2010

IDENTIFYING WILDLIFE CROSSING ZONES FOR THE PRIORITIZATION OF HIGHWAY MITIGATION MEASURES ALONG U.S. HIGHWAY 2: WEST GLACIER, MT TO MILEPOST 193

Mike J. Roesch
The University of Montana

Recommended Citation

Roesch, Mike J., "IDENTIFYING WILDLIFE CROSSING ZONES FOR THE PRIORITIZATION OF HIGHWAY MITIGATION MEASURES ALONG U.S. HIGHWAY 2: WEST GLACIER, MT TO MILEPOST 193" (2010). *Graduate Student Theses, Dissertations, & Professional Papers*. 540.
https://scholarworks.umt.edu/etd/540

IDENTIFYING WILDLIFE CROSSING ZONES FOR THE PRIORITIZATION OF HIGHWAY MITIGATION MEASURES ALONG U.S. HIGHWAY 2: WEST GLACIER, MT TO MILEPOST 193

By

MICHAEL JAMES ROESCH

B.A., Creative Writing & English, University of Illinois, Urbana-Champaign, IL, 2006

Professional Paper

presented in partial fulfillment of the requirements
for the degree of

Master of Science
in Environmental Studies

The University of Montana
Missoula, MT

May 2010

Approved by:

Perry Brown, Associate Provost for Graduate Education
Graduate School

Len Broberg, Chair
Environmental Studies Department

Dan Spencer, Co-Chair
Environmental Studies Department

John Waller, Co-Chair
College of Forestry and Conservation

Roesch, Mike, Master of Science, May 2010 Major
Environmental Studies

Identifying Wildlife Crossing Zones for the Prioritization of Highway Mitigation Measures along U.S. Highway 2: West Glacier, MT to Milepost 193

Chairperson: Len Broberg

Co-Chairperson: Dan Spencer

Co-Chairperson: John Waller

Abstract

Highways have been shown to fragment wildlife habitats and populations. In order to mitigate the effects that highways have on wildlife, it is important to assess where wildlife appear to be moving in close proximity to the highway. I surveyed for wildlife trails that approached either side of a ~64 km stretch U.S. Highway 2 (US-2) and monitored these trails with remote cameras. Ungulates, especially deer, were the most commonly photographed animals on trails. A limited number of photographs were also taken of coyote, black bear, snowshoe hare, wolf, and cougar. Camera images showed that wildlife tended to use roadside trails during hours of lower traffic volumes. I used multiple logistic regression at three scales (50 m, 250 m, and 500 m) followed by model selection with Akaike's Information Criterion to assess the impacts of certain landscape features on the location of wildlife trails (used) versus randomly generated points (unused). I examined the clustering of wildlife trails and found them to be clustered at all distance scales less than 39 km—with the strongest clustering occurring at the 5-8 km scales. The 5 km segment of highway with the highest density of trails was located from Milepost (MP) 181-184. Crossing zones were delineated based on a combination of the number of trails, previously identified wildlife crossings, camera incidents-per-day, potential parcels of land for conservation, and highway and railroad structures in a given area (usually a 5 km segment). The results of this study may serve as useful baseline information to the Great Northern Environmental Stewardship Area working group (GNESA) and its partners to help guide future research and mitigation projects in the US-2 corridor.

CONTENTS

Page

Identifying Wildlife Crossing Zones for the Prioritization of Highway Mitigation Measures along U.S. Highway 2: West Glacier, MT to Milepost 193

FIGURES Page

TABLES

APPENDICES

INTRODUCTION

The presence of transportation corridors located within and between vital ecosystems is often problematic because these corridors can inhibit wildlife movement. The ever-expanding global transportation network poses one of the greatest threats to wildlife populations worldwide (Forman et al. 2003). Forman (2000) estimated that one-fifth of the nation's land is ecologically impacted by the U.S. road system. Highways, roads, and railroads can negatively affect wildlife populations through roadkill, direct losses of habitat, wildlife avoidance of roads, and impeded wildlife movement across roads (Mace et al. 1996, Servheen et al. 1998). Some highways and railroads can function as mortality-sinks for wildlife (Aresco 2003, Weir et al. 2004). Highways that bisect crucial habitat areas can also present a danger to humans due to the risk of high-speed wildlife-vehicle collisions. For example, there are over 1 million deer-vehicle collisions annually in the US which result in more than 200 human fatalities, 29,000 human injuries, and approximately $1 billion in damage (Conover et al. 1995). Bissonette et al. (2008) estimated that, in Utah alone, the overall costs associated with deer-vehicle collisions are $7,529,242 per year.

Transportation corridors such as highways and railroads have the potential to fragment habitats and otherwise continuous population distributions (Forman et al. 2003). Such fragmentation threatens the viability and persistence of wildlife populations by inhibiting demographic exchange, disrupting gene flow, and thus reducing genetic diversity (Saunders 1991, Forman et al. 2003, Epps et al. 2005). Wildlife populations that are isolated by fragmentation have an increased probability of extinction, which poses a threat to the viability of a metapopulation (Shaffer and Samson 1985). This decreased chance of survival is a major concern for a number of wide-ranging mammals—especially threatened or endangered species.

Recent efforts in conservation have been made to mitigate the negative effects of highways, roads, and railroads on wildlife. Common mitigation measures include warning signs, roadside fencing and structures such as wildlife overpasses, underpasses, culverts, and roadside fencing. These "crossing" structures are designed to help reduce road-related mortality rates and preserve habitat connectivity and gene flow by increasing road permeability for wildlife (Beier 1995, Foster and Humphrey 1995, Clevenger and Waltho 2000, Hoctor et al. 2000, Forman et al. 2003, Clevenger and Waltho 2005). Research has shown that wildlife do not cross highways randomly, but that the occurrence of wildlife crossings appears to be spatially clustered (e.g. Singer and Doherty 1985, Waller and Servheen 2005, Lewis 2007). Specific areas where wildlife naturally tend to cross a transportation corridor may be referred to as *crossing zones.*

RESEARCH TOPIC

My research aimed to identify wildlife crossing zones along a 64 km (40 mi) stretch of US-2. Other research supports focusing highway mitigation efforts in areas where there are wildlife trails or where wildlife have been shown to naturally cross a roadway (e.g. Singer and Doherty 1985, Foster and Humphrey 1995, Alexander and Waters 1999). Since little is known about the locations and frequencies of wildlife crossings on US-2, my primary goal was to provide baseline information about where wildlife appeared to moving in close proximity to the highway. The primary intended audience for this paper is the Great Northern Environmental Stewardship Area working group (GNESA) and its partners, including: the Montana Department of Transportation (MDT), Glacier National Park, the U.S. Forest Service, the BNSF Railroad, and Montana Fish Wildlife and Parks. Information about crossing zones will ideally allow GNESA and its partners to prioritize areas where more specific and sophisticated future wildlife crossing research is needed—which will subsequently help determine where GNESA should advocate for future wildlife mitigation measures in the US-2 corridor.

STUDY AREA

US-2 is the northernmost east-west running highway in the continental United States. The total length of highway from Washington to Maine is 4,150 km. There are 1072 km (666 mi) of US-2 in Montana—all of which is 2-lane highway except for a total of 64 km (40 mi) of 4-lane highway. The study area was a 64 km section of the highway from West Glacier, MT—Milepost (MP) 153—to MP193, which was located just past Snowslip, MT (Fig. 1). Most of the study area was 2-lane highway, except for a 1.6 km (1 mi) stretch between MP174-174.6 which was 4-lane. The speed limit in the study area is 112 kph (70 mph) except for the stretch between MP179.5 and MP184.5, where the speed limit was 88 kph (55 mph). Many sections of the highway had a 0.5-1 m tall guardrail on one or both shoulders of the highway.

The elevation of the highway ranged from 965 m (3169 ft) in West Glacier to 1341 m (4400 ft) at MP193. US-2 passed through five small communities in the study area: Nyack (MP164), Pinnacle (MP174), and Essex (MP180), Nimrod (MP184), and Snowslip (MP191). The highway was paralleled by a major Burlington-Northern Santa Fe (BNSF) railroad line for the entire study area. US-2 was also paralleled by the Middle Fork of the Flathead River (Middle Fork) from West Glacier to Nimrod (48 km, 30 mi), and by Bear Creek from Nimrod to MP193 (24 km, 15 mi). While the highway itself was near the valley bottom of the Middle Fork, the surrounding landscape was primarily rugged mountainous terrain. The dominant roadside vegetation in the US-2 corridor, not including the highway right-of-way, was primarily coniferous forest. Vegetation in the US-2 corridor was primarily coniferous forest and mixed coniferous/deciduous forest. The MDT reported in 2006 that the mean daily traffic volume in the study area was 1816 vehicles, with 110 of those being commercial vehicles (http://www.mdt.mt.gov). Waller and Servheen (2005) found that the average bi-directional hourly traffic near Essex, MT was 77 cars/hr.

