ground squirrel	23-Jun-12	45.416	-111.731	54.7	287	
Ground squirrel	23-Jun-12	44.849	-111.532	11	287	
Ground squirrel	23-Jun-12	44.871	-111.347	8.4	287	
Ground squirrel	23-Jun-12	44.827	-111.46	1.5	287	
Ground squirrel	25-Jun-12	44.77	-111.469	4.1	87	
Ground squirrel	25-Jun-12	44.77	-111.469	4.1	87	

Species	Date	Lat	Long	Milepost	Highway	Total
Ground squirrel	28-Jun-12	45.046	-111.648	26.8	287	
Ground squirrel	28-Jun-12	44.724	-111.471	0.9	87	
Ground squirrel	28-Jun-12	44.827	-111.46	1.5	287	
Ground squirrel	30-Jun-12	44.775	-111.47	4.5	87	
Ground squirrel	30-Jun-12	44.775	-111.47	4.5	87	
Ground squirrel	30-Jun-12	44.775	-111.47	4.5	87	
Ground squirrel	30-Jun-12	44.733	-111.47	1.5	87	
Ground squirrel	3-Jul-12	44.823	-111.483	7.9	87	
Ground squirrel	5-Jul-12	44.76	-111.467	3.4	87	
Ground squirrel	5-Jul-12	44.737	-111.469	1.8	87	
Ground squirrel	7-Jul-12	44.722	-111.471	0.8	87	
Ground squirrel	7-Jul-12	44.723	-111.471	0.8	87	
Ground squirrel	7-Jul-12	44.762	-111.467	3.5	87	
Ground squirrel	7-Jul-12	44.827	-111.453	1.8	287	
Ground squirrel	9-Jul-12	44.804	-111.215	17.1	287	
Ground squirrel	9-Jul-12	44.83	-111.478	0.5	287	
Ground squirrel	11-Jul-12	44.941	-111.611	18.7	287	
Ground squirrel	13-Jul-12	44.771	-111.469	4.2	87	
Ground squirrel	16-Jul-12	44.782	-111.116	22.3	287	
Ground squirrel	16-Jul-12	44.814	-111.256	14.6	287	
Ground squirrel	20-Jul-12	44.763	-111.467	3.6	87	
Ground squirrel	30-Jul-12	44.828	-111.466	1.2	287	
Ground squirrel	6-May-13	44.737	-111.469	1.8	87	
Ground squirrel	11-May-13	44.738	-111.469	1.9	87	
Ground squirrel	18-May-13	45.288	-111.684	43.8	287	
Ground squirrel	24-Jun-13	44.831	-111.48	0.3	287	
Ground squirrel	28-Jun-13	45.287	-111.684	43.8	287	
Ground squirrel	28-Jun-13	44.775	-111.47	4.5	87	
Ground squirrel	28-Jun-13	44.827	-111.461	1.4	287	
Ground squirrel	1-Jul-13	44.762	-111.467	3.5	87	
Ground squirrel	5-Jul-13	44.762	-111.467	3.5	87	
Ground squirrel	10-Jul-13	45.058	-111.647	27.7	287	
Ground squirrel	10-Jul-13	44.833	-111.489	8.6	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Ground squirrel	10-Jul-13	44.776	-111.47	4.5	87	
Ground squirrel	10-Jul-13	44.751	-111.468	2.8	87	
Ground squirrel	12-Jul-13	44.771	-111.469	4.2	87	
Ground squirrel	12-Jul-13	44.771	-111.469	4.2	87	
Ground squirrel	12-Jul-13	44.827	-111.463	1.3	287	
Ground squirrel	15-Jul-13	44.731	-111.47	1.4	87	
Ground squirrel	17-Jul-13	45.392	-111.731	53.1	287	
Ground squirrel	17-Jul-13	45.266	-111.679	42.3	287	
Ground squirrel	17-Jul-13	45.264	-111.679	42.1	287	
Ground squirrel	22-Jul-13	44.834	-111.493	8.8	287	
Ground squirrel	2-Aug-13	44.718	-111.472	0.5	87	
Ground squirrel	31-Mar-14	45.371	-111.731	50.6	287	
Ground squirrel	4-Apr-14	45.392	-111.731	53.1	287	
Chipmunk						**2**
Chipmunk	23-Jul-12	44.899	-111.588	15.5	287	
Chipmunk	24-Sep-12	44.804	-111.209	17.4	287	
Rat	25-Jul-12	45.119	-111.661	32	287	**1**
Small mammal						**5**
Small mammal	20-Jul-12	44.834	-111.425	3.5	287	
Small mammal	2-Jan-13	45.523	-111.695	63	287	
Small mammal	17-Jun-13	44.836	-111.502	9.3	287	
Small mammal	24-Jun-13	45.09	-111.648	29.9	287	
Small mammal	26-Jun-13	45.231	-111.679	39.9	287	
Mammal						**42**
Mammal	18-Apr-12	44.847	-111.528	10.8	287	
Mammal	18-May-12	45.275	-111.679	42.9	287	
Mammal	18-May-12	44.931	-111.605	18	287	
Mammal	4-Jun-12	45.193	-111.679	37.3	287	
Mammal	7-Jul-12	45.201	-111.679	37.8	287	
Mammal	27-Jul-12	44.889	-111.579	14.7	287	
Mammal	3-Aug-12	45.233	-111.679	40	287	
Mammal	20-Aug-12	45.364	-111.731	50.1	287	
Mammal	22-Aug-12	45.433	-111.731	55.9	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Mammal	7-Sep-12	45.485	-111.704	60	287	
Mammal	19-Sep-12	45.005	-111.648	23.9	287	
Mammal	3-Oct-12	44.984	-111.648	22.4	287	
Mammal	2-Nov-12	44.938	-111.609	18.5	287	
Mammal	12-Dec-12	45.236	-111.679	40.2	287	
Mammal	21-Dec-12	44.885	-111.573	14.3	287	
Mammal	25-Jan-13	44.843	-111.521	10.3	287	
Mammal	25-Jan-13	45.001	-111.648	23.6	287	
Mammal	6-Feb-13	45.255	-111.679	41.5	287	
Mammal	1-Mar-13	44.903	-111.594	15.9	287	
Mammal	6-Mar-13	45.554	-111.695	65.3	287	
Mammal	8-Mar-13	44.825	-111.484	8	87	
Mammal	15-Mar-13	45.069	-111.646	28.4	287	
Mammal	18-Mar-13	45.115	-111.658	31.7	287	
Mammal	27-Mar-13	44.798	-111.476	6.1	87	
Mammal	12-Apr-13	45.276	-111.68	43	287	
Mammal	11-May-13	44.791	-111.474	5.6	87	
Mammal	5-Jun-13	45.424	-111.731	55.2	287	
Mammal	24-Jun-13	44.848	-111.531	10.9	287	
Mammal	28-Jun-13	45.347	-111.722	48.5	287	
Mammal	3-Jul-13	45.34	-111.711	47.8	287	
Mammal	11-Sep-13	44.716	-111.471	0.4	87	
Mammal	16-Sep-13	45.249	-111.679	41.1	287	
Mammal	16-Oct-13	45.378	-111.731	51.1	287	
Mammal	13-Nov-13	45.241	-111.679	40.6	287	
Mammal	22-Nov-13	44.857	-111.544	11.8	287	
Mammal	22-Jan-14	44.844	-111.524	10.5	287	
Mammal	19-Feb-14	45.314	-111.698	45.8	287	
Mammal	5-Mar-14	44.842	-111.519	10.2	287	
Mammal	24-Mar-14	45.001	-111.648	23.6	287	
Mammal	4-Apr-14	44.814	-111.481	7.2	87	
Mammal	4-Apr-14	44.766	-111.468	3.8	87	
Mammal	4-Apr-14	44.763	-111.467	3.6	87	

Species	Date	Lat	Long	Milepost	Highway	Total
Golden eagle	27-Mar-13	44.885	-111.573	14.3	287	**1**
Ferruginous hawk	28-Jun-12	45.229	-111.679	39.7	287	**1**
Red-tailed hawk						**2**
Red-tailed hawk	16-Apr-12	45.482	-111.707	59.7	287	
Red-tailed hawk	29-Aug-12	45.325	-111.699	46.5	287	
Rough-legged hawk						**3**
Rough-legged hawk***	14-Nov-12	45.25	-111.679	41.2	287	
Rough-legged hawk	14-Nov-12	45.25	-111.679	41.2	287	
Rough-legged hawk	23-Nov-12	45.322	-111.699	46.3	287	
Hawk						**3**
Hawk	8-Aug-12	45.292	-111.686	44.1	287	
Hawk	3-Sep-12	44.826	-111.271	13.5	287	
Hawk	26-Nov-12	45.304	-111.693	45	287	
Great horned owl						**5**
Great horned owl	31-Aug-12	44.933	-111.605	18.1	287	
Great horned owl	8-Oct-12	45.083	-111.647	29.4	287	
Great horned owl	12-Nov-12	44.952	-111.618	19.6	287	
Great horned owl	11-Sep-13	44.753	-111.467	2.9	87	
Great horned owl	15-Jan-14	44.926	-111.603	17.6	287	
Raptor						**4**
Raptor	1-Jul-13	45.271	-111.679	42.6	287	
Raptor	9-Aug-13	45.32	-111.699	46.2	287	
Raptor	14-Aug-13	44.784	-111.473	5.1	87	
Raptor	23-Oct-13	45.252	-111.679	41.3	287	
Canada goose	18-Nov-13	45.547	-111.697	64.8	287	**1**
Mallard						**2**
Mallard	23-Jul-12	45.068	-111.646	28.4	287	
Mallard	23-Jul-12	45.073	-111.646	28.7	287	
Duck						**3**

Species	Date	Lat	Long	Milepost	Highway	Total
Duck	3-Aug-12	45.2	-111.679	37.7	287	
Duck	10-Jun-13	44.838	-111.509	9.6	287	
Duck	14-Oct-13	44.797	-111.154	20.2	287	
Grouse	2-Sep-13	44.887	-111.575	14.5	287	**1**
Gull	26-Jul-13	44.791	-111.137	21.1	287	**1**
Raven						**2**
Raven	3-Jul-12	44.936	-111.608	18.4	287	
Raven	5-Aug-13	44.833	-111.279	12.8	287	
Crow						**2**
Crow	9-Jul-12	45.437	-111.732	56.2	287	
Crow	19-Aug-13	45.455	-111.731	57.5	287	
Magpie						**24**
Magpie	18-Jun-12	44.827	-111.46	1.5	287	
Magpie	13-Jul-12	45.336	-111.704	47.3	287	
Magpie	16-Jul-12	45.286	-111.683	43.7	287	
Magpie	25-Jul-12	44.829	-111.487	8.3	87	
Magpie	1-Aug-12	45.519	-111.689	62.6	287	
Magpie	13-Aug-12	44.908	-111.597	16.3	287	
Magpie	26-Sep-12	45.455	-111.731	57.5	287	
Magpie	28-Sep-12	45.455	-111.731	57.5	287	
Magpie	19-Jun-13	44.828	-111.469	0.9	287	
Magpie	28-Jun-13	45.53	-111.699	63.6	287	
Magpie	28-Jun-13	45.461	-111.73	57.8	287	
Magpie	3-Jul-13	45.289	-111.685	43.9	287	
Magpie	29-Jul-13	45.305	-111.694	45.1	287	
Magpie	29-Jul-13	44.892	-111.582	15	287	
Magpie	29-Jul-13	45.331	-111.7	46.9	287	
Magpie	2-Aug-13	44.882	-111.571	14.1	287	
Magpie	9-Aug-13	44.91	-111.599	16.5	287	
Magpie	12-Aug-13	44.867	-111.559	12.9	287	
Magpie	23-Aug-13	45.547	-111.697	64.8	287	
Magpie	26-Aug-13	44.93	-111.605	17.9	287	
Magpie	21-Oct-13	44.828	-111.486	8.2	87	