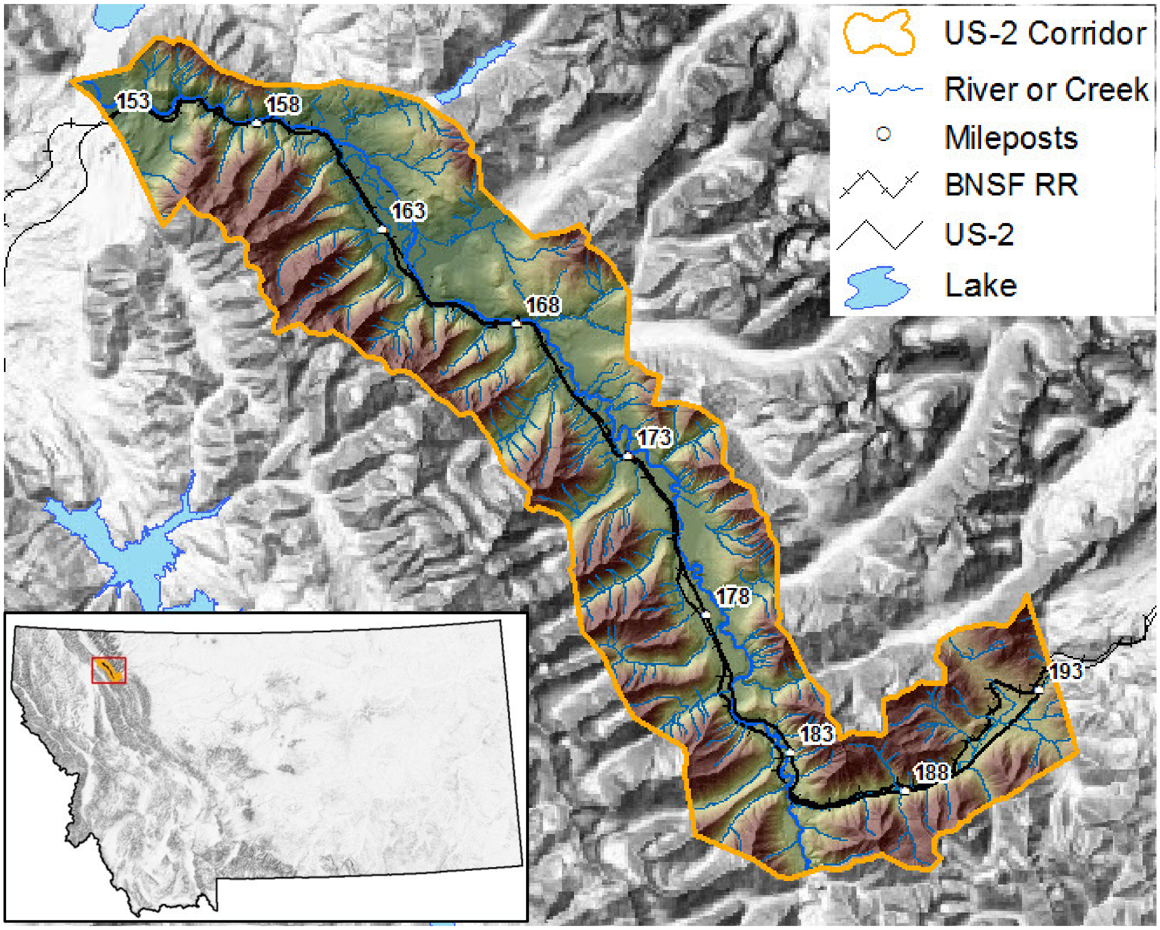

Figure 1. Map of study area with inset map of Montana.

The mean population density in the study area section of GNESA-defined US-2 corridor was 3.27 persons/km^2 (density data acquired from www.nris.mt.gov). The mean population density amongst census blocks that either intersected or directly bordered US-2 was 3.96 persons/km^2. The highway separates Glacier National Park to the north from the Bob Marshall Wilderness complex to the south—which are both part of the Crown of the Continent ecosystem (CCE). The CCE is an 18-million acre international area comprised of mountainous regions in northwest Montana, southwest

Alberta, and southeast British Columbia. In Montana, the CCE includes Glacier National Park, parts of the Blackfeet and Flathead Indian Reservations, parts of five national forests, four wilderness areas, Bureau of Land Management land, state lands, and private lands; and in Alberta and British Columbia, the CCE includes Waterton National Park, the Castle Wilderness, the Flathead Valley, several national and provincial forests, and private lands.

The US-2 transportation corridor is a narrow strip of human development surrounded by expansive areas of wilderness, national forests, and national parks. Waller and Servheen (2005) refer to US-2 as a fracture zone that has not yet fully disrupted ecological connectivity between Glacier National Park and the Bob Marshall Wilderness. However, Waller and Servheen (2005) also predict that if traffic volumes continue to increase, the highway could become impermeable to grizzly bears (*Ursus arctos*) within the next thirty years. There are several other mammalian species found in the study area that could potentially be affected by US-2, including: mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), elk (*Cervus canadensis*), moose (*Alces alces*), black bear (*Ursus americanus*), bobcat (*Lynx rufus*), Canada lynx (*Lynx canadensis*), cougar (*Puma concolor*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), pine marten (*Martes americana*), mountain goat (*Oreamnos americanus*), wolverine (*Gulo gulo*), snowshoe hare (*Lepus americanus)* and gray wolf (*Canis lupis*). In order to mitigate the effects of the highway on the wildlife populations in the CCE, it is crucial to identify wildlife crossing zones along US-2.

In 2001, the Montana Legislature passed a bill requiring the MDT to widen US-2 from 2 lanes to 4 lanes in order to improve traffic and local economies throughout the state. Then, in 2004, the state and federal transportation departments determined that US-2 should not be widened, but that efforts should instead be focused on improving the 2-lane configuration. Yet, private groups such as the Highway 2 Association still strongly advocate for the widening of US-2 to 4 lanes in Montana. Widening US-2 to 4-lanes could accelerate the process of fragmentation between Glacier National Park and the Bob Marshall Wilderness complex. This threat, coupled with continued development and increasing traffic volumes in the study area make it important to examine where wildlife are crossing the highway so that mitigation measures can be taken to protect both drivers and wildlife.

METHODS

Identifying Wildlife Trails

I wanted this research to encompass a broad suite of mammalian species. One initial assumption I had was that multiple wildlife species create, use, and share trails near the highway. Thus, I surveyed for wildlife trails along the highway. Wildlife trail identification surveys were conducted from May 2008 to October 2008. From May 2009 to October 2009, these trails were revisited in order to examine persistence across multiple years. Surveys consisted of walking along the highway right-of-way at the edge of the vegetative cover and looking for wildlife trails that extended into the vegetation. Wildlife trails along US-2 often resembled narrow human hiking trails, and were usually indicated by a path of bare dirt and rock through an otherwise vegetated landscape. The edge of cover was primarily mature conifer forest, but occasionally consisted of shrubs or mixed forest. I surveyed the edge of cover because most trails dissipated or disappeared as they exited cover toward the road. If the edge of cover was too thick to clearly see through, I walked slightly inside the edge of cover. Surveys were conducted along both sides of the highway for the entire length of the study area.

During trail identification surveys, I also identified existing highway structures that may facilitate wildlife movement across the highway such as culverts, overpasses, underpasses, bridges, and railroad tunnels (e.g. Foster and Humphrey 1995, Clevenger and Waltho 1999, Clevenger and Waltho 2000, Ng et al 2004). Some of the structures I identified, depending on their proximity to wildlife trails, may be good candidates for structural adjustments or retro-fittings that would make them better suited for wildlife use. I counted the number of trails and the number of GNESA wildlife crossing locations located within 1 km of each highway bridge or tunnel. GNESA crossing locations were locations where MDT and BNSF railroad personnel frequently observed wildlife on or near the the highway.

I marked the Universal Transverse Mercator (UTM) coordinates for trails and structures using a hand-held Garmin eTrex Vista HCx Global Positioning Satellite (GPS) device (accuracy < 30m) at the point where they intersected the edge of cover. Each trail was assigned a 3-digit numeric label. If two or more trails were located with 10 m of each other at the edge of cover, they were marked as separate trails only if they did not intersect each other within a distance of ~20 m. Otherwise, a single point was marked at the midpoint between them and they were counted as one trail. I marked trails regardless of whether there was a corresponding trail on the other side of the highway. Trails were classified as either major or minor. There were two principal qualifications for major trails. First, the ground cover vegetation was either well worn away or entirely worn away. Second, major trails extended more than 20 meters into vegetative cover. Minor trails were less defined, shorter in length, or both. Some minor trails were less than 20 meters in length and appeared to be simply entry or exit points for wildlife crossings. Other minor trails extended more than 20 meters into cover, but were narrower and more overgrown with vegetation than were major trails. Due to these characteristics, I assumed that major trails were used more frequently than minor trails. I also speculated that minor trails were used more by individual animals, and that major trails were used more by groups of animals, such as deer or elk.

I focused the majority of my analyses on major trails and their location attributes since I believed that major trails were more heavily used by wildlife than were minor trails. For the remainder of this paper, major trails will be referred to simply as trails unless otherwise specified. At each trail location, I recorded the presence/absence of a guardrail and the presence/absence of a highway passing zone (dotted center line). I also marked GPS waypoints at both ends of every guardrail in the study area, and then digitally connected the endpoints to create a complete digital guardrail layer for the entire study area.

Monitoring Trails with Remote Cameras

From June 2008 to August 2008 and from May 2009 to October 2009, I used 6 Cuddeback Excite digital infrared remote cameras to monitor a sample of wildlife trails along US-2. In 2008, cameras were rotated to six different trails approximately every two weeks. There were 4 camera sessions. Only 3 cameras were available to use in Session 1, and only 4 cameras were available in Session 2. Due to limited cameras and time, I attempted to distribute the cameras evenly across the study area over the course of the 2008 field season. One camera in Session 1 was used to monitor a box culvert. A total of 18 trails (4 minor, 14 major) and 1 box culvert were monitored in 2008. No trails were monitored in more than one session.

From May 2009 through October 2009, I monitored wildlife trails along US-2 using the same six Cuddeback Excite cameras that were used in 2008. Cameras were rotated roughly once a month for 5 months. The lengths of the five sessions were 26 days, 28 days, 43 days, 28 days, and 27 days. It was possible for the same trail to be monitored in multiple or consecutive sessions. A total of 23 different trails (3 minor, 19 major) were monitored in 2009. Of those, 16 trails were monitored in only one session, 5 trails were monitored in two sessions, and 2 trails were monitored in three sessions.

In each camera session, I randomly chose three trails for camera monitoring. However, not all trails were conducive to cameras. An ideal camera location required a tree of about 25-50 cm in diameter that (a) was 3-6 meters from the trail, (b) a camera could be fastened to at a height of 1-1.25 meters with a Master Python Adjustable Locking Cable, (c) was within 15 meters from the edge of cover, and (d) had a mostly unobstructed view of the trail. These requirements were necessary so that a camera's infrared beam could be aimed perpendicular to the trail at a height of about 0.75 meters without obstruction or interference. If a selected trail was not conducive to camera monitoring, a different trail was randomly selected. For each selected trail, the nearest major trail located on the opposite side of the highway was also monitored. If a major trail could not be located within ~500 meters on the opposite side of the highway, the best available minor trail in proximity was selected. The cameras were triggered by heat and motion. Pictures were taken whenever a moving animal crossed the infrared beam, and the date and time were stored for each picture. The cameras had a 1-minute delay between pictures.