Species	Date	Lat	Long	Milepost	Highway	Total
Magpie	30-Oct-13	45.301	-111.692	44.8	287	
Magpie	18-Nov-13	45.301	-111.692	44.8	287	
Magpie	31-Jan-14	44.785	-111.473	5.2	87	
Corvidae						**4**
Corvidae	24-Apr-13	45.554	-111.694	65.3	287	
Corvidae	17-Jun-13	45.002	-111.648	23.7	287	
Corvidae	17-Jul-13	44.804	-111.225	16.6	287	
Corvidae	31-Jul-13	45.299	-111.692	44.7	287	
Robin						**9**
Robin	27-Apr-12	44.862	-111.372	7	287	
Robin	9-May-12	44.876	-111.567	13.6	287	
Robin	1-Aug-12	44.852	-111.403	5.2	287	
Robin	3-Aug-12	44.871	-111.347	8.4	287	
Robin	3-Apr-13	44.812	-111.253	14.8	287	
Robin	20-May-13	44.852	-111.402	5.3	287	
Robin	12-Jun-13	44.861	-111.546	12.1	287	
Robin	26-Jul-13	44.803	-111.17	19.3	287	
Robin	28-Mar-14	45.331	-111.7	46.9	287	
Western meadow lark	8-Oct-12	45.433	-111.731	55.9	287	**1**
Western tanager	20-Aug-12	44.856	-111.387	6.1	287	**1**
Red-winged blackbird	3-Jul-12	44.862	-111.37	7.1	287	**1**
Swallow	10-Jul-13	45.456	-111.731	57.5	287	**1**
Bird						**50**
Bird	30-May-12	44.9	-111.589	15.6	287	
Bird	6-Jun-12	45.566	-111.691	66.1	287	
Bird	9-Jun-12	44.844	-111.304	11.4	287	
Bird	13-Jun-12	45.568	-111.69	66.2	287	
Bird	13-Jun-12	45.461	-111.73	57.8	287	
Bird	13-Jun-12	44.761	-111.467	3.5	87	
Bird	18-Jun-12	45.43	-111.731	55.7	287	
Bird	23-Jun-12	45.442	-111.731	56.5	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Bird	28-Jun-12	45.568	-111.69	66.2	287	
Bird	30-Jun-12	45.339	-111.708	47.6	287	
Bird	3-Jul-12	44.853	-111.399	5.4	287	
Bird	5-Jul-12	44.888	-111.576	14.6	287	
Bird	5-Jul-12	44.867	-111.558	12.8	287	
Bird	7-Jul-12	45.196	-111.679	37.5	287	
Bird	11-Jul-12	44.796	-111.152	20.3	287	
Bird	11-Jul-12	45.336	-111.704	47.3	287	
Bird	16-Jul-12	44.802	-111.167	19.5	287	
Bird	23-Jul-12	45.337	-111.707	47.5	287	
Bird	23-Jul-12	45.337	-111.706	47.5	287	
Bird	25-Jul-12	45.52	-111.691	62.7	287	
Bird	25-Jul-12	44.711	-111.469	0	87	
Bird	27-Jul-12	45.524	-111.697	63.1	287	
Bird	3-Aug-12	44.827	-111.449	2	287	
Bird	3-Aug-12	44.857	-111.324	10	287	
Bird	10-Aug-12	44.828	-111.437	2.6	287	
Bird	10-Aug-12	44.8	-111.162	19.7	287	
Bird	13-Aug-12	44.741	-111.469	2.1	87	
Bird	15-Aug-12	45.44	-111.732	56.4	287	
Bird	15-Aug-12	44.74	-111.469	2	87	
Bird	17-Aug-12	45.337	-111.707	47.5	287	
Bird	20-Aug-12	45.359	-111.732	49.7	287	
Bird	24-Aug-12	44.752	-111.468	2.8	87	
Bird	24-Aug-12	44.801	-111.234	16.1	287	
Bird	24-Aug-12	45.427	-111.731	55.4	287	
Bird	27-Aug-12	44.785	-111.122	22	287	
Bird	18-Mar-13	44.804	-111.207	17.5	287	
Bird	18-May-13	44.997	-111.648	23.3	287	
Bird	7-Jun-13	44.856	-111.323	10.1	287	
Bird	21-Jun-13	44.806	-111.243	15.5	287	
Bird	28-Jun-13	45.331	-111.7	46.9	287	
Bird	12-Jul-13	45.314	-111.698	45.8	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Bird	19-Jul-13	45.198	-111.679	37.6	287	
Bird	2-Aug-13	45.25	-111.679	41.2	287	
Bird	5-Aug-13	44.86	-111.381	6.5	287	
Bird	19-Aug-13	44.827	-111.46	1.5	287	
Bird	21-Aug-13	44.977	-111.645	21.9	287	
Bird	20-Sep-13	45.082	-111.647	29.3	287	
Bird	2-Oct-13	45.373	-111.731	50.7	287	
Bird	7-Oct-13	45.435	-111.732	56	287	
Bird	9-Oct-13	45.463	-111.73	58	287	
Unknown (blood smear)						**59**
Unknown (blood smear)	30-Apr-12	45.477	-111.714	59.2	287	
Unknown (blood smear)	30-Apr-12	45.243	-111.679	40.7	287	
Unknown (blood smear)	2-May-12	44.976	-111.645	21.8	287	
Unknown (blood smear)	7-May-12	44.949	-111.615	19.3	287	
Unknown (blood smear)	21-May-12	45.329	-111.699	46.8	287	
Unknown (blood smear)	4-Jun-12	44.846	-111.527	10.7	287	
Unknown (blood smear)	6-Jun-12	45.344	-111.718	48.2	287	
Unknown (blood smear)	16-Jun-12	45.21	-111.679	38.4	287	
Unknown (blood smear)	28-Jun-12	45.347	-111.723	48.5	287	
Unknown (blood smear)	3-Jul-12	44.985	-111.648	22.4	287	
Unknown (blood smear)	13-Jul-12	45.091	-111.648	29.9	287	
Unknown (blood smear)	20-Jul-12	44.892	-111.581	14.9	287	
Unknown (blood smear)	3-Aug-12	45.287	-111.683	43.7	287	
Unknown (blood smear)	6-Aug-12	45.539	-111.7	64.2	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Unknown (blood smear)	8-Aug-12	44.832	-111.489	8.5	87	
Unknown (blood smear)	13-Aug-12	45.501	-111.695	61.2	287	
Unknown (blood smear)	20-Aug-12	44.835	-111.496	9	287	
Unknown (blood smear)	20-Aug-12	44.865	-111.554	12.6	287	
Unknown (blood smear)	5-Sep-12	44.835	-111.497	9	287	
Unknown (blood smear)	19-Sep-12	45.087	-111.647	29.7	287	
Unknown (blood smear)	28-Sep-12	45.43	-111.731	55.7	287	
Unknown (blood smear)	19-Oct-12	44.931	-111.605	18	287	
Unknown (blood smear)	22-Oct-12	44.843	-111.521	10.3	287	
Unknown (blood smear)	5-Nov-12	45.367	-111.731	50.3	287	
Unknown (blood smear)	12-Nov-12	44.787	-111.473	5.3	87	
Unknown (blood smear)	16-Nov-12	45.291	-111.686	44.1	287	
Unknown (blood smear)	7-Jan-13	45.087	-111.648	29.7	287	
Unknown (blood smear)	14-Jan-13	45.145	-111.678	34	287	
Unknown (blood smear)	4-Feb-13	44.908	-111.597	16.3	287	
Unknown (blood smear)	4-Mar-13	44.855	-111.395	5.7	287	
Unknown (blood smear)	12-Mar-13	45.36	-111.732	49.8	287	
Unknown (blood smear)	15-Mar-13	45.341	-111.712	47.9	287	
Unknown (blood smear)	1-Apr-13	45.374	-111.731	50.8	287	
Unknown (blood smear)	17-Apr-13	45.397	-111.731	53.4	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Unknown (blood smear)	19-Apr-13	45.057	-111.647	27.6	287	
Unknown (blood smear)	1-May-13	45.308	-111.695	45.3	287	
Unknown (blood smear)	11-May-13	45.373	-111.731	50.7	287	
Unknown (blood smear)	29-May-13	45.348	-111.723	48.5	287	
Unknown (blood smear)	3-Jun-13	44.966	-111.638	21	287	
Unknown (blood smear)	7-Jun-13	44.761	-111.467	3.5	87	
Unknown (blood smear)	10-Jul-13	45.348	-111.723	48.5	287	
Unknown (blood smear)	9-Aug-13	45.441	-111.732	56.5	287	
Unknown (blood smear)	9-Aug-13	45.36	-111.732	49.8	287	
Unknown (blood smear)	20-Sep-13	45.101	-111.649	30.7	287	
Unknown (blood smear)	23-Sep-13	44.961	-111.628	20.4	287	
Unknown (blood smear)	7-Oct-13	45.463	-111.73	58	287	
Unknown (blood smear)	9-Oct-13	44.854	-111.54	11.5	287	
Unknown (blood smear)	16-Oct-13	44.792	-111.475	5.7	87	
Unknown (blood smear)	16-Oct-13	45.099	-111.649	30.5	287	
Unknown (blood smear)	25-Oct-13	44.842	-111.52	10.2	287	
Unknown (blood smear)	28-Oct-13	45.169	-111.679	35.6	287	
Unknown (blood smear)	28-Oct-13	45.163	-111.679	35.2	287	
Unknown (blood smear)	21-Dec-13	44.77	-111.469	4.1	87	
Unknown (blood smear)	20-Jan-14	45.013	-111.648	24.5	287	

Species	Date	Lat	Long	Milepost	Highway	Total
Unknown (blood smear)	22-Jan-14	45.069	-111.646	28.4	287	
Unknown (blood smear)	12-Feb-14	44.979	-111.646	22	287	
Unknown (blood smear)	3-Mar-14	44.855	-111.391	5.9	287	
Unknown (blood smear)	7-Apr-14	45.306	-111.694	45.2	287	
Unknown (blood smear)	9-Apr-14	44.755	-111.467	3.1	87	
Total						**676**

*Elk–vehicle collision occurred but elk was reported live at last sighting. Damage was done to the vehicle, so it is likely that the elk sustained life-threatening injuries.

**The wolf was killed by a vehicle and found by an employee at the Sun Ranch who notified MT FWP. Joe Knarr, FWP Warden Sergeant, delivered it to the FWP Wildlife Health Laboratory in Bozeman where Tiffany Allen also worked. The exact location was also reported to us by Steve Primm and confirmed by Tiffany Allen.

***Rough-legged hawk found injured on road-side. Picked up and taken to the Montana Raptor Conservation Center where it died the following day.

[1] Reported by Bob Inman, wolverine ecologist with the Wildlife Conservation Society.

[2] Reported by Steve Primm, biologist with People and Predators, and Northern Rockies Conservation Cooperative NGOs.

[3] Reported by a MT Highway Patrol officer.

[4] Reported by Julie Cunningham, MT FWP wildlife biologist.

[5] Reported by Terry Quirk, Madison Valley resident.

[6] Reported by Ryan Gosse, MT FWP warden.

[7] Reported by Kevin Frey, MT FWP bear specialist, and Jim Smolczynski, MT FWP warden.

9.6 Appendix F: Species Recorded by Remote Cameras

Species and individuals recorded with remote cameras (crossing through culverts or under bridges in the study area) by camera location.