Data Analysis

Trails

ArcInfo GIS version 9.3 (Environmental Systems Research Institute, Redlands, CA, USA) was used for all GIS analyses. Shapefiles for wildlife trails, highway structures, and cameras were created from GPS points. Shapefiles for landscape and transportation features in the US-2 corridor were accessed from the GNESA GIS database. I also accessed a shapefile from the GNESA database that showed previously identified wildlife crossing locations. GNESA crossing locations were categorized by species and based on places where MDT and BNSF personel frequently observed wildlife on or near the the highway. Data for roadkill incidents between 1998-2007 were acquired from three sources: the GNESA roadkill database, the MDT roadkill database, and from GNESA wildlife crossing descriptions that contained information about roadkill incidents. Roadkill data are not inclusive of all roadkill incidents as they were acquired and reported voluntarily and opportunistically by MDT employees, motorists, and wildlife biologists. All roadkill incidents were merged into a single shapefile. All shapefiles were converted to feature classes and assigned NAD 83 Universal Tranverse Mercator Zone 12 projected coordinate system.

To test for linear spatial clustering of trails, I measured the "driving" distance (km) along US-2 from the starting point of MP153 to each trail. These distances were then entered into a script that calculated Ripley's L-values (Ripley 1981) in the software program R (R Foundation for Statistical Computing, Vienna, Austria). The Ripley's script generated a plot of expected clustering based on 1000 iterations of 100 randomly generated trail locations. A 95% confidence envelope was computed and plotted for the expected clustering. Results were displayed as L(h), the actual trails, against distance. Trails were considered to be significantly clustered at distance scales in which the L(h) values were greater than the upper 95% confidence envelope.

In ArcInfo, I divided US-2 into sequential 1 km segments. I also divided the highway into 3 km segments and 5 km segments. I then ran several enumeration analyses, which consisted of counting the number of trails, GNESA wildlife crossing locations, and roadkill per highway segment at all three distance scales. I also measured the distance between each trail and its nearest neighbor.

Shapefiles for the edges of vegetative cover were created by digitizing the edges of cover based on natural-color aerial photos from the Montana Natural Resource Information System (NRIS; nris.mt.gov/nsdi/orthophotos/). Although trails had been marked at the edge of vegetative cover, I snapped them to the digitized edge of vegetative cover to account for any errors in GPS accuracy.

In order to compare the attributes—or variables—of trail locations to those of non-trail locations, I used random points to represent non-trail locations. Three of the variables I wanted to measure were terrain ruggedness, road density, and population density. I wanted to assess these variables at three scales: 50 m, 250 m, and 500 m. I chose 50 m as the smallest scale because I wanted to look at fine scale differences between trail locations and random point locations. I chose 500 m as the maximum scale because I believed that, due to the relatively homogenous nature of the surrounding landscape, differences between trail locations and non-trail locations would become less meaningful at broader scales.

I measured terrain ruggedness, road density, and population density within buffers that I created around each trail and random point. Since I chose to measure these three variables at three scales, I created a 50 m buffer, a 250 m buffer, and a 500 m around each trail prior to generating random points (buffer size refers to radius length). I needed to create 50 m, 250 m, and 500 m buffers around each random point as well, but I wanted to ensure that trail buffers and random point buffers of corresponding size (e.g. 50 m) would not overlap. In order to prevent buffer overlap at each of the three scales—and thus preserve the mutual exclusivity between trail and random point buffers—I generated three different sets of random points (the Rand50m set, the Rand250m set, and the

Rand500m set). For the Rand50m set, I prevented random points from falling within 100 m of a trail so that 50 m trail buffers would not overlap with 50 m random point buffers. The same process was applied to the Rand250m set and the Rand500m set. I chose to make random points at least 10 m apart from each other since this is the same distance required for trails to be considered distinct. Random points were generated within 20 m of the edge of vegetative cover on either side of the highway, and were then snapped to the edge of cover after they had been generated.

A 30 m digital elevation model file (DEM) was acquired from the GNESA GIS database. I used the 30 m DEM to calculate standard deviation of elevation for each trail buffer and each random point buffer. Standard deviation of elevation was used as an indicator of terrain ruggedness (Waller and Servheen 2005). Shapefiles for roads and for land ownership in the US-2 corridor were also aquired from the GNESA database. I calculated road density, not including US-2, for each buffer by summing the number of 20 m segments of road per buffer. I used a population density layer from NRIS and the Hawth's polygon-in-polygon analysis extension in ArcMap to calculate the mean population density (persons/km^2) for each buffer.

Several other variables were measured for trails and random points. I combined land ownerhsip types into five categories: National Forest, Private Land, Glacier National Park (GNP), State Trust Lands, and Conservation Easements. Although conservation easements are not actually a land ownership category, I used them as such because they were defined as a category in the GNESA shapefile. Land ownership type for each trail and random point was determined by the ownership type at the exact location of the trail or random point. For each random point and trail location, I measured the distance in meters to: the nearest riparian area, the BNSF railroad, and the edge of cover from the center of the higway.

Cameras

Each animal that was captured on a camera image was recorded as an *incident*. For multiple images that were taken within 10 minutes of each other, I used my best judgment to determine whether or not the images were taken of the same individual animal. If I determined that the images were of the same animal, the multiple images were recorded as a single incident and I recorded the time of the incident as the midpoint between all relevant images. I categorized all camera incidents based on the species in the image and the hour (1 through 24) in which the image was taken. I grouped mule deer and white-tailed deer together as Deer because it was often difficult to distinguish the two species in camera images.

I also categorized all camera images into either dawn, day, dusk, or night (Waller and Servheen 2005). Dawn was the period between civil twilight and sunrise, and dusk was the period between sunset and civil twilight. Morning civil twilight begins and civil twilight ends when the sun is 6 degrees below the horizon. Night was the period between the end of evening twilight and the beginning of morning twilight, and day was the period between sunrise and sunset. Sunrise, sunset, and civil twilight were calculated for Essex, Montana based on calendars from www.sunrisesunset.com.

I created five hourly traffic volume categories—lowest, low, medium, high, and highest—based on US-2 hourly traffic volume data reported by Waller and Servheen (2005). The traffic categories were defined as: Lowest (vehicles/hr < 20), Low (20 < vehicles/hr < 60), Moderate (60 < vehicles/hr < 80), High (80 < vehicles/hr < 130), and Highest (vehicles/hr >130). I then compared the number of camera incidents per hour to the hourly traffic volume categories, and I counted the number of camera incidents per traffic volume category. I also assessed the number of camera images per time category (dawn, day, dusk, and night). Since elk were the second most common species caught on camera besides deer, and because elk-vehicle collisions can be relatively severe, I created a table of camera locations that had at least one elk incident. At each of these locations, I documented the distance to the nearest GNESA elk crossing location. Lastly, I ranked camera locations based on the number of incidents-per-day captured at a given location.

Modeling

I used logistic regression to assess the level of influence that certain landscape variables had on the location of trails. I created three full models—one for each scale, or set of random points. I will refer to these three models individually as the 50m model, the 250m model, and the 500m model; and I will refer to them collectively as the *full models*. I compared the spatial attributes of trails to the attributes of random points (non-trails) in a binary logistic regression analysis in SPSS statistical software version 18 (SPSS Inc., Chicago, IL, USA). The dependent variable cases were coded "1" for trail locations and "0" (zero) for random point locations. I tested each of the following indedendent variables for univariate significance in simple logistic regression analyses: distance to a riparian area (DistRip), distance from the highway to vegetative cover (DistCov), distance to the railroad (DistRR), population density (PopDens), standard deviation of elevation (ElevSD), road density (Roads), and land ownership (GNP). Before running the multiple logistic regression, I used the collinearity diagnostics of a linear regression analysis to test for multicollinearity between variables (Menard 1995). The variables for each full model were then entered into seperate multiple logistic regression analyses. The land ownership variable was referred to as GNP because I chose to make land ownership a binary variable that was coded “1” if the point was located within Glacier National Park boundaries and “0” (zero) if it was not. I wanted to assess impact, if any, that land ownership by GNP might have on the presence of trails. The GNP variable also inherently accounted for speed limit, which was 88kph (55mph) within GNP boundaries and 112kph (70mph) in the rest of the study area.

I expected that trails, in comparison to random points, would be closer to riparian areas and have a shorter distance from the highway to the edge of cover. I expected trails to be further from the railroad for two reasons: (a) because wildlife may avoid the railroad directly, and (b) because increased distance between the highway and railroad may provide animals with a better opportunity to move and forage in areas near the highway. I also expected trails to be in areas with a lower standard deviation in elevation, lower population density, and lower density of roads.

I used Akaike’s Information Criterion corrected for small sample size ($\mathbf{AICc = AIC + 2K(K+1)/(n-K-1)}$) to compare candidate models within each of the three full models (Akaike 1973, Burnham and Anderson 2002). I used the formula below to compute the difference in AICc (ΔAICc) between each given model and the best candidate model (AICc_{min}; e.g. Akaike 1978, Burnham and Anderson 2002),

$$\mathbf{\Delta AICc \equiv \Delta_i = AICc_i - AICc_{min}}$$

A model with $\Delta_i = 0$ (zero) was considered to be the best approximating model for a given data set, and models with $\Delta_i \leq 2$ were considered to be within the range of plausible models that substantially described a given data set (Burnham and Anderson 2002). The most parsimonious model was the model within the set of plausible models ($\Delta_i \leq 2$) that had the fewest independent variables, or degrees of freedom (df). I obtained a Hosmer and Lemeshow chi-square (X^2) goodness-of-fit statistic and a corresponding significance (p-value) for each model. Models with Hosmer and Lemeshow p-value > 0.05 were considered to adequately fit a given data set.

RESULTS

Wildlife Trails

A total of 88 major trails were identified (Fig. 2). Of those, 40 (45%) were located on the north side of US-2 and 48 (55%) were located on the south side of US-2. Results of the Ripley's L cluster analysis showed that trails were significantly clustered at all distance scales less than 38 km, but were most strongly clustered at the 5-8 km scales (Fig. 3). Strong clustering also occurred at the 15-20 km scales, which may represent the distance between two segments of US-2 with high density of trails. The mean distance between each trail and its nearest neighbor was 169 m (s = 247 m). The majority of trails were located on either National Forest or Glacier National Park land (Fig. 4). Of the 88 major trails I identified, 49 (56%) had a trail within 500 m on the opposite side of the highway and 39 (44%) did not.

Results of the enumeration analysis (i.e. trails per highway segment) at the 1 km scale showed that 44 (69%) of 64 segments contained either zero or 1 trail, and 7 segments that contained more than 5 trails. Segments that contained at least one trail are shown in Table 1. The 1 km segment with the most trails (N = 8) was located in between MP181-182. The 3 km segments with the most trails were segments were located at MP181-182.9 and MP182.9-184.7 (Table 2). At the 5 km scale, segment 10 contained the most trails (N=26, 30%), and was located from ~MP181-184 (Table 3). Since trails were most strongly clustered at the 5 km scale, I have included a map (Fig. 5) showing the number of trails per 5 km segment. The 8 km stretch of US-2 from MP179-184 contained 36 (41%) of the 88 trails. Bridges and tunnels located along US-2 and the number of trails and GNESA crossing locations within 1 km of each structure are listed in Table 4.

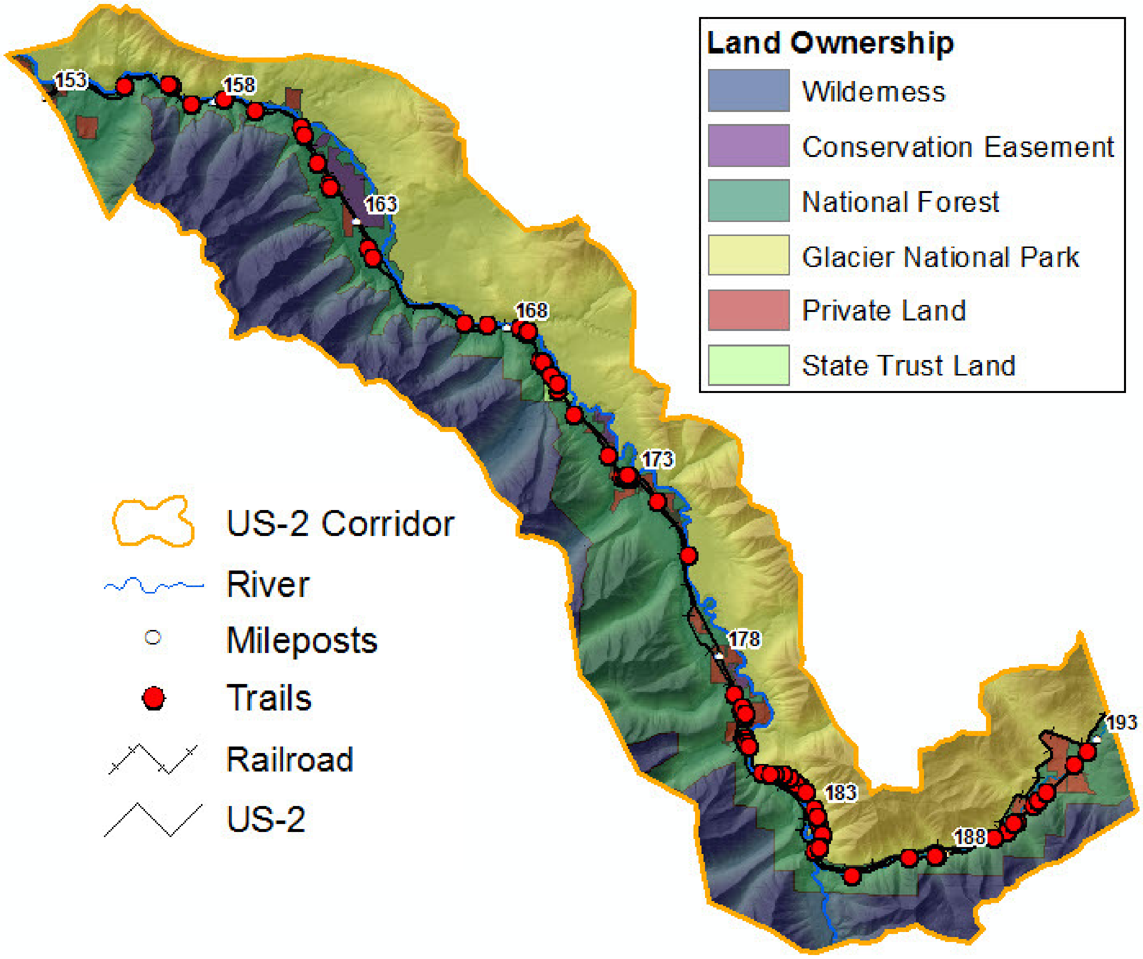

Figure 2. Map of wildlife trails and land ownership in the study area.

Within the study area, there were 60 guardrails: 40 on the north side and 20 on the south side of US-2. The sum distance of all guardrails was ~30 km. Of the 88 trails, 57 (75%) were located in areas where no guardrail was present, 7 (10%) were located at the end of a guardrail. Thus, 64 (85%) trails were located where there was zero or 1 guardrail. 61 (69%) trails were located in highway no-passing zones. All 88 trails were located in areas with only 2 lanes; and thus, no trails were located in the four lane stretch from MP173.5-174.5.

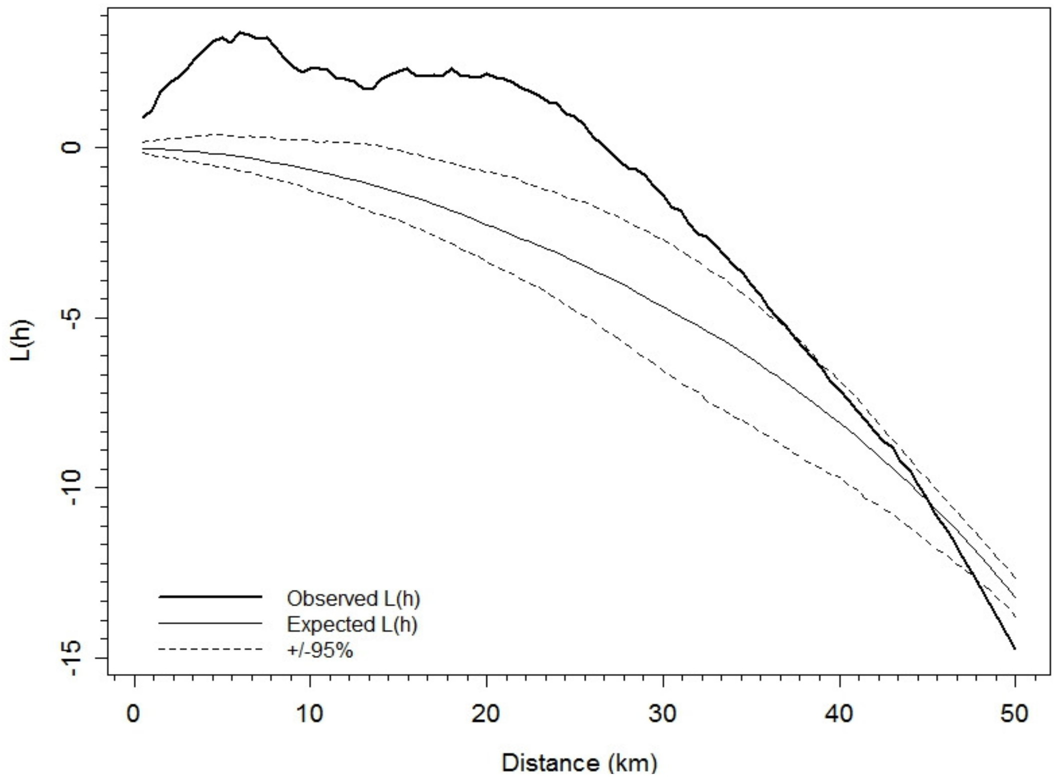

Figure 3. Results of Ripley's L test for linear clustering of trails.
**When observed L(h) is larger than expected L(h), trails are more clustered than a random distribution at that distance. When observed L(h) is smaller than expected L(H), trails are more dispersed than a random distribution at that distance. When observed L(h) is larger than the upper 95% confidence envelope, trail clustering is statistically significant. When Observed L(h) is smaller than the lower 95% confidence envelope, trail dispersion is statistically significant.*

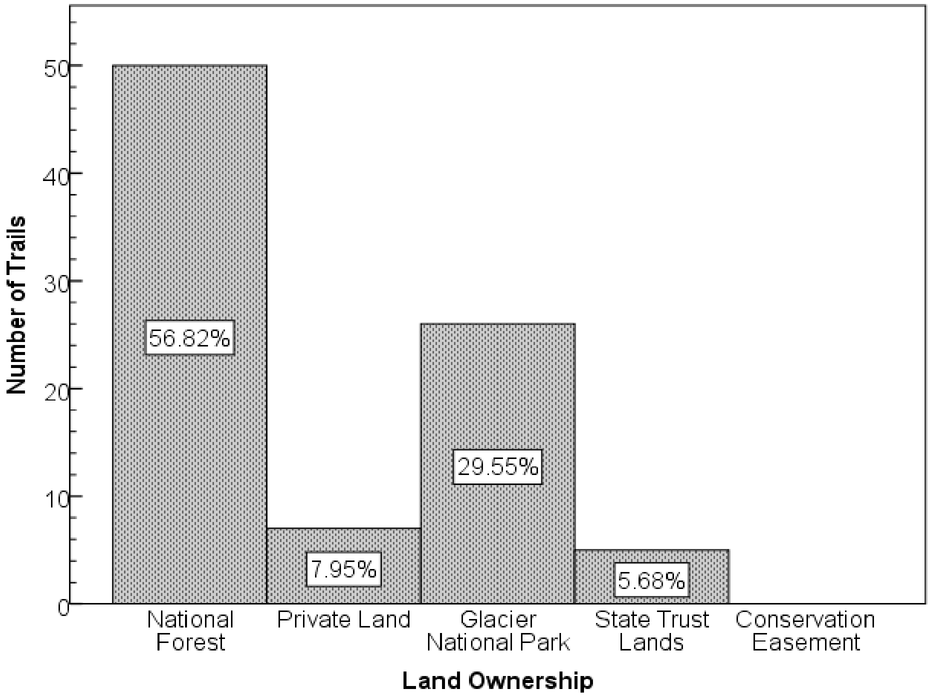

Figure 4. Land ownership at trail locations.