Structure (RP = mile post)	Minimum number of days camera operated	Species	Total
Stock culvert at RP3.5 MT 87	577	Badger	42
		Bird	12
		Coyote	3
		Fox	9
		Hare/rabbit	21
		Long-tailed weasel	1
		Medium mammal	2
		Raccoon	1
Stock culvert at RP 5.2 MT 87	453	Badger	12
		Bird	3
		Blue bird	1
		Coyote	2
		Domestic dog	1
		Flicker	2
		Hare/rabbit	28
		Human	6
		Medium mammal	2
		Raccoon	1
Stock culvert at RP 6.7 MT 87	584	Badger	4
		Coyote	1
		Domestic dog	1
		Hare/rabbit	22
		Human	2
		Long-tailed weasel	2
Beaver Creek Bridge at RP 7.3 US 287 (both cameras combined)	721 (east) 484 (west)	Beaver	1
		Deer sp.	28
		Domestic dog	5
		Fox	4
		Human	49

Structure (RP = mile post)	Minimum number of days camera operated	Species	Total
		Moose	23
		Mountain lion	1
		Mule deer	404
		Raccoon	1
		Red squirrel	3
		White-tailed deer	7
Grayling Creek Bridge at RP 20.0 US 287	656	Beaver	14
		Bird	2
		Boreal owl	2
		Canada goose	5
		Domestic dog	6
		Flicker	1
		Fox	1
		Grouse	1
		Human	68
		Mallard	4
		Medium mammal	7
		Moose	1
		Otter	2
		Raccoon	7
Indian Creek Bridge at RP 29.6 US 287	687	Cattle	10
		Deer sp.	2
		Elk	2
		Hare/rabbit	1
		Human	26
		Merganser	2
		Mule deer	98
		Raccoon	14
		Skunk	1
		White-tailed deer	2
Madison River Bridge at Ennis at RP 29.6 US 287	518	Deer sp.	4
		Domestic cat	11
		Domestic dog	23

Structure (RP = mile post)	Minimum number of days camera operated	Species	Total
		Hare/rabbit	2
		Human	482
		Mammal	2
		Medium mammal	3
		Mule deer	104
		Raccoon	6
		Skunk	1
		White-tailed deer	3
Underpass south of Madison River Bridge at Ennis at RPP 48.4 US 287 Note: the large numbers of deer are not necessarily passing under the highway, but appear to be resting in the shade every day.	700	Badger	1
		Cattle	20
		Deer sp.	77
		Domestic cat	11
		Domestic dog	1
		Fox	2
		Goose	5
		Great horned owl	1
		Hare/rabbit	57
		Heron	3
		Human	33
		Long-tailed weasel	2
		Mammal	1
		Medium mammal	1
		Mule deer	575
		Owl	1
		Porcupine	1
		Raccoon	16
		Ring-necked pheasant	2
		Skunk	1
		White-tailed deer	68
Madison River Bridge at RP 8.1 MT 87*	457	Badger**	1
		Bobcat	1
		Canada goose	81
		Cattle	1

Structure (RP = mile post)	Minimum number of days camera operated	Species	Total
		Domestic dog	310
		Fox	2
		Hare\rabbit	4
		Human	3,328
		Medium mammal	4
		Mule deer	54
		Raccoon	44
		Skunk	2
		Weasel	1
North Meadow Creek Bridge at RP 57.5 US 287	671	Bird	1
		Duck	12
		Heron	17
		Human	18
		Medium mammal	6
		Raccoon	17
		White-tailed deer	1
O'Dell Creek Bridge at RP 48.0 US 287	516	Bird	8
		Chipmunk	1
		Deer sp.	1
		Domestic cat	7
		Hare/rabbit	14
		Human	21
		Long-tailed weasel	1
		Mallard	2
		Medium mammal	7
		Mink	2
		Mule deer	2
		Muskrat	4
		Raccoon	27
		Skunk	11

*Due to large numbers, we collected only one year of data (26 September 2012 through 25 September 2013) at this site for humans and associated domestic dogs. The minimum number of days the camera operated during this one-year period is 292.

**A badger was observed passing underneath the bridge at the camera location by Lance Craighead as the camera was being installed.

9.7 Appendix G: Locations of Live Animals in the Vicinity of the Highway.

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
Badger	11 April – 30 June 2012 (Quarter 1)	0	0
		1-24	1
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	1
	01 July – 30 September 2012 (Quarter 2)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 October – 31 December 2012 (Quarter 3)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 January – 31 March 2013 (Quarter 4)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
		0	1
		1-24	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
	01 April – 30 June 2013 (Quarter 5)	25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	1
	01 July – 30 September 2013 (Quarter 6)	0	0
		1-24	1
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	1
	01 October – 31 December 2013 (Quarter 7)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
Black bear	11 April – 30 June 2012 (Quarter 1)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
	01 July – 30 September 2012 (Quarter 2)	0	1*
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	1
	01 October – 31 December 2012 (Quarter 3)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 January – 31 March 2013 (Quarter 4)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 April – 30 June 2013 (Quarter 5)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 July – 30 September 2013 (Quarter 6)	0	0
		1-24	1**
		25-49	0
		50-99	0
		100-499	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		≥500	0
		total	1
	01 October – 31 December 2013 (Quarter 7)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
Bighorn sheep	11 April – 30 June 2012 (Quarter 1)	0	194
		1-24	123
		25-49	50
		50-99	0
		100-499	92
		≥500	0
		total	459
	01 July – 30 September 2012 (Quarter 2)	0	4
		1-24	12
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	16
	01 October – 31 December 2012 (Quarter 3)	0	199
		1-24	18
		25-49	39

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		50-99	53
		100-499	0
		≥500	0
		total	309
	01 January – 31 March 2013 (Quarter 4)	0	669
		1-24	370
		25-49	486
		50-99	159
		100-499	263
		≥500	0
		total	1947
	01 April – 30 June 2013 (Quarter 5)	0	327
		1-24	134
		25-49	107
		50-99	111
		100-499	27
		≥500	0
		total	706
	01 July – 30 September 2013 (Quarter 6)	0	25
		1-24	15
		25-49	0
		50-99	0
		100-499	2
		≥500	0
		total	42
	01 October – 31 December 2013 (Quarter 7)	0	125
		1-24	72
		25-49	7
		50-99	150
		100-499	259
		≥500	0
		total	613
		0	1,008

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	1-24	334
		25-49	279
		50-99	102
		100-499	381
		≥500	0
		total	2,104
Bison	11 April – 30 June 2012 (Quarter 1)	0	29
		1-24	6
		25-49	46
		50-99	38
		100-499	53
		≥500	0
		total	172
	01 July – 30 September 2012 (Quarter 2)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 October – 31 December 2012 (Quarter 3)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 January – 31 March 2013 (Quarter 4)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		total	0
	01 April – 30 June 2013 (Quarter 5)	0	34
		1-24	65
		25-49	26
		50-99	17
		100-499	82
		≥500	0
		total	224
	01 July – 30 September 2013 (Quarter 6)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 October – 31 December 2013 (Quarter 7)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
Coyote	11 April – 30 June 2012 (Quarter 1)	0	1
		1-24	0
		25-49	0
		50-99	1

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		100-499	2
		≥500	0
		total	4
	01 July – 30 September 2012 (Quarter 2)	0	0
		1-24	1
		25-49	0
		50-99	3
		100-499	1
		≥500	0
		total	5
	01 October – 31 December 2012 (Quarter 3)	0	1
		1-24	0
		25-49	0
		50-99	4
		100-499	5
		≥500	0
		total	10
	01 January – 31 March 2013 (Quarter 4)	0	2
		1-24	0
		25-49	0
		50-99	0
		100-499	5
		≥500	2
		total	9
	01 April – 30 June 2013 (Quarter 5)	0	1
		1-24	0
		25-49	1
		50-99	1
		100-499	0
		≥500	0
		total	3
	01 July – 30 September	0	1
		1-24	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
	2013 (Quarter 6)	25-49	0
		50-99	1
		100-499	2
		≥500	0
		total	4
	01 October – 31 December 2013 (Quarter 7)	0	2
		1-24	1
		25-49	0
		50-99	0
		100-499	4
		≥500	0
		total	7
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	0
		1-24	1
		25-49	0
		50-99	0
		100-499	2
		≥500	1
		total	3
Duck***	11 April – 30 June 2012 (Quarter 1)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 July – 30 September 2012 (Quarter 2)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
	01 October – 31 December 2012 (Quarter 3)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 January – 31 March 2013 (Quarter 4)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 April – 30 June 2013 (Quarter 5)	0	9
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	9
	01 July – 30 September 2013 (Quarter 6)	0	8
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	8
	01 October – 31 December 2013 (Quarter 7)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		≥500	0
		total	0
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
Elk	11 April – 30 June 2012 (Quarter 1)	0	2
		1-24	12
		25-49	13
		50-99	0
		100-499	30
		≥500	717
		total	774
	01 July – 30 September 2012 (Quarter 2)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 October – 31 December 2012 (Quarter 3)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	100
		≥500	1,792
		total	1892
	01 January – 31 March 2013 (Quarter 4)	0	0
		1-24	0
		25-49	4

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		50-99	38
		100-499	6,949
		≥500	28,750
		total	35,741
	01 April – 30 June 2013 (Quarter 5)	0	1
		1-24	0
		25-49	8
		50-99	48
		100-499	3,776
		≥500	8,063
		total	11,896
	01 July – 30 September 2013 (Quarter 6)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 October – 31 December 2013 (Quarter 7)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	1,748
		≥500	10,671
		total	12,419
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	35
		1-24	13
		25-49	0
		50-99	755
		100-499	12,564
		≥500	68,777
		total	82,144
Hare		0	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
	11 April – 30 June 2012 (Quarter 1)	1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 July – 30 September 2012 (Quarter 2)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 October – 31 December 2012 (Quarter 3)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 January – 31 March 2013 (Quarter 4)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 April – 30 June 2013 (Quarter 5)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		total	0
	01 July – 30 September 2013 (Quarter 6)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 October – 31 December 2013 (Quarter 7)	0	1
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	1
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
Marmot	11 April – 30 June 2012 (Quarter 1)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 July – 30 September 2012 (Quarter 2)	0	0
		1-24	1
		25-49	0
		50-99	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		100-499	0
		≥500	0
		total	1
	01 October – 31 December 2012 (Quarter 3)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 January – 31 March 2013 (Quarter 4)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 April – 30 June 2013 (Quarter 5)	0	0
		1-24	1
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	1
	01 July – 30 September 2013 (Quarter 6)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
		0	0
		1-24	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
	01 October – 31 December 2013 (Quarter 7)	25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
Moose	11 April – 30 June 2012 (Quarter 1)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 July – 30 September 2012 (Quarter 2)	0	0
		1-24	0
		25-49	2
		50-99	0
		100-499	0
		≥500	0
		total	2
	01 October – 31 December 2012 (Quarter 3)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
	01 January – 31 March 2013 (Quarter 4)	0	1
		1-24	0
		25-49	0
		50-99	1
		100-499	0
		≥500	0
		total	2
	01 April – 30 June 2013 (Quarter 5)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	2
		≥500	0
		total	2
	01 July – 30 September 2013 (Quarter 6)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 October – 31 December 2013 (Quarter 7)	0	1
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	1
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		≥500	0
		total	0
Mountain goat	11 April – 30 June 2012 (Quarter 1)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	12
		total	12
	01 July – 30 September 2012 (Quarter 2)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	1
		total	1
	01 October – 31 December 2012 (Quarter 3)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	5
		total	5
	01 January – 31 March 2013 (Quarter 4)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 April – 30 June 2013 (Quarter 5)	0	0
		1-24	0
		25-49	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		50-99	0
		100-499	0
		≥500	4
		total	4
	01 July – 30 September 2013 (Quarter 6)	0	0
		1-24	0
		25-49	8
		50-99	0
		100-499	0
		≥500	0
		total	8
	01 October – 31 December 2013 (Quarter 7)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	1
		total	1
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
Mule deer	11 April – 30 June 2012 (Quarter 1)	0	0
		1-24	3
		25-49	3
		50-99	3
		100-499	1
		≥500	0
		total	10
		0	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
	01 July – 30 September 2012 (Quarter 2)	1-24	0
		25-49	7
		50-99	6
		100-499	0
		≥500	0
		total	13
	01 October – 31 December 2012 (Quarter 3)	0	0
		1-24	4
		25-49	0
		50-99	15
		100-499	2
		≥500	0
		total	21
	01 January – 31 March 2013 (Quarter 4)	0	0
		1-24	25
		25-49	76
		50-99	93
		100-499	55
		≥500	0
		total	249
	01 April – 30 June 2013 (Quarter 5)	0	10
		1-24	35
		25-49	0
		50-99	61
		100-499	302
		≥500	0
		total	408
	01 July – 30 September 2013 (Quarter 6)	0	1
		1-24	0
		25-49	0
		50-99	1
		100-499	6
		≥500	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		total	8
	01 October – 31 December 2013 (Quarter 7)	0	6
		1-24	1
		25-49	0
		50-99	0
		100-499	36
		≥500	1
		total	44
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	0
		1-24	16
		25-49	83
		50-99	47
		100-499	316
		≥500	0
		total	462
Pronghorn	11 April – 30 June 2012 (Quarter 1)	0	9
		1-24	109
		25-49	196
		50-99	387
		100-499	748
		≥500	114
		total	1,563
	01 July – 30 September 2012 (Quarter 2)	0	3
		1-24	47
		25-49	232
		50-99	933
		100-499	1,065
		≥500	66
		total	2,346
	01 October – 31 December 2012 (Quarter 3)	0	16
		1-24	155
		25-49	1,027
		50-99	805