Table 1. Results of 1 km enumeration analysis for trails, GNESA wildlife crossings, and roadkill.

MP	Trails	GNESA	Roadkill
154.9	1	1	2
156.1	2	1	1
157.4	1	1	0
158.0	1	1	2
158.6	1	1	0
159.9	1	0	1
160.5	1	0	0
161.1	1	0	0
161.8	3	1	1
163.6	3	1	0
166.8	1	1	0
167.4	1	0	2
168.0	2	0	2
168.6	1	1	2
169.3	5	0	1
169.9	2	0	0
170.5	1	0	1
171.8	1	1	4
172.4	5	0	1
173.0	3	1	3
173.6	1	1	9
175.5	1	0	2
178.6	1	0	1
179.3	5	2	0
179.9	4	0	3
181.1	8	2	5
181.8	6	1	0
182.4	2	0	0
183.0	5	0	0
183.6	5	0	0
184.9	1	1	0
186.1	1	0	0
187.4	2	0	0
188.6	1	0	0
189.3	3	1	0
189.9	2	1	2
190.5	1	0	0
191.1	1	1	0
191.8	1	1	0

** Only segments that had at least one trail are included in the table. MP delineates the starting point (western boundary) of a segment.*

Table 2. Results of 3 km enumeration analysis for trails, GNESA wildlife crossings, and roadkill.

MP	Trails	GNESA	Roadkill
153.0	0	1	4
154.9	3	3	3
156.7	2	2	2
158.6	2	2	2
160.4	5	1	1
162.3	3	1	3
164.2	0	0	0
166.0	2	1	2
167.9	8	1	5
169.7	3	0	1
171.6	9	2	8
173.5	1	3	12
175.3	1	2	2
177.2	1	1	1
179.1	9	2	6
181.0	16	3	5
182.9	10	0	0
184.7	2	2	2
187.0	2	0	0
189.1	6	2	2
191.0	3	2	0

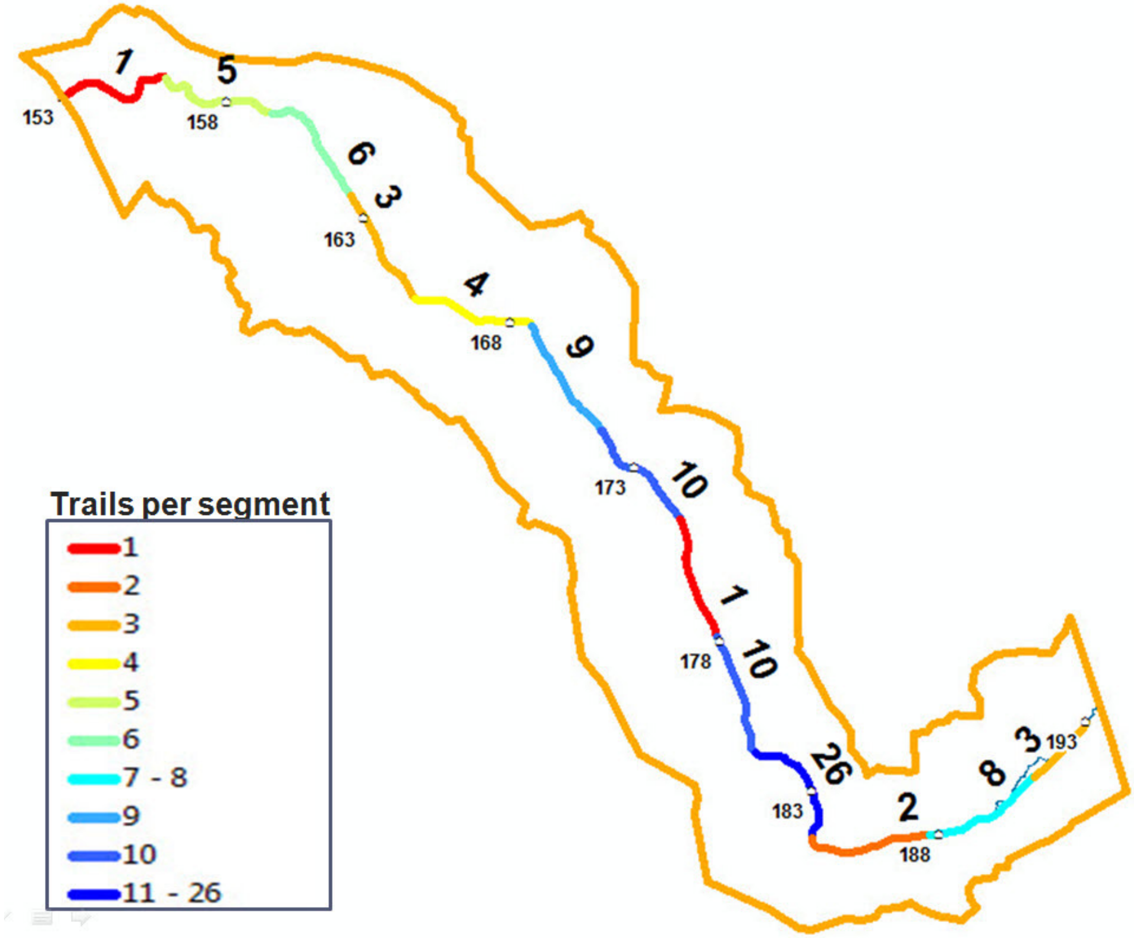

Figure 5. Trails per 5 km segment of US-2.

Table 3. Results of 5 km enumeration analysis for trails, GNESA wildlife crossings, and roadkill.

MP	Trails	GNESA	Roadkill
153.0	1	3	6
156.1	5	4	3
159.2	6	2	3
162.4	3	1	3
165.5	4	1	4
168.6	9	1	4
171.7	10	5	17
174.8	1	2	5
178.0	10	3	7
181.1	26	3	5
184.2	2	2	2
187.3	8	2	2
190.4	3	2	0

Table 4. List of bridges and tunnels along US-2 and the number of trails and GNESA wildlife crossing locations within 1 km.

Structure	**MP**	**Trails**	**GNESA**
RR Tunnel 2	153.0	2	2
RR Tunnel 3	156.1	3	2
Bridge over Deerlick Creek	159.2	2	0
Bridge over RR 1	162.4	0	0
Bridge over RR 2	165.5	2	1
RR Tunnel 1	168.6	8	1
Middle Fork Flathead Bridge at Essex	171.7	4	0
Goat Underpass	174.8	8	2
Bridge over Snowslide Gulch	178.0	7	1
RR Bridge over Hwy	181.1	6	0
Bridge over Bear Creek	184.2	1	1
Bridge over Devil Creek	187.3	4	1
Bridge over Bear Creek 2	190.4	1	1

Cameras

Results from both years of camera monitoring are shown in Table 5. There were 59 wildlife incidents in 2008 and 253 wildlife incidents in 2009, for a two year total of 312 incidents (Table 5). Animals appeared to use roadside trails during hours of low traffic volumes (Fig. 6). The hour with the most camera incidents was the 21:00 hour. The traffic category with the most incidents was “Lowest” (N = 144, 46%). There were slightly more daytime incidents than nighttime incidents (Fig. 7). The most incidents per day in 2008 at a camera location in a single session was 0.47 at trail 304 (MP 160.5), and the most incidents per day at a camera location in 2009 in a single session was 0.69 at trail 540 (Table 6). There was an average of 0.22 incidents per day amongst monitored trails in 2008, and an average of 0.28 incidents per day in 2009. The average for the two years combined was 0.25 incidents per day.

Table 5. Camera incidents by species and year.

Species	2008	2008%	2009	2009%	Total	Total %
Deer	45	76.3	159	62.8	204	65.4
Elk	10	16.9	76	30.0	86	27.6
Moose	3	5.1	5	2.0	8	2.6
Black Bear	0	0.0	5	2.0	5	1.6
Coyote	0	0.0	1	0.4	1	0.3
Hare	1	1.7	5	2.0	6	1.9
Wolf	0	0.0	1	0.4	1	0.3
Cougar	0	0.0	1	0.4	1	0.3
Total	**59**	**100**	**253**	**100**	**312**	**100**

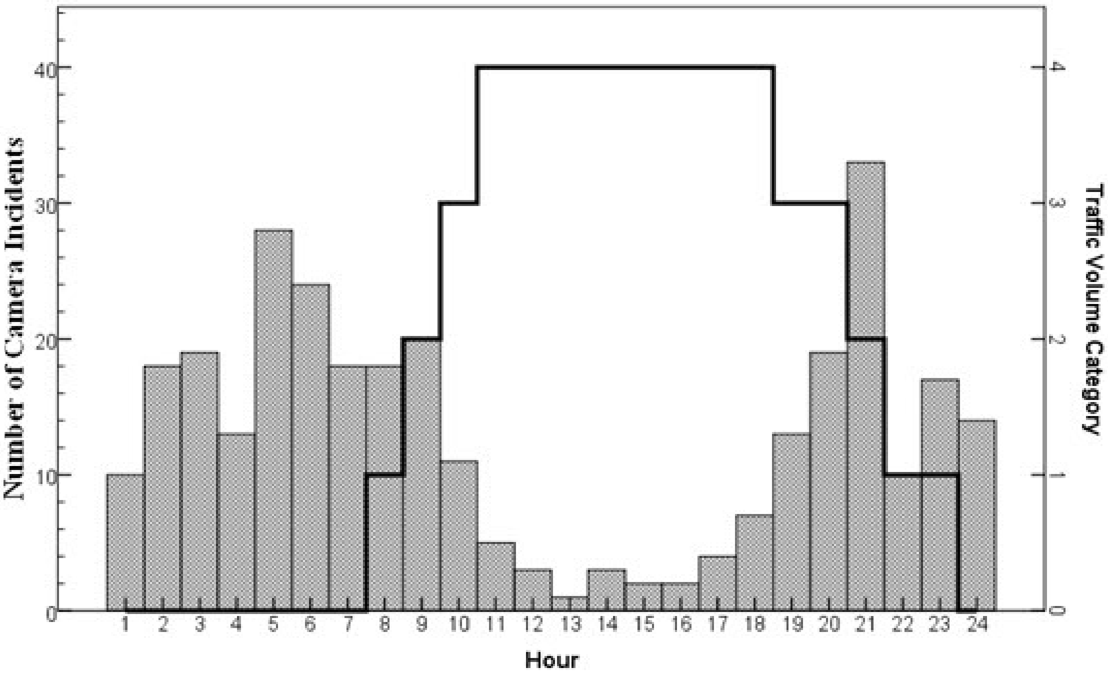

Figure 6. Total number of camera incidents per hour (*bars*) plotted against hourly traffic volume categories (*lines*).