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		100-499	1,315
		≥500	649
		total	3,967
	01 January – 31 March 2013 (Quarter 4)	0	0
		1-24	20
		25-49	479
		50-99	891
		100-499	1,067
		≥500	273
		total	2,730
	01 April – 30 June 2013 (Quarter 5)	0	13
		1-24	98
		25-49	241
		50-99	980
		100-499	1,248
		≥500	20
		total	2,600
	01 July – 30 September 2013 (Quarter 6)	0	0
		1-24	31
		25-49	202
		50-99	736
		100-499	1,253
		≥500	299
		total	2,521
	01 October – 31 December 2013 (Quarter 7)	0	0
		1-24	305
		25-49	604
		50-99	691
		100-499	4,626
		≥500	1,224
		total	7,450
	01 January – 09 April 2014	0	0
		1-24	275

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
	(Quarter 8, plus 9 days of April)	25-49	516
		50-99	1,172
		100-499	2,134
		≥500	1,090
		total	5,187
Red fox	11 April – 30 June 2012 (Quarter 1)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 July – 30 September 2012 (Quarter 2)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 October – 31 December 2012 (Quarter 3)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 January – 31 March 2013 (Quarter 4)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
	01 April – 30 June 2013 (Quarter 5)	0	2
		1-24	0
		25-49	0
		50-99	9
		100-499	1
		≥500	0
		total	12
	01 July – 30 September 2013 (Quarter 6)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 October – 31 December 2013 (Quarter 7)	0	1
		1-24	0
		25-49	0
		50-99	0
		100-499	1
		≥500	0
		total	2
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	0
		1-24	0
		25-49	1
		50-99	0
		100-499	0
		≥500	0
		total	1
White-tailed deer	11 April – 30 June 2012 (Quarter 1)	0	7
		1-24	1
		25-49	21
		50-99	27
		100-499	54

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		≥500	1
		total	111
	01 July – 30 September 2012 (Quarter 2)	0	1
		1-24	2
		25-49	4
		50-99	5
		100-499	0
		≥500	0
		total	12
	01 October – 31 December 2012 (Quarter 3)	0	6
		1-24	9
		25-49	47
		50-99	43
		100-499	277
		≥500	33
		total	415
	01 January – 31 March 2013 (Quarter 4)	0	2
		1-24	0
		25-49	32
		50-99	121
		100-499	459
		≥500	10
		total	624
	01 April – 30 June 2013 (Quarter 5)	0	0
		1-24	2
		25-49	5
		50-99	27
		100-499	127
		≥500	6
		total	167
	01 July – 30 September 2013 (Quarter 6)	0	1
		1-24	1
		25-49	17

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		50-99	10
		100-499	12
		≥500	0
		total	41
	01 October – 31 December 2013 (Quarter 7)	0	4
		1-24	26
		25-49	25
		50-99	75
		100-499	430
		≥500	84
		total	644
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	4
		1-24	84
		25-49	6
		50-99	114
		100-499	775
		≥500	216
		total	1,199
Wolf	11 April – 30 June 2012 (Quarter 1)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 July – 30 September 2012 (Quarter 2)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
		0	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
	01 October – 31 December 2012 (Quarter 3)	1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 January – 31 March 2013 (Quarter 4)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	3
		≥500	7
		total	10
	01 April – 30 June 2013 (Quarter 5)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 July – 30 September 2013 (Quarter 6)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0
	01 October – 31 December 2013 (Quarter 7)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0

Species	Dates (Quarter)	Estimated distance from highway (yards)	Count estimate
		total	0
	01 January – 09 April 2014 (Quarter 8, plus 9 days of April)	0	0
		1-24	0
		25-49	0
		50-99	0
		100-499	0
		≥500	0
		total	0

9.8 Appendix H: Snow Track Crossing Location Data

Species	Number of Crossings	Date	Lat	Long	Milepost	Highway
Bighorn sheep	200	18-Jan-13	44.855	-111.395	5.7	287
	200	18-Jan-13	44.83	-111.476	0.5	287
	20	30-Dec-13	44.826	-111.445	2.2	287
	3	30-Dec-13	44.856	-111.388	6.1	287
	50	8-Jan-14	44.828	-111.464	1.3	287
	1	8-Jan-14	44.837	-111.42	3.9	287
	10	4-Feb-14	44.826	-111.448	2.1	287
	5	4-Feb-14	44.831	-111.425	3.3	287
Elk	1	18-Jun-12	44.855	-111.395	5.7	287
	6	9-Jan-13	44.83	-111.478	0.5	287
	4	18-Jan-13	44.857	-111.544	11.8	287
	20	24-Nov-13	44.737	-111.469	1.8	87
	1	24-Nov-13	44.743	-111.469	2.2	87
	1	24-Nov-13	44.744	-111.469	2.3	87
	20	24-Nov-13	44.75	-111.468	2.7	87
	10	24-Nov-13	44.753	-111.467	2.9	87
	100	24-Nov-13	44.757	-111.467	3.2	87
	20	24-Nov-13	44.77	-111.469	4.1	87
	1	24-Nov-13	44.776	-111.47	4.5	87
	50	24-Nov-13	44.802	-111.477	6.4	87
	5	24-Nov-13	44.811	-111.48	7	87
	8	24-Nov-13	44.813	-111.48	7.2	87
	20	24-Nov-13	44.821	-111.482	7.7	87
	50	6-Dec-13	44.997	-111.648	23.3	287
	200	6-Dec-13	44.991	-111.648	22.8	287
	3	6-Dec-13	45.53	-111.699	63.6	287
	1	6-Dec-13	45.518	-111.688	62.5	287
	1	6-Dec-13	45.495	-111.697	60.7	287
	8	6-Dec-13	45.056	-111.647	27.5	287
	2	6-Dec-13	45.056	-111.647	27.5	287
	6	6-Dec-13	45.054	-111.647	27.4	287
	2	6-Dec-13	45.054	-111.647	27.4	287

Species	Number of Crossings	Date	Lat	Long	Milepost	Highway
	10	6-Dec-13	45.02	-111.648	25	287
	10	6-Dec-13	45.02	-111.648	25	287
	20	6-Dec-13	45.02	-111.648	25	287
	10	6-Dec-13	45.02	-111.648	25	287
	30	6-Dec-13	45.019	-111.648	25	287
	50	6-Dec-13	45.018	-111.648	24.9	287
	50	6-Dec-13	45.018	-111.648	24.9	287
	40	6-Dec-13	45.017	-111.648	24.8	287
	50	6-Dec-13	45.016	-111.648	24.7	287
	30	6-Dec-13	45.015	-111.648	24.7	287
	20	6-Dec-13	45.014	-111.648	24.6	287
	40	6-Dec-13	45.013	-111.648	24.5	287
	150	6-Dec-13	44.997	-111.648	23.3	287
	20	6-Dec-13	44.996	-111.648	23.2	287
	150	6-Dec-13	44.991	-111.648	22.8	287
	2	6-Dec-13	44.96	-111.626	20.3	287
	2	6-Dec-13	44.959	-111.625	20.2	287
	6	6-Dec-13	44.929	-111.605	17.8	287
	6	6-Dec-13	44.902	-111.592	15.8	287
	10	27-Dec-13	44.889	-111.578	14.7	287
	6	27-Dec-13	44.864	-111.551	12.4	287
	4	27-Dec-13	44.861	-111.546	12.1	287
	4	27-Dec-13	44.86	-111.545	12	287
	30	27-Dec-13	44.837	-111.506	9.5	287
	20	27-Dec-13	44.801	-111.477	6.3	87
	10	30-Dec-13	44.997	-111.648	23.3	287
	100	1-Jan-14	45.034	-111.648	26	287
	100	1-Jan-14	45.023	-111.648	25.2	287
	10	6-Jan-14	44.804	-111.478	6.5	87
	15	15-Jan-14	44.93	-111.604	17.9	287
	6	4-Feb-14	44.804	-111.172	19.2	287
	10	10-Feb-14	45.085	-111.647	29.5	287
	50	10-Feb-14	45.084	-111.647	29.5	287

Species	Number of Crossings	Date	Lat	Long	Milepost	Highway
	300	10-Feb-14	45.079	-111.647	29.1	287
	100	10-Feb-14	45.074	-111.646	28.8	287
	18	10-Feb-14	45.066	-111.646	28.2	287
	100	4-Mar-14	45.046	-111.648	26.8	287
	20	4-Mar-14	45.016	-111.648	24.7	287
	30	4-Mar-14	45.015	-111.648	24.7	287
	50	4-Mar-14	44.987	-111.648	22.6	287
	20	4-Mar-14	44.982	-111.648	22.2	287
	20	4-Mar-14	44.973	-111.644	21.6	287
	30	4-Mar-14	44.973	-111.644	21.6	287
Moose	2	18-Jan-13	44.869	-111.354	8	287
	8	27-Dec-13	44.869	-111.356	7.9	287
	1	27-Dec-13	44.794	-111.148	20.6	287
	2	30-Dec-13	44.849	-111.409	4.9	287
	3	30-Dec-13	44.856	-111.386	6.1	287
	3	30-Dec-13	44.858	-111.384	6.3	287
	2	30-Dec-13	44.851	-111.318	10.5	287
	2	6-Jan-14	44.795	-111.15	20.4	287
	1	6-Jan-14	44.794	-111.147	20.6	287
	2	8-Jan-14	44.86	-111.38	6.6	287
	2	8-Jan-14	44.869	-111.356	7.9	287
	1	8-Jan-14	44.87	-111.34	8.8	287
	2	8-Jan-14	44.862	-111.369	7.1	287
	1	8-Jan-14	44.86	-111.38	6.6	287
	1	4-Feb-14	44.871	-111.35	8.3	287
	1	4-Feb-14	44.871	-111.348	8.4	287
Deer spp.	1	11-Apr-12	45.347	-111.722	48.5	287
	1	11-Apr-12	44.927	-111.603	17.7	287
	2	9-Jan-13	44.813	-111.48	7.2	87
	1	9-Jan-13	44.819	-111.482	7.6	87
	4	9-Jan-13	44.82	-111.482	7.7	87
	5	18-Jan-13	44.832	-111.276	13	287
	1	18-Jan-13	44.848	-111.312	10.9	287

Species	Number of Crossings	Date	Lat	Long	Milepost	Highway
	1	18-Jan-13	44.853	-111.538	11.4	287
	1	18-Jan-13	44.855	-111.543	11.7	287
	6	18-Jan-13	44.862	-111.546	12.2	287
	12	18-Jan-13	44.869	-111.561	13.1	287
	8	18-Jan-13	44.898	-111.586	15.4	287
	2	24-Nov-13	44.722	-111.471	0.8	87
	3	24-Nov-13	44.725	-111.471	1	87
	1	24-Nov-13	44.727	-111.471	1.1	87
	1	24-Nov-13	44.733	-111.47	1.5	87
	1	24-Nov-13	44.734	-111.47	1.6	87
	1	24-Nov-13	44.736	-111.469	1.7	87
	2	24-Nov-13	44.739	-111.469	2	87
	2	24-Nov-13	44.74	-111.469	2	87
	1	24-Nov-13	44.744	-111.469	2.3	87
	3	24-Nov-13	44.745	-111.468	2.4	87
	10	24-Nov-13	44.75	-111.468	2.7	87
	10	24-Nov-13	44.751	-111.468	2.8	87
	2	24-Nov-13	44.76	-111.467	3.4	87
	3	24-Nov-13	44.775	-111.47	4.5	87
	2	24-Nov-13	44.776	-111.47	4.5	87
	10	24-Nov-13	44.798	-111.476	6.1	87
	100	24-Nov-13	44.8	-111.477	6.2	87
	5	24-Nov-13	44.823	-111.483	7.9	87
	6	6-Dec-13	45.547	-111.697	64.8	287
	8	6-Dec-13	45.546	-111.697	64.7	287
	12	6-Dec-13	45.545	-111.698	64.6	287
	4	6-Dec-13	45.543	-111.698	64.5	287
	4	6-Dec-13	45.543	-111.698	64.5	287
	2	6-Dec-13	45.542	-111.698	64.4	287
	12	6-Dec-13	45.542	-111.699	64.4	287
	4	6-Dec-13	45.54	-111.699	64.3	287
	6	6-Dec-13	45.539	-111.7	64.2	287
	4	6-Dec-13	45.526	-111.698	63.3	287

Species	Number of Crossings	Date	Lat	Long	Milepost	Highway
	1	6-Dec-13	45.526	-111.698	63.3	287
	40	6-Dec-13	45.522	-111.694	62.9	287
	6	6-Dec-13	45.521	-111.691	62.8	287
	1	6-Dec-13	45.52	-111.69	62.7	287
	3	6-Dec-13	45.499	-111.697	61	287
	2	6-Dec-13	45.43	-111.731	55.7	287
	6	6-Dec-13	45.392	-111.731	53.1	287
	40	6-Dec-13	45.34	-111.711	47.8	287
	2	6-Dec-13	45.306	-111.694	45.2	287
	2	6-Dec-13	45.305	-111.694	45.1	287
	4	6-Dec-13	45.301	-111.692	44.8	287
	2	6-Dec-13	45.301	-111.692	44.8	287
	3	6-Dec-13	45.298	-111.691	44.6	287
	1	6-Dec-13	45.294	-111.688	44.3	287
	2	6-Dec-13	45.288	-111.684	43.8	287
	2	6-Dec-13	45.288	-111.684	43.8	287
	10	6-Dec-13	45.275	-111.679	42.9	287
	20	6-Dec-13	45.274	-111.679	42.8	287
	2	6-Dec-13	45.273	-111.679	42.8	287
	10	6-Dec-13	45.272	-111.679	42.7	287
	4	6-Dec-13	45.27	-111.679	42.6	287
	2	6-Dec-13	45.27	-111.679	42.6	287
	3	6-Dec-13	45.261	-111.679	41.9	287
	2	6-Dec-13	45.191	-111.679	37.1	287
	20	6-Dec-13	45.043	-111.648	26.6	287
	8	6-Dec-13	45.041	-111.648	26.5	287
	2	6-Dec-13	45.04	-111.648	26.4	287
	2	6-Dec-13	45.038	-111.648	26.3	287
	6	6-Dec-13	45.022	-111.648	25.2	287
	6	6-Dec-13	44.914	-111.602	16.8	287
	6	6-Dec-13	44.902	-111.592	15.8	287
	1	6-Dec-13	44.894	-111.583	15.1	287
	20	6-Dec-13	44.848	-111.53	10.9	287

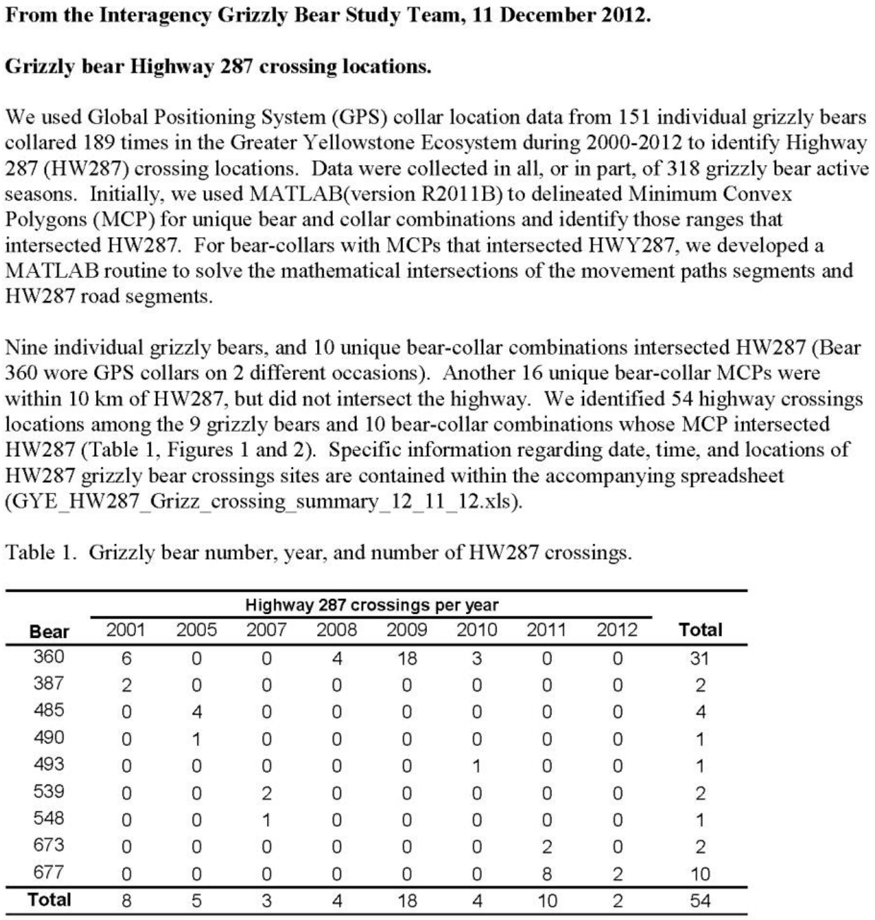
Species	Number of Crossings	Date	Lat	Long	Milepost	Highway
	4	27-Dec-13	44.901	-111.591	15.7	287
	8	27-Dec-13	44.9	-111.589	15.6	287
	4	27-Dec-13	44.899	-111.587	15.5	287
	10	27-Dec-13	44.895	-111.584	15.2	287
	5	27-Dec-13	44.894	-111.583	15.1	287
	10	27-Dec-13	44.893	-111.582	15	287
	10	27-Dec-13	44.891	-111.58	14.9	287
	10	27-Dec-13	44.884	-111.573	14.3	287
	10	27-Dec-13	44.869	-111.562	13.1	287
	4	27-Dec-13	44.857	-111.544	11.8	287
	6	27-Dec-13	44.853	-111.539	11.4	287
	10	27-Dec-13	44.851	-111.536	11.2	287
	10	27-Dec-13	44.848	-111.53	10.9	287
	10	27-Dec-13	44.844	-111.523	10.4	287
	20	27-Dec-13	44.787	-111.473	5.3	87
	6	27-Dec-13	44.86	-111.379	6.6	287
	6	27-Dec-13	44.847	-111.31	11	287
	6	1-Jan-14	44.845	-111.307	11.2	287
	4	6-Jan-14	44.815	-111.481	7.3	87
	10	6-Jan-14	44.806	-111.243	15.5	287
	2	6-Jan-14	44.862	-111.546	12.2	287
	1	8-Jan-14	44.804	-111.226	16.5	287
	1	8-Jan-14	44.836	-111.289	12.3	287
	3	8-Jan-14	44.85	-111.315	10.7	287
	2	8-Jan-14	44.856	-111.324	10.1	287
	2	8-Jan-14	44.869	-111.354	8	287
	2	10-Jan-14	44.898	-111.586	15.4	287
	3	4-Feb-14	45.522	-111.694	62.9	287
	15	4-Feb-14	45.34	-111.712	47.8	287
	9	4-Feb-14	45.34	-111.711	47.8	287
	6	4-Feb-14	45.201	-111.679	37.8	287
	6	4-Feb-14	45.196	-111.679	37.5	287
	2	10-Feb-14	45.528	-111.699	63.4	287

Species	Number of Crossings	Date	Lat	Long	Milepost	Highway
	50	10-Feb-14	45.341	-111.712	47.9	287
	30	10-Feb-14	44.936	-111.607	18.3	287
	10	4-Mar-14	44.973	-111.644	21.6	287
	10	4-Mar-14	44.973	-111.644	21.6	287
	30	4-Mar-14	44.968	-111.641	21.2	287
Deer/Pronghorn	8	6-Dec-13	45.424	-111.731	55.2	287
	3	6-Dec-13	45.26	-111.679	41.9	287
	4	6-Dec-13	45.26	-111.679	41.9	287
	8	6-Dec-13	45.253	-111.679	41.4	287
	4	6-Dec-13	45.249	-111.679	41.1	287
	6	6-Dec-13	45.248	-111.679	41	287
	8	6-Dec-13	45.248	-111.679	41	287
	4	6-Dec-13	45.248	-111.679	41	287
	4	6-Dec-13	45.247	-111.679	41	287
	1	6-Dec-13	45.244	-111.679	40.8	287
	3	6-Dec-13	45.235	-111.679	40.2	287
	4	6-Dec-13	45.189	-111.679	37	287
	2	6-Dec-13	45.181	-111.679	36.4	287
	2	6-Dec-13	45.168	-111.679	35.5	287
	6	6-Dec-13	45.16	-111.679	35	287
	4	6-Dec-13	45.16	-111.679	35	287
	6	6-Dec-13	45.154	-111.679	34.6	287
	16	6-Dec-13	45.145	-111.678	34	287
	6	6-Dec-13	45.141	-111.676	33.7	287
	1	6-Dec-13	45.134	-111.671	33.2	287
	1	6-Dec-13	45.104	-111.651	30.9	287
	6	6-Dec-13	45.096	-111.649	30.3	287
	2	6-Dec-13	45.091	-111.648	29.9	287
	10	6-Dec-13	45.077	-111.646	29	287
	10	6-Dec-13	45.077	-111.647	29	287
	6	6-Dec-13	45.075	-111.646	28.8	287
	6	6-Dec-13	45.065	-111.646	28.1	287
	20	6-Dec-13	45.064	-111.646	28.1	287