**Traffic Categories based on hourly traffic volumes from Waller and Servheen (2005): 0=Lowest (vehicles/hr < 20), 1=Low (20 < vehicles/hr < 60), 2=Moderate (60 < vehicles/hr < 80), 3=High (80 < vehicles/hr < 130), and 4=Highest (vehicles/hr >130).*

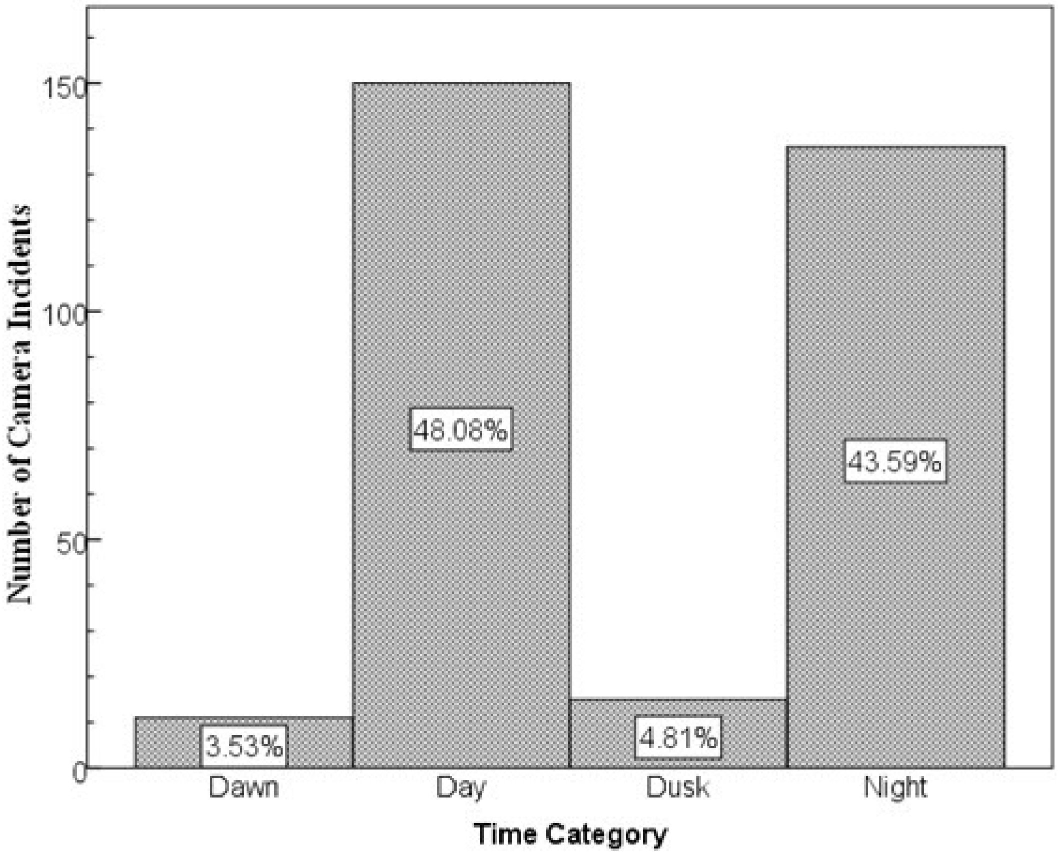

Figure 7. Number and percentage of camera incidents per time category.

Table 6. Camera results arranged according to incidents-per-day (descending).

Trail	MP	Incidents/ Day	Trail	MP	Incidents/ Day
540	181.8	0.69	428	169.4	0.23
548	181.2	0.65	510	183.2	0.23
478	187	0.50	513	184	0.22
443	172.8	0.47	444	183.1	0.15
501	187.8	0.46	484	189.8	0.12
542	181.6	0.42	508	160.5	0.11
521	179.4	0.41	514	184	0.11
377	167.5	0.38	402	168.3	0.08
589	172.9	0.38	493	177.4	0.08
547	181.4	0.34	537	181.5	0.08
307	160.5	0.33	512	181.6	0.07
392	168.9	0.33	488	189.4	0.06
436	182.1	0.33	590	172.9	0.05
415	169.9	0.27	379	167.5	0.04
546	181.4	0.27	421	170.9	0.00
361	163.9	0.25	479	175.4	0.00
304	160.5	0.23	545	181.6	0.00

Table 7. Results for camera locations that had at least one elk incident.

Trail	**MP**	**Elk Incidents**	**Elk Incidents per day**	**Dist to GNESA Elk**	**Land Ownership**
548	181.2	10	0.38	1.72	GNP
478	187	19	0.35	1.19	National Forest
510	183.2	16	0.23	0.27	GNP
521	179.4	7	0.21	0.20	Private
443	172.8	3	0.2	0.12	National Forest
501	187.8	5	0.18	2.14	National Forest
540	181.8	4	0.15	0.46	GNP
444	183.1	9	0.13	0.11	GNP
547	181.4	5	0.07	1.72	GNP
415	169.9	1	0.04	2.67	State Trust
484	189.8	1	0.04	1.01	National Forest
513	184	1	0.04	0.10	GNP
443	167.5	1	0.04	0.41	National Forest
377	172.8	1	0.04	0.38	National Forest
589	172.9	3	0.03	1.01	National Forest

** The distance (km) from each camera location to the nearest GNESA elk crossing location is also listed.*

Modeling

Multicollinearity would have been considered problematic for variables whose tolerance (Tol.) was less than 0.1 and whose variance inflation factor (VIF) was greater than 10. However, multicollinearity was not an issue for any of the three models (Tol. > .4, VIF ≤ 2). All three full models contained seven variables: GNP, DistCov, DistRip, DistRR, ElevSD, PopDens, and Roads.

In all three data sets, trail locations had a shorter distance from the center of the highway to the edge of cover than did random point locations (Table 8). Also, trails were located closer to riparian areas and further from the BNSF railroad than were random points. At the 50 m scale, elevation standard deviation was smaller for trails; and at the 100 m and 500 m scales, elevation standard deviation was greater for trails. Road density and population density were higher for trails in all three data sets. Lastly, the percentage of points within GNP boundaries was greater for trails in all three data sets.

Table 8. Summary statistics (mean) for trails (N = 88) and random points (Rand; N = 500) at the 50 m, 250 m, and 500 m scales.

Model	**DistCov**	**DistRip**	**DistRR**	**ElevSD**	**Roads**	**PopDens**	**GNP%**
Trails 50m	35.76	265.19	236.17	7.99	2.02	3.86	29.55
Rand 50m	71.08	340.50	201.72	8.75	.93	3.17	10.22
Trails 250m	35.76	265.19	236.17	28.18	18.37	3.90	29.55
Rand 250m	84.88	364.68	196.21	25.75	13.48	3.23	5.00
Trails 500m	35.76	265.19	236.17	51.91	51.84	3.68	29.55
Rand 500m	107.75	386.08	191.36	44.00	43.13	3.27	5.00

** Distance (Dist) variables and ElevSD are measured in meters. Population Density (PopDens) is a measure of persons/km^2, Roads is the number of 20 m segments of road per buffer, and GNP% is the percentage of trails or random points within GNP boundaries.*

50m Model

In univariate analyses, the variables GNP, DistRip, DistCov, and Roads all had signficant coefficients ($p < 0.05$); and the variables ElevSD, DistRR, and PopDens lacked significance. There were four models in the set of plausible models (Table 9). The full model (model 4) showed goodness-of-fit, but had three non-significant variable coefficients. Models 2 and 3 were the most parsimonious models. Model 2 and Model 3 both consisted of five variables—all of which had significant coefficients.

Based on the coefficients (β) of variables in the best approximating model, it appeared that trails were negatively correlated to distance to cover, distance to riparian area, and elevation standard deviation; and trails were positively correlated to land ownership by GNP, population density, and road density (Table 10).

250m Model

In univariate analyses, the variables GNP, DistRip, DistCov, and Roads all had signficant coefficients ($p < 0.05$); and the variables ElevSD, DistRR, and PopDens lacked significance. There were three models in the set of plausible models (Table 11). The full model lacked fit and was not included in the set of plausible models.

Table 9. Set of plausible models ($\Delta_i < 2$) for the 50m model.

Model	Variables in model	-2LL	df	$AICc_i$	Δ_i	X^2	P
1	GNP, DistCov, DistRip, ElevSD, PopDens, Roads	440.64	6	456.89	0.00	8.58	0.38
2	GNP, DistCov, DistRip, PopDens, Roads	443.16	5	457.36	0.47	3.65	0.89
3	GNP, DistCov, DistRip, ElevSD, PopDens	443.90	5	458.10	1.21	11.87	0.16
4	GNP, DistCov, DistRip, DistRR, ElevSD, PopDens, Roads *(full)*	440.37	7	458.68	1.79	5.38	0.72

** -2LL = log likelihood, df = degrees of freedom, $\Delta_i = [AICc_i - AICc_{min}]$, X^2 = Hosmer and Lemeshow chi-square, and P = chi-square significance. P values > 0.05 suggest overall goodness-of-fit for a given model. N = 588 for all models.*

Table 10. Parameter estimates for the best approximating model of the 50m model data set.