Species	Number of Crossings	Date	Lat	Long	Milepost	Highway
	6	6-Dec-13	45.064	-111.646	28.1	287
	2	6-Dec-13	45.063	-111.647	28	287
	2	6-Dec-13	45.061	-111.647	27.9	287
	2	6-Dec-13	45.058	-111.647	27.7	287
	2	6-Dec-13	45.045	-111.648	26.8	287
	8	6-Dec-13	45.043	-111.648	26.6	287
	20	4-Feb-14	45.247	-111.679	41	287
	1	4-Feb-14	45.238	-111.679	40.4	287
	10	4-Feb-14	45.233	-111.679	40	287
	4	4-Feb-14	45.182	-111.679	36.5	287
Ungulate	15	8-Jan-14	44.809	-111.25	15.1	287
Badger	1	27-Dec-13	44.803	-111.478	6.5	87
Coyote	1	24-Nov-13	44.742	-111.469	2.2	87
	1	24-Nov-13	44.766	-111.468	3.8	87
	1	24-Nov-13	44.766	-111.468	3.8	87
	2	6-Dec-13	45.335	-111.701	47.2	287
	1	6-Dec-13	45.259	-111.679	41.8	287
	2	6-Dec-13	45.201	-111.679	37.8	287
	2	6-Dec-13	45.199	-111.679	37.7	287
	3	6-Dec-13	45.16	-111.679	35	287
	2	6-Dec-13	45.152	-111.679	34.5	287
	1	6-Dec-13	45.113	-111.657	31.6	287
	1	27-Dec-13	44.846	-111.527	10.7	287
	2	27-Dec-13	44.817	-111.482	7.5	87
	1	27-Dec-13	44.786	-111.473	5.2	87
Large carnivore	1	6-Dec-13	44.958	-111.623	20.1	287
	1	6-Dec-13	44.957	-111.622	20	287
Marten	1	27-Dec-13	44.86	-111.545	12	287
Hare	20	27-Dec-13	44.848	-111.53	10.9	287
	10	27-Dec-13	44.844	-111.523	10.4	287
	20	27-Dec-13	44.817	-111.482	7.5	87
	20	27-Dec-13	44.787	-111.473	5.3	87
	30	27-Dec-13	44.786	-111.473	5.2	87

Species	Number of Crossings	Date	Lat	Long	Milepost	Highway
	2	8-Jan-14	44.832	-111.277	13	287
	1	4-Feb-14	44.869	-111.354	8	287
Rabbit	10	24-Nov-13	44.786	-111.473	5.2	87
	5	6-Dec-13	45.392	-111.731	53.1	287
	8	6-Dec-13	45.246	-111.679	40.9	287

9.9 Appendix I: Grizzly Bear US 287 Crossings and Location Summary



From the Interagency Grizzly Bear Study Team, 11 December 2012.

Grizzly bear Highway 287 crossing locations.

We used Global Positioning System (GPS) collar location data from 151 individual grizzly bears collared 189 times in the Greater Yellowstone Ecosystem during 2000-2012 to identify Highway 287 (HW287) crossing locations. Data were collected in all, or in part, of 318 grizzly bear active seasons. Initially, we used MATLAB(version R2011B) to delineated Minimum Convex Polygons (MCP) for unique bear and collar combinations and identify those ranges that intersected HW287. For bear-collars with MCPs that intersected HWY287, we developed a MATLAB routine to solve the mathematical intersections of the movement paths segments and HW287 road segments.

Nine individual grizzly bears, and 10 unique bear-collar combinations intersected HW287 (Bear 360 wore GPS collars on 2 different occasions). Another 16 unique bear-collar MCPs were within 10 km of HW287, but did not intersect the highway. We identified 54 highway crossings locations among the 9 grizzly bears and 10 bear-collar combinations whose MCP intersected HW287 (Table 1, Figures 1 and 2). Specific information regarding date, time, and locations of HW287 grizzly bear crossings sites are contained within the accompanying spreadsheet (GYE_HW287_Grizz_crossing_summary_12_11_12.xls).

Table 1. Grizzly bear number, year, and number of HW287 crossings.

	Highway 287 crossings per year								
Bear	2001	2005	2007	2008	2009	2010	2011	2012	**Total**
360	6	0	0	4	18	3	0	0	31
387	2	0	0	0	0	0	0	0	2
485	0	4	0	0	0	0	0	0	4
490	0	1	0	0	0	0	0	0	1
493	0	0	0	0	0	1	0	0	1
539	0	0	2	0	0	0	0	0	2
548	0	0	1	0	0	0	0	0	1
673	0	0	0	0	0	0	2	0	2
677	0	0	0	0	0	0	8	2	10
Total	8	5	3	4	18	4	10	2	54

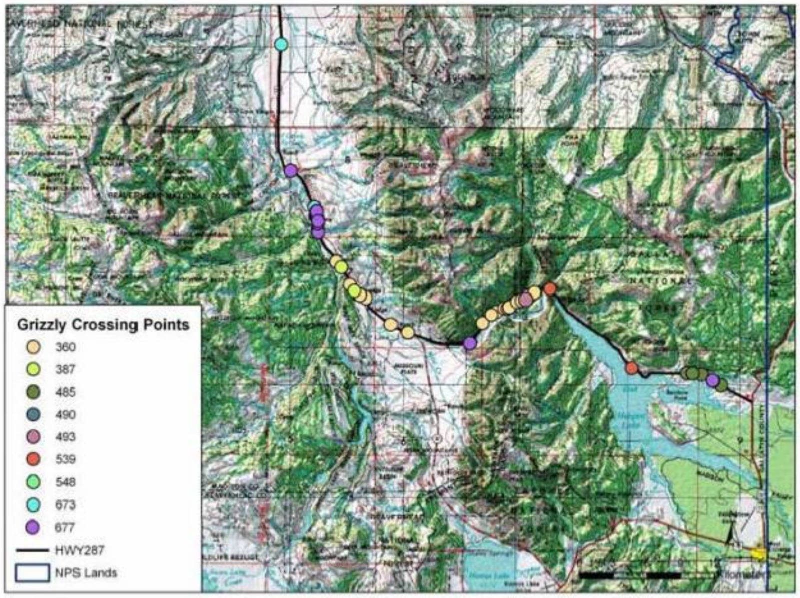


Figure 1. Locations of Highway 287 grizzly bear crossing sites for 9 individual grizzly bears identified from GPS collar locations during 2000-2012.

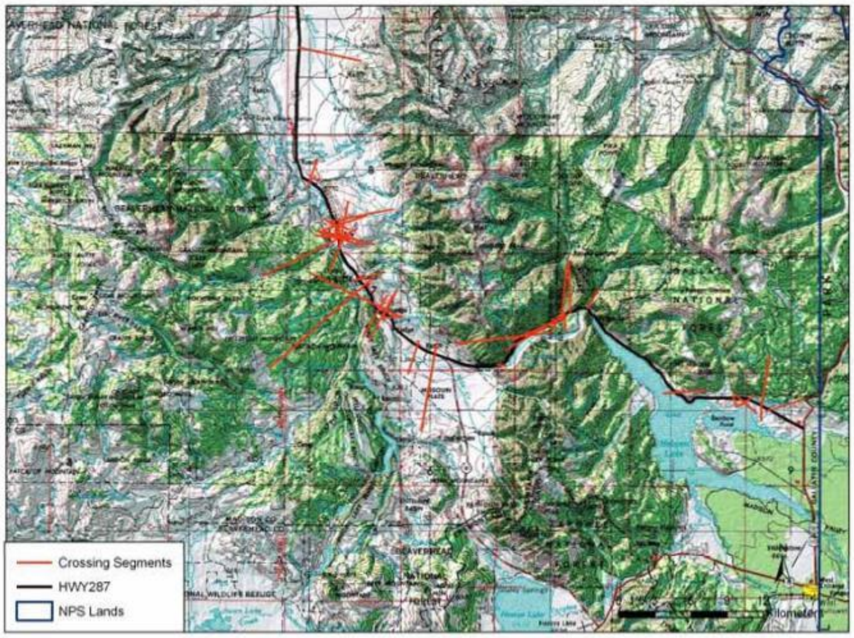
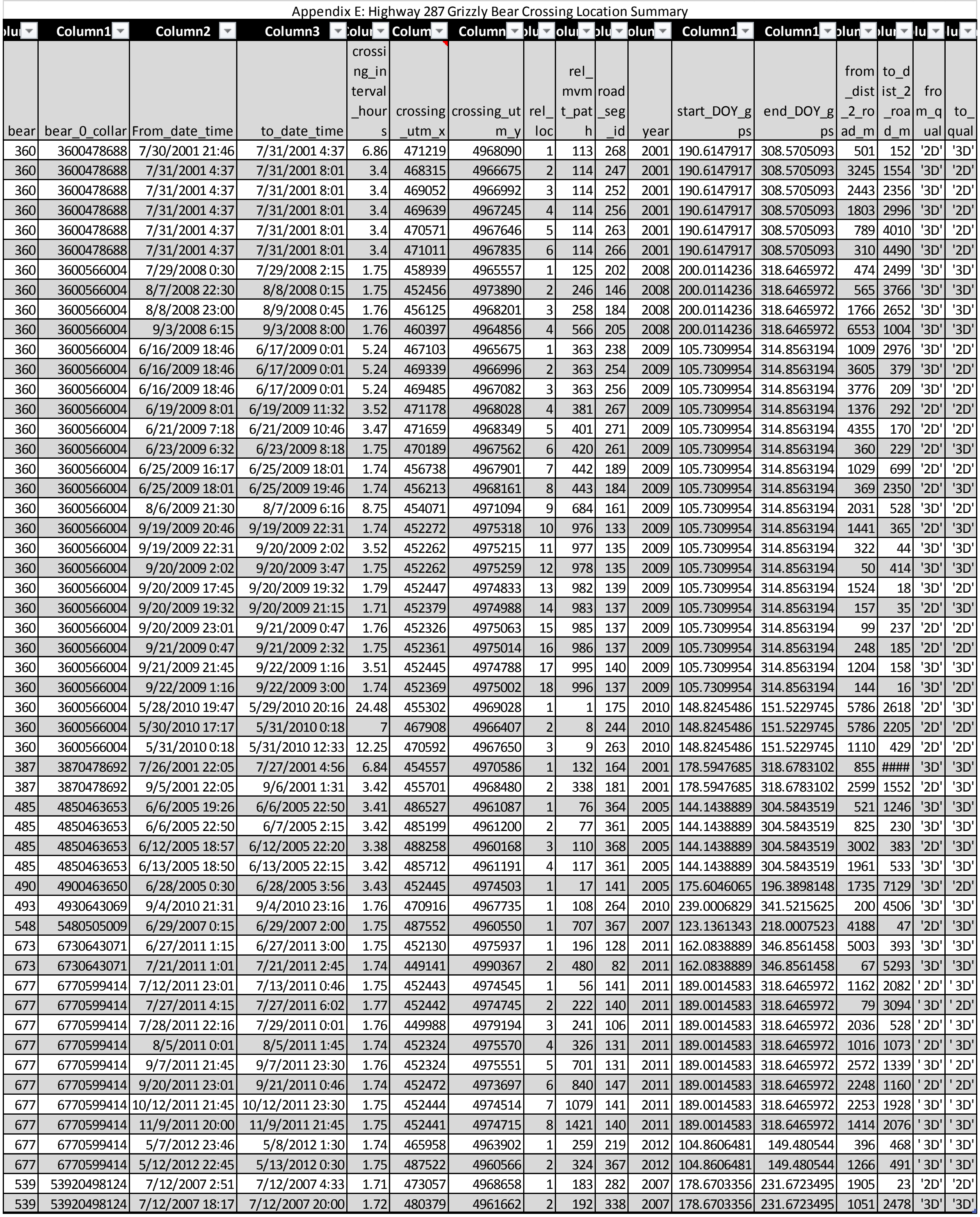


Figure 2. Locations of Highway 287 grizzly bear crossing paths for 9 individual grizzly bears identified from GPS collar locations during 2000-2012.

From the Interagency Grizzly Bear Study Team, 2011.



Appendix E: Highway 287 Grizzly Bear Crossing Location Summary

olu	Column1	Column2	Column3	olur	Colum	Column	olu	olur	olu	olun	Column1	Column1	olun	olur	lu	lu
bear	bear_0_collar	From_date_time	to_date_time	crossing_interval_hours	crossing_utm_x	crossing_utm_y	rel_loc	rel_mvmt_path	road_seg_id	year	start_DOY_gps	end_DOY_gps	from_dist_2_road_m	to_dist_2_road_m	from_qual	to_qual
360	3600478688	7/30/2001 21:46	7/31/2001 4:37	6.86	471219	4968090	1	113	268	2001	190.6147917	308.5705093	501	152	'2D'	'3D'
360	3600478688	7/31/2001 4:37	7/31/2001 8:01	3.4	468315	4966675	2	114	247	2001	190.6147917	308.5705093	3245	1554	'3D'	'2D'
360	3600478688	7/31/2001 4:37	7/31/2001 8:01	3.4	469052	4966992	3	114	252	2001	190.6147917	308.5705093	2443	2356	'3D'	'2D'
360	3600478688	7/31/2001 4:37	7/31/2001 8:01	3.4	469639	4967245	4	114	256	2001	190.6147917	308.5705093	1803	2996	'3D'	'2D'
360	3600478688	7/31/2001 4:37	7/31/2001 8:01	3.4	470571	4967646	5	114	263	2001	190.6147917	308.5705093	789	4010	'3D'	'2D'
360	3600478688	7/31/2001 4:37	7/31/2001 8:01	3.4	471011	4967835	6	114	266	2001	190.6147917	308.5705093	310	4490	'3D'	'2D'
360	3600566004	7/29/2008 0:30	7/29/2008 2:15	1.75	458939	4965557	1	125	202	2008	200.0114236	318.6465972	474	2499	'3D'	'3D'
360	3600566004	8/7/2008 22:30	8/8/2008 0:15	1.75	452456	4973890	2	246	146	2008	200.0114236	318.6465972	565	3766	'3D'	'3D'
360	3600566004	8/8/2008 23:00	8/9/2008 0:45	1.76	456125	4968201	3	258	184	2008	200.0114236	318.6465972	1766	2652	'3D'	'3D'
360	3600566004	9/3/2008 6:15	9/3/2008 8:00	1.76	460397	4964856	4	566	205	2008	200.0114236	318.6465972	6553	1004	'3D'	'3D'
360	3600566004	6/16/2009 18:46	6/17/2009 0:01	5.24	467103	4965675	1	363	238	2009	105.7309954	314.8563194	1009	2976	'3D'	'2D'
360	3600566004	6/16/2009 18:46	6/17/2009 0:01	5.24	469339	4966996	2	363	254	2009	105.7309954	314.8563194	3605	379	'3D'	'2D'
360	3600566004	6/16/2009 18:46	6/17/2009 0:01	5.24	469485	4967082	3	363	256	2009	105.7309954	314.8563194	3776	209	'3D'	'2D'
360	3600566004	6/19/2009 8:01	6/19/2009 11:32	3.52	471178	4968028	4	381	267	2009	105.7309954	314.8563194	1376	292	'2D'	'2D'
360	3600566004	6/21/2009 7:18	6/21/2009 10:46	3.47	471659	4968349	5	401	271	2009	105.7309954	314.8563194	4355	170	'2D'	'2D'
360	3600566004	6/23/2009 6:32	6/23/2009 8:18	1.75	470189	4967562	6	420	261	2009	105.7309954	314.8563194	360	229	'2D'	'3D'
360	3600566004	6/25/2009 16:17	6/25/2009 18:01	1.74	456738	4967901	7	442	189	2009	105.7309954	314.8563194	1029	699	'2D'	'2D'
360	3600566004	6/25/2009 18:01	6/25/2009 19:46	1.74	456213	4968161	8	443	184	2009	105.7309954	314.8563194	369	2350	'2D'	'3D'
360	3600566004	8/6/2009 21:30	8/7/2009 6:16	8.75	454071	4971094	9	684	161	2009	105.7309954	314.8563194	2031	528	'3D'	'2D'
360	3600566004	9/19/2009 20:46	9/19/2009 22:31	1.74	452272	4975318	10	976	133	2009	105.7309954	314.8563194	1441	365	'2D'	'3D'
360	3600566004	9/19/2009 22:31	9/20/2009 2:02	3.52	452262	4975215	11	977	135	2009	105.7309954	314.8563194	322	44	'3D'	'3D'
360	3600566004	9/20/2009 2:02	9/20/2009 3:47	1.75	452262	4975259	12	978	135	2009	105.7309954	314.8563194	50	414	'3D'	'3D'
360	3600566004	9/20/2009 17:45	9/20/2009 19:32	1.79	452447	4974833	13	982	139	2009	105.7309954	314.8563194	1524	18	'3D'	'2D'
360	3600566004	9/20/2009 19:32	9/20/2009 21:15	1.71	452379	4974988	14	983	137	2009	105.7309954	314.8563194	157	35	'2D'	'3D'
360	3600566004	9/20/2009 23:01	9/21/2009 0:47	1.76	452326	4975063	15	985	137	2009	105.7309954	314.8563194	99	237	'2D'	'2D'
360	3600566004	9/21/2009 0:47	9/21/2009 2:32	1.75	452361	4975014	16	986	137	2009	105.7309954	314.8563194	248	185	'2D'	'2D'
360	3600566004	9/21/2009 21:45	9/22/2009 1:16	3.51	452445	4974788	17	995	140	2009	105.7309954	314.8563194	1204	158	'3D'	'3D'
360	3600566004	9/22/2009 1:16	9/22/2009 3:00	1.74	452369	4975002	18	996	137	2009	105.7309954	314.8563194	144	16	'3D'	'2D'
360	3600566004	5/28/2010 19:47	5/29/2010 20:16	24.48	455302	4969028	1	1	175	2010	148.8245486	151.5229745	5786	2618	'2D'	'3D'
360	3600566004	5/30/2010 17:17	5/31/2010 0:18	7	467908	4966407	2	8	244	2010	148.8245486	151.5229745	5786	2205	'2D'	'2D'
360	3600566004	5/31/2010 0:18	5/31/2010 12:33	12.25	470592	4967650	3	9	263	2010	148.8245486	151.5229745	1110	429	'2D'	'2D'
387	3870478692	7/26/2001 22:05	7/27/2001 4:56	6.84	454557	4970586	1	132	164	2001	178.5947685	318.6783102	855	####	'3D'	'3D'
387	3870478692	9/5/2001 22:05	9/6/2001 1:31	3.42	455701	4968480	2	338	181	2001	178.5947685	318.6783102	2599	1552	'2D'	'3D'
485	4850463653	6/6/2005 19:26	6/6/2005 22:50	3.41	486527	4961087	1	76	364	2005	144.1438889	304.5843519	521	1246	'3D'	'3D'
485	4850463653	6/6/2005 22:50	6/7/2005 2:15	3.42	485199	4961200	2	77	361	2005	144.1438889	304.5843519	825	230	'3D'	'3D'
485	4850463653	6/12/2005 18:57	6/12/2005 22:20	3.38	488258	4960168	3	110	368	2005	144.1438889	304.5843519	3002	383	'2D'	'3D'
485	4850463653	6/13/2005 18:50	6/13/2005 22:15	3.42	485712	4961191	4	117	361	2005	144.1438889	304.5843519	1961	533	'3D'	'3D'
490	4900463650	6/28/2005 0:30	6/28/2005 3:56	3.43	452445	4974503	1	17	141	2005	175.6046065	196.3898148	1735	7129	'3D'	'2D'
493	4930643069	9/4/2010 21:31	9/4/2010 23:16	1.76	470916	4967735	1	108	264	2010	239.0006829	341.5215625	200	4506	'3D'	'3D'
548	5480505009	6/29/2007 0:15	6/29/2007 2:00	1.75	487552	4960550	1	707	367	2007	123.1361343	218.0007523	4188	47	'2D'	'3D'
673	6730643071	6/27/2011 1:15	6/27/2011 3:00	1.75	452130	4975937	1	196	128	2011	162.0838889	346.8561458	5003	393	'3D'	'3D'
673	6730643071	7/21/2011 1:01	7/21/2011 2:45	1.74	449141	4990367	2	480	82	2011	162.0838889	346.8561458	67	5293	'3D'	'3D'
677	6770599414	7/12/2011 23:01	7/13/2011 0:46	1.75	452443	4974545	1	56	141	2011	189.0014583	318.6465972	1162	2082	' 2D'	' 3D'
677	6770599414	7/27/2011 4:15	7/27/2011 6:02	1.77	452442	4974745	2	222	140	2011	189.0014583	318.6465972	79	3094	' 3D'	' 2D'
677	6770599414	7/28/2011 22:16	7/29/2011 0:01	1.76	449988	4979194	3	241	106	2011	189.0014583	318.6465972	2036	528	' 2D'	' 3D'
677	6770599414	8/5/2011 0:01	8/5/2011 1:45	1.74	452324	4975570	4	326	131	2011	189.0014583	318.6465972	1016	1073	' 2D'	' 3D'
677	6770599414	9/7/2011 21:45	9/7/2011 23:30	1.76	452324	4975551	5	701	131	2011	189.0014583	318.6465972	2572	1339	' 3D'	' 2D'
677	6770599414	9/20/2011 23:01	9/21/2011 0:46	1.74	452472	4973697	6	840	147	2011	189.0014583	318.6465972	2248	1160	' 2D'	' 2D'
677	6770599414	10/12/2011 21:45	10/12/2011 23:30	1.75	452444	4974514	7	1079	141	2011	189.0014583	318.6465972	2253	1928	' 3D'	' 3D'
677	6770599414	11/9/2011 20:00	11/9/2011 21:45	1.75	452441	4974715	8	1421	140	2011	189.0014583	318.6465972	1414	2076	' 3D'	' 3D'
677	6770599414	5/7/2012 23:46	5/8/2012 1:30	1.74	465958	4963902	1	259	219	2012	104.8606481	149.480544	396	468	' 3D'	' 3D'
677	6770599414	5/12/2012 22:45	5/13/2012 0:30	1.75	487522	4960566	2	324	367	2012	104.8606481	149.480544	1266	491	' 3D'	' 3D'
539	53920498124	7/12/2007 2:51	7/12/2007 4:33	1.71	473057	4968658	1	183	282	2007	178.6703356	231.6723495	1905	23	'2D'	'2D'
539	53920498124	7/12/2007 18:17	7/12/2007 20:00	1.72	480379	4961662	2	192	338	2007	178.6703356	231.6723495	1051	2478	'3D'	'3D'