Variable	ß	S.E.	Wald	P	Exp(B)	-95%	+95%
GNP	1.017	0.359	8.025	0.005	2.764	1.368	5.584
DistCov	-0.013	0.004	9.791	0.002	0.987	0.979	0.995
DistRip	-0.001	0.001	4.406	0.036	0.999	0.998	1.000
ElevSD	-0.031	0.020	2.429	0.119	0.969	0.932	1.008
PopDens	0.043	0.018	5.840	0.016	1.044	1.008	1.082
Roads	0.127	0.068	3.457	0.063	1.135	0.993	1.298
Constant	-1.020	0.318	10.262	0.001	0.361		

Table 11. Set of plausible models ($\Delta_i < 2$) and the full 250m model.

Model	Variables in model	-2LL	df	$AICc_i$	Δ_i	X^2	P
1	GNP, DistCov, DistRip, DistRR, PopDens	398.94	5	412.69	0.00	21.92	0.01
2	GNP, DistCov, DistRip, DistRR, PopDens, Roads	398.19	6	414.44	1.31	17.98	0.02
3	GNP, DistCov, DistRip, DistRR, ElevSD, PopDens	398.88	6	415.13	2.00	22.19	0.01
full	GNP, DistCov, DistRip, DistRR, ElevSD, PopDens, Roads	398.15	7	416.46	3.33	17.98	0.02

** -2LL = log likelihood, df = degrees of freedom, $\Delta_i = [AICc_i - AICc_{min}]$, X^2 = Hosmer and Lemeshow chi-square, and P = chi-square significance. P values > 0.05 suggest overall goodness-of-fit for a given model. N = 588 for all models.*

The full model had two non-significant variable coefficients: Roads and ElevSD. Model 1 was the most parsimonious model. It consisted of five variables— GNP, DistRip, DistCov and PopDens—all of which had significant coefficients. However, Model 1 lacked fit according to the Hosmer and Lemeshow goodness-of-fit test—as did the rest of the models in the set of plausible models. Based on the coefficients (β) of variables in the best approximating model, it appeared that trails were negatively correlated to distance to cover and distance to riparian area; and trails were positively correlated to land ownership by GNP, population density, and distance to the railroad (Table 12).

Table 12. Parameter estimates for the best approximating model of the 250m model data set.

Variable	β	S.E.	Wald	P	Exp(B)	-95%	+95%
GNP	2.194	0.379	33.592	< 0.001	8.969	4.271	18.833
DistCov	-0.020	0.004	22.405	< 0.001	0.980	0.972	0.988
DistRip	-0.002	0.001	7.404	0.007	0.998	0.997	1.000
DistRR	0.002	0.001	6.363	0.012	1.002	1.000	1.003
PopDens	0.066	0.021	10.120	0.001	1.069	1.026	1.113
Constant	-1.166	0.269	18.735	< 0.001	0.311		

500m Model

In univariate analyses, the variables GNP, DistRip, DistCov, ElevSD all had signficant coefficients ($p < 0.05$); and the variables Roads, DistRR, and PopDens lacked significance. There were three models in the set of plausible models (Table 13). The full model lacked overall fit, was not included in the set of plausible models, and had two non-significant variable coefficients (Roads and ElevSD). Model 1 was the most parsimonious model. It consisted of five variables— GNP, DistRip, DistCov, DistRR and PopDens—all of which had significant coefficients. However, model1 lacked overall fit. The only model in the set of plausible models that showed goodness-of-fit was model 3. Thus, I have included Table 15 to show the parameter estimates for model 3.

Based on the coefficients (β) of variables in the best approximating model, it appeared that trails were negatively correlated to distance to cover and distance to riparian area; and trails were positively correlated to land ownership by GNP, population density, and distance to the railroad (Table 14).

Table 13. Set of plausible models ($\Delta_i < 2$) and the full 500m model.

Model	**Variables in model**	**-2LL**	**df**	**$AICc_i$**	**Δ_i**	**X^2**	**P**
1	GNP, DistCov, DistRip, DistRR, PopDens	386.99	5	401.18	0.00	16.67	0.03
2	GNP, DistCov, DistRip, DistRR, ElevSD, PopDens	386.33	6	402.58	1.40	13.57	0.09
3	GNP, DistCov, DistRip, DistRR, PopDens, Roads	386.65	6	402.90	1.72	8.19	0.41
full	GNP, DistCov, DistRip, DistRR, ElevSD, PopDens, Roads	385.86	7	404.17	2.99	14.52	0.07

** -2LL = log likelihood, df = degrees of freedom, $\Delta_i = [AICc_i - AICc_{min}]$, X^2 = Hosmer and Lemeshow chi-square, and P = chi-square significance. P values > 0.05 suggest overall goodness-of-fit for a given model. N = 588 for all models.*

Table 14. Parameter estimates for the best approximating model of the 500m model data set.

Variable	**ß**	**S.E.**	**Wald**	**P**	**Exp(B)**	**-95%**	**+95%**
GNP	2.194	0.387	30.899	< 0.001	8.579	4.021	18.305
DistCov	-0.018	0.004	19.656	< 0.001	0.983	0.975	0.999
DistRip	-0.002	0.001	9.902	0.002	0.998	0.997	0.999
DistRR	0.002	0.001	8.114	0.004	1.002	1.001	1.003
PopDens	0.058	0.020	8.693	0.003	1.060	1.020	1.102
Constant	-1.105	0.266	17.242	< 0.001	0.311		

Table 15. Parameter estimates for model 3 of the 500m model data set.

Variable	**ß**	**S.E.**	**Wald**	**P**	**Exp(B)**	**-95%**	**+95%**
GNP	2.158	0.387	31.023	< 0.001	8.656	4.050	18.499
DistCov	-0.018	0.004	19.731	< 0.001	0.983	0.975	0.990
DistRip	-0.002	0.001	9.769	0.002	0.998	0.997	0.999
DistRR	0.002	0.001	6.226	0.013	1.002	1.000	1.003
PopDens	0.049	0.025	3.837	0.050	1.050	1.000	1.103
Roads	0.002	0.004	0.348	0.555	1.002	0.994	1.011
Constant	-1.171	0.289	16.416	< 0.001	0.310		

DISCUSSION

I surveyed for wildlife trails at the edge of vegetative cover on either side of US-2 from MP153 to MP193. A total of 88 major wildlife trails were identified. I found that the large majority (N = 64, 85%) of trails were located either at the end of a guardrail or in areas where there were no guardrails present. These results appear consistent with other research that has shown wildlife avoidance of guardrails (Barnum 2003, Clevenger et al. 2006) or wildlife selection of areas where guardrails end (Barnum 2007). Clevenger et al. (2006) suggest that barriers such as guardrails may obstruct animal movement and funnel animals to barrier ends, or that animals may avoid landscape features associated with barriers (e.g. steep roadside topography).These results suggest that the barrier is obstructing animal movement and funneling animals to barrier ends, or particular features in the landscape associated with barriers such as lakes and steep topography are deterring animals from approaching the highway at these locations. Although there is little, if any, research examining the effects of the number of lanes on wildlife highway crossings, I found that no trails were located in the only four-lane stretch of highway in the study area. However, this may be due to the fact that this stretch of highway ran through the residential community of Pinnacle, MT. Wildlife trails were most significantly clustered at the 5-8 km scales.

Although several studies have used cameras to monitor highway structures for wildlife use, very few studies have used remote cameras to monitor roadside trails. Thus, it is difficult to determine whether the average incidents-per-day in my study is more or less than normal. For example, Scheick and Jones (1999) monitored wildlife trails US Highway 64 in North Carolina but did not report how many animals-per-day were detected. Switalski et al. (2007) found an average of about 0.4 wildlife incidents-per-day;

yet, these results were not for trails, but for decommissioned forest service roads in Idaho's Clearwater National Forest. Also, Servheen and Shoemaker (2003) found a "use rating" (i.e. incidents-per-day) of about 0.46 at highway underpasses on Interstate 90 from Alberton to St. Regis, Montana. Results from my camera monitoring surveys were probably conservative due to animals using monitored trails without being caught on camera. The ratio of the number of animals using a monitored trail to the number of animals actually caught on camera was unknown. I speculate the majority of ungulates and bears that passed in front of cameras were photographed since these animals are large and, thus, more likely to be detected by the camera's infrared beam. Smaller animals—such as coyotes, foxes, bobcats, lynx, snowshoe hares, pine martens, and possibly cougars—may have been missed by cameras more frequently than larger animals due to their size.

I initially assumed that multiple species create, use, and share trails near the highway. Results of camera surveys showed a total of 8 different mammalian species using the trails I identified, with deer and elk being by far the most commonly photographed species. Consequently, it may be that the trails I identified are mostly deer and elk trails that receive occasional use by other species. A total of 312 wildlife incidents were caught on camera during 2008 and 2009. Wildlife appeared to use trails more frequently during hours of relatively lower traffic volumes. Other studies have also shown higher use of highway crossings by wildlife during periods of lower traffic volumes (e.g. Waller and Servheen 2005, Gagnon et al. 2007). Further monitoring of wildlife trails with remote cameras should be considered by future research projects in the US-2 corridor in order to gain a more complete understanding of wildlife activity on roadside trails.

I was unable to document the presence/absence of a passing zone for randomly generated points because there were no shapefiles for passing zones in the study area. Also, I was unable to document the presence/absence/end of a guardrail for random points. I had been able to document the presence/absence of guardrails for trails while I was in the field; but I thought that the spatial errors associated with digitally snapping random points to US-2 and navigating to these points in the field with a GPS would have resulted in inaccurate data. Passing zone and guardrail data might have been useful in the logistic regression analyses.

I delineated wildlife crossing zones based on the number of trails, previously identified wildlife crossings (GNESA crossings), camera incidents-per-day, potential parcels of land for conservation, and highway and railroad structures in a given area. Of the features listed above, the most important in determining crossing zones was the number of trails in a given area. Camera results and GNESA crossings were the second most important factors. I ranked camera results primarily by wildlife incidents-per-day, but I also considered the types and diversity of species caught on camera in an area.