9.10 Appendix J: Carcass and Track Correlation

Appendix J: Table 1. Carcass versus Track Correlation Matrix

Layer	All Carcass	All Tracks	Deer Carcass	Deer Tracks	Elk Carcass	Elk Tracks	Non-ungulate Carcass	Non-ungulate tracks	Pronghorn Carcass	Pronghorn Visual	Ungulate Carcass	Ungulate Tracks
All Carcass	1	0.57703	0.87458	0.84583	0.57873	0.40959	0.96214	0.48743	0.6951	0.43824	0.93106	0.56994
All Tracks	0.57703	1	0.26321	0.67865	0.9024	0.94881	0.59699	0.22733	0.28711	0.20155	0.53162	0.99766
Deer Carcass	0.87458	0.26321	1	0.66227	0.3692	0.13463	0.79242	0.3569	0.69358	0.31392	0.94608	0.2659
Deer Tracks	0.84583	0.67865	0.66227	1	0.62414	0.48098	0.91444	0.44174	0.50566	0.39465	0.74846	0.67101
Elk Carcass	0.57873	0.9024	0.3692	0.62414	1	0.91187	0.54167	0.19835	0.24305	0.16906	0.63509	0.90939
Elk Tracks	0.40959	0.94881	0.13463	0.48098	0.91187	1	0.39264	0.12463	0.18401	0.10656	0.42522	0.95286
Non-ungulate Carcass	0.96214	0.59699	0.79242	0.91444	0.54167	0.39264	1	0.52835	0.65716	0.47903	0.84117	0.58667
Non-ungulate tracks	0.48743	0.22733	0.3569	0.44174	0.19835	0.12463	0.52835	1	0.38593	0.9889	0.36818	0.22753
Pronghorn Carcass	0.6951	0.28711	0.69358	0.50566	0.24305	0.18401	0.65716	0.38593	1	0.3636	0.67012	0.2832
Pronghorn Visual	0.43824	0.20155	0.31392	0.39465	0.16906	0.10656	0.47903	0.9889	0.3636	1	0.32432	0.20231
Ungulate Carcass	0.93106	0.53162	0.94608	0.74846	0.63509	0.42522	0.84117	0.36818	0.67012	0.32432	1	0.53547
Ungulate Tracks	0.56994	0.99766	0.2659	0.67101	0.90939	0.95286	0.58667	0.22753	0.2832	0.20231	0.53547	1

Highway Crossing Failure versus Success Correlation Matrix

Pairwise comparisons using a correlation matrix were performed for Highway Crossing Failure (WVC or Carcass) versus Success (snow track crossing locations or visual observations of crossing) for deer, elk and pronghorn (Table 2). This analysis compares the spatial locations of these variables. Pronghorn success represents very few data points since pronghorn tracks could not be distinguished from deer tracks in the snow conditions that were present.

Appendix J: Table 2. Highway Crossing Failure (Carcass) versus Success Correlation Matrix

Layer	All Fail	All Success	Deer Fail	Deer Success	Elk Fail	Elk Success	Non-ungulate Fail	Non-ungulate Success	Pronghorn Fail	Pronghorn Success	Ungulate Fail	Ungulate Success
All Fail	1	0.59329	0.86831	0.80225	0.60807	0.41977	0.95758	0.62841	0.65235	0.63911	0.92388	0.57781
All Success	0.59329	1	0.26679	0.66106	0.84989	0.93721	0.57749	0.42994	0.24321	0.31365	0.60192	0.99909
Deer Fail	0.86831	0.26679	1	0.56702	0.39	0.13717	0.80004	0.51683	0.66494	0.5535	0.90064	0.25048
Deer Success	0.80225	0.66106	0.56702	1	0.50041	0.40839	0.88054	0.66955	0.44703	0.64018	0.64475	0.64964
Elk Fail	0.60807	0.84989	0.39	0.50041	1	0.85991	0.51168	0.33814	0.17305	0.19161	0.73248	0.84205
Elk Success	0.41977	0.93721	0.13717	0.40839	0.85991	1	0.34732	0.20705	0.10991	0.11167	0.51197	0.94054
Non-ungulate Fail	0.95758	0.57749	0.80004	0.88054	0.51168	0.34732	1	0.75423	0.65933	0.75389	0.81655	0.55861
Non-ungulate Success	0.62841	0.42994	0.51683	0.66955	0.33814	0.20705	0.75423	1	0.47081	0.78364	0.50523	0.40613
Pronghorn Fail	0.65235	0.24321	0.66494	0.44703	0.17305	0.10991	0.65933	0.47081	1	0.66492	0.57768	0.22907
Pronghorn Success	0.63911	0.31365	0.5535	0.64018	0.19161	0.11167	0.75389	0.78364	0.66492	1	0.47801	0.29188
Ungulate Fail	0.92388	0.60192	0.90064	0.64475	0.73248	0.51197	0.81655	0.50523	0.57768	0.47801	1	0.58877
Ungulate Success	0.57781	0.99909	0.25048	0.64964	0.84205	0.94054	0.55861	0.40613	0.22907	0.29188	0.58877	1

Visual versus Track Correlation Matrix

Pairwise comparisons using a correlation matrix were performed for Visual observations of live animals versus Tracks (snow track crossing locations) for deer, elk and pronghorn (Table 3). This analysis compares the spatial locations of these variables. Pronghorn track data are not present since pronghorn tracks could not be distinguished from deer tracks in the snow conditions that were present.

Appendix F: Table 3. Visual versus Track Correlation Matrix

------------------	All Visual	All Tracks	Deer Visual	Deer Tracks	Elk Visual	Elk Tracks	Pronghorn Visual	Ungulate Visual	Ungulate Tracks
All Visual	1	0.59193	0.21501	0.43618	0.91588	0.59508	0.38304	0.93178	0.61184
All Tracks	0.59193	1	0.15013	0.67865	0.56773	0.94881	0.20155	0.64482	0.99766
Deer Visual	0.21501	0.15013	1	0.26019	0.07946	0.1097	0.2765	0.12992	0.15341
Deer Tracks	0.43618	0.67865	0.26019	1	0.30453	0.48098	0.39465	0.38592	0.67101
Elk Visual	0.91588	0.56773	0.07946	0.30453	1	0.62971	0.13203	0.94637	0.58904
Elk Tracks	0.59508	0.94881	0.1097	0.48098	0.62971	1	0.10656	0.68048	0.95286
Pronghorn Visual	0.38304	0.20155	0.2765	0.39465	0.13203	0.10656	1	0.1459	0.20231
Ungulate Visual	0.93178	0.64482	0.12992	0.38592	0.94637	0.68048	0.1459	1	0.66667
Ungulate Tracks	0.61184	0.99766	0.15341	0.67101	0.58904	0.95286	0.20231	0.66667	1

9.11 Appendix K: Remote Camera Images

This appendix displays two photos for each remote camera that was installed in underpasses along US 287 and MT 87 in the study area.

The first photo shows the location of the camera within or just outside of the underpass. The second photo is a representative photo from each remote camera.

Stock culvert at RP 3.5, MT 87

Appendix K, Figure 1: Stock culvert at RP 3.5, MT 87 -- Camera location (Photo courtesy of Lance Craighead, ChI)

Appendix K, Figure 2: Stock culvert at RP 3.5, MT 87 -- Camera image (project photo)

Stock culvert at RP 5.2, MT 87

Appendix K, Figure 3: Stock culvert at RP 5.2, MT 87 -- Camera location (Photo courtesy of Lance Craighead, ChI)

Appendix K, Figure 4: Stock culvert at RP 5.2, MT 87 -- Camera image (project photo)

Stock culvert at RP 6.7, MT 87

Appendix K, Figure 5: Stock culvert at RP 6.7, MT 87 -- Camera location (Photo courtesy of Lance Craighead, ChI)

Appendix K, Figure 6: Stock culvert at RP 6.7, MT 87 -- Camera Image (project photo). Note that the date and time on this image are incorrect.

Madison River Bridge, MT 87

Appendix K, Figure 7: Madison River Bridge, MT 87 - Camera location. Camera was placed on this meter station at a later date (photo courtesy of Lance Craighead, ChI)

Appendix K, Figure 8: Madison River Bridge, MT 87 - Camera image (project photo)

Beaver Creek – east end of bridge, US 287

Appendix K, Figure 9: Beaver Creek Bridge (east) - camera location (photo courtesy of Lance Craighead, CrI).

Appendix K, Figure 10: Beaver Creek Bridge (east) - camera image (project photo).

Beaver Creek – west end of bridge, US 287

Appendix K, Figure 11: Beaver Creek Bridge (west) - camera location (photo courtesy of Lance Craighead, CrI)

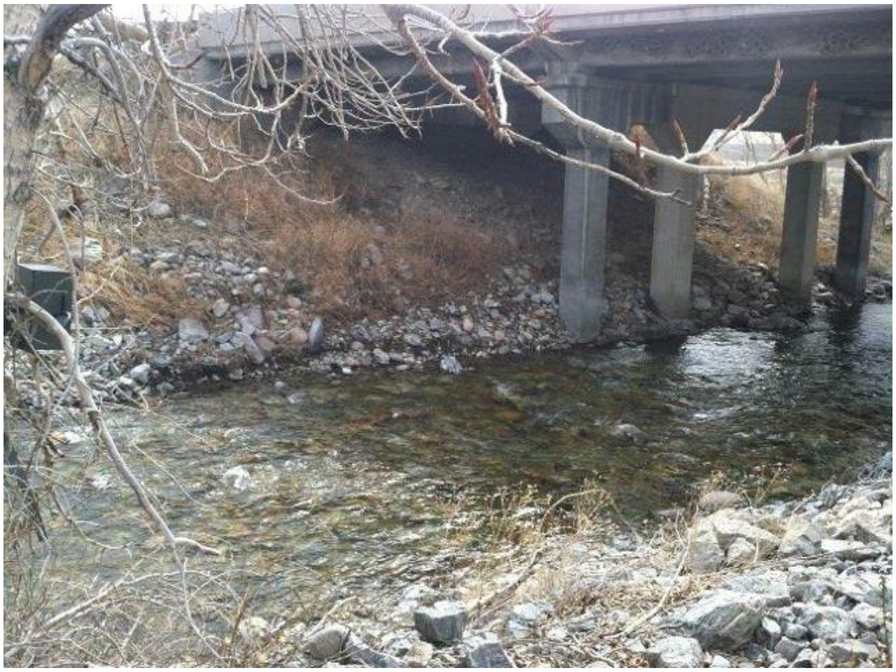
Appendix K, Figure 12: Beaver Creek Bridge (west) - camera image (project photo)

Grayling Creek Bridge, US 287

Appendix K, Figure 13: Grayling Creek Bridge, US 287 - camera location. Note: the camera is not visible in this photo, but is located at the southwest corner under the bridge, which correlates to the upper right quadrant of this photo (Photo courtesy of Lance Craighead, CrI).

Appendix K, Figure 14: Grayling Creek Bridge, US 287 - camera image (project photo).

Indian Creek bridge, US 287



Appendix K, Figure 15: Indian Creek Bridge, US 287 - camera location (photo courtesy of Lance Craighead, ChI).

Appendix K, Figure 16: Indian Creek Bridge, US 287 - camera image (project photo).

Madison River Bridge at Ennis, US 287

Appendix K, Figure 17: Madison River Bridge at Ennis, US 287 - camera location (photo courtesy of Lance Craighead, CrI).

Appendix K, Figure 18: Madison River Bridge at Ennis, US 287 - camera image (project photo)

Underpass south of Madison River Bridge at Ennis, US 287

Appendix K, Figure 19: Underpass south of Madison River Bridge at Ennis, US 287 - camera location (photo courtesy of Lance Craighead, CrI).

Appendix K, Figure 20: Underpass south of Madison River Bridge at Ennis, US 287 - camera image (project photo).

North Meadow Creek bridge, US 287

Appendix K, Figure 21: North Meadow Creek Bridge, US 287 - camera location. Note: the camera is not in view in this photo, but it was located on a post just out of view to the left side of this photo (photo courtesy of Lance Craighead, CrI).

Appendix K, Figure 22: North Meadow Creek Bridge, US 287 - camera image (project photo).

O’Dell Creek bridge, US 287

Appendix K, Figure 23: O’Dell Creek Bridge, US 287 - camera location (photo courtesy of Lance Craighead, CrI).

Appendix K, Figure 24: O’Dell Creek Bridge, US 287 - camera image (project photo).