I found that the primary crossing zone in the study area was located from MP179-184. This 8 km stretch of US-2 contained 36 (41%) of the 88 trails (Fig. 8-9). The 5 km segment of US-2 with the most trails (N=26, 30%) was located from ~MP181-184, the 3 km segment with the most trails (N = 16, 18%) was located from MP181-182.9, and the 1 km segment with the most trails (N=8, 9%) was located from MP181-181.8. A total of 8 trails—which included four of the top ten camera locations (in terms of incidents-per-day)—were located between MP181-182. Deer, moose, black bear, coyote, and elk were all caught on camera between MP181-184. While conducting trail identification and camera surveys, I frequently spotted groups of mule deer on or alongside the highway in this area.

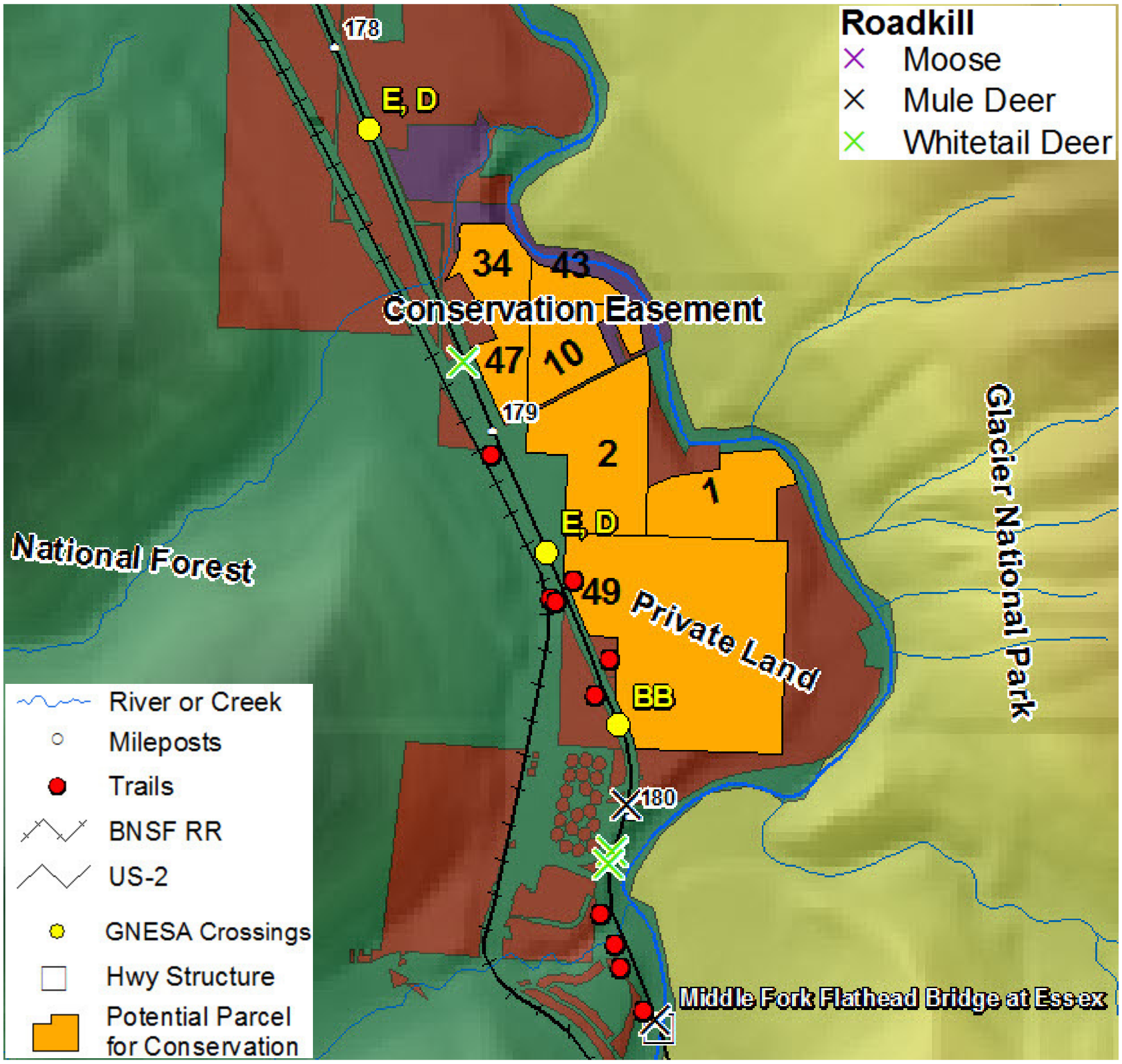

Figure 8. Trails, GNESA wildlife crossings, roadkill, highway structures, and potential conservation parcels near Essex, MT.
**Parcels 1 and 2 = USFS. Parcels 10, 34, 43, and 47 = Private Landowner. Parcel 49 = Three Hole Limited Partnership.*
***GNESA crossings: BB = Black Bear, and D = Deer, E = Elk.*

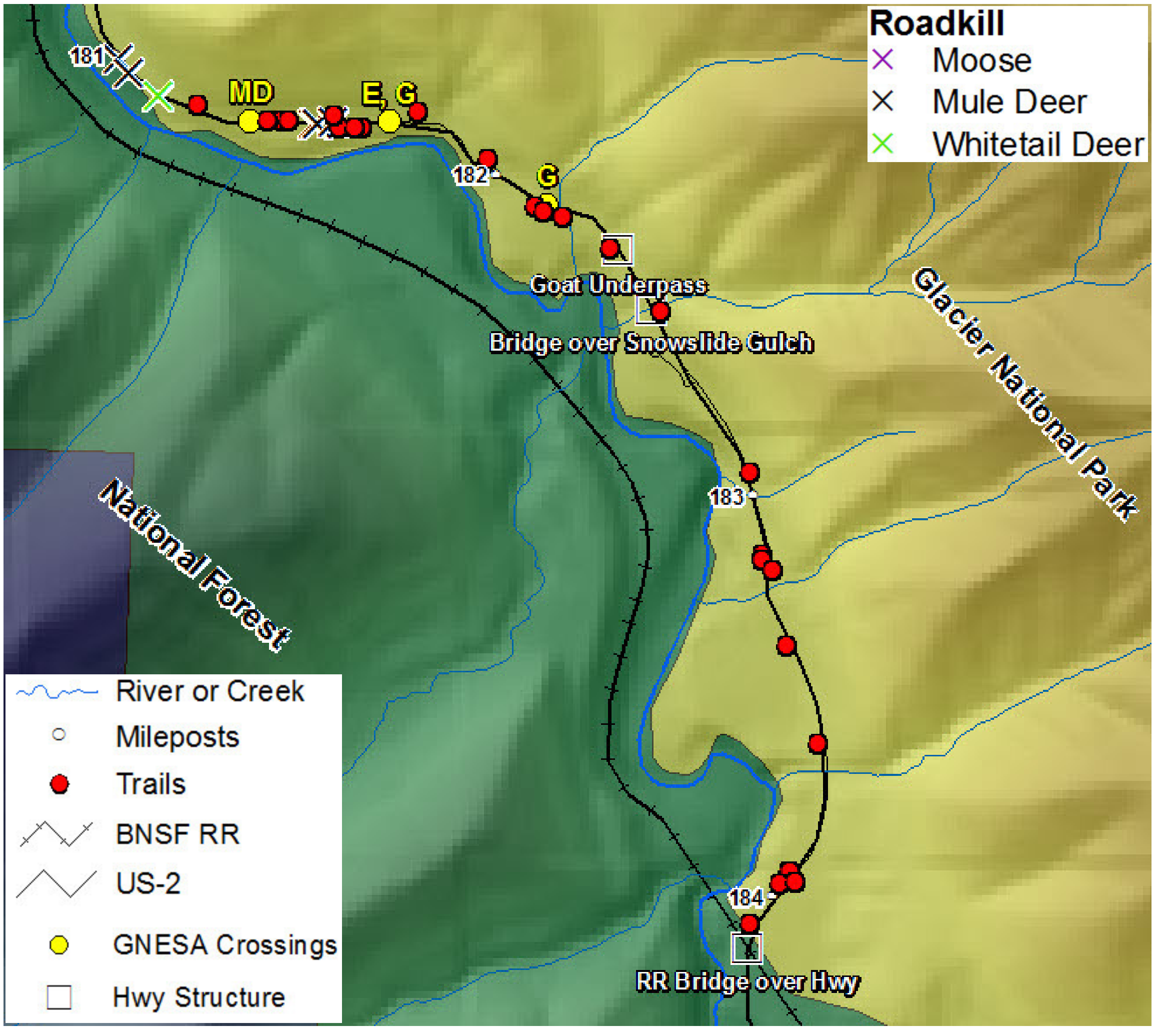

Figure 9. Trails, GNESA wildlife crossings, roadkill, and highway structures from MP181-184. **GNESA crossings: E = Elk, G = Goats, and MD =Mule Deer.*

The stretch of US-2 from MP179-184 was entirely a no-passing zone. Also, unlike the rest of the study area, the speed limit from ~MP181-184 was 88 kph (55 mph) as opposed to 112 kph (70 mph). Although research has shown that reduced speed limits can reduce the rate of wildlife-vehicle collisions (Bertwistle 1999, Seiler 2005) and that high speed limits are one of the leading causes of wildlife-vehicle collisions (Pojar et al. 1975, Case 1978), little research has been done to study the effects of speed limit or passing zones on the presence of roadside wildlife trails.

The stretch of US-2 from MP180.5-184 was the only section of the study area where the highway was inside GNP boundaries—where hunting of any kind is prohibited. Results of all three logistic regression models showed that there was a significant positive correlation between GNP land ownership and the presence of wildlife trails. Compared to most of the study area, there was a relatively large distance between the BNSF railroad and US-2 in this area, which may provide wildlife with fewer obstacles and more room on either side of the highway to move and forage.

The only railroad bridge over the Middle Fork of the Flathead River was located near MP184. This large truss bridge may provide animals with a safe opportunity for crossing the BNSF railroad. Also, the mountain goat underpass, a highway bridge over Snowslide Gulch, a highway bridge over the Middle Fork of the Flathead River, and a railroad bridge over the highway are all located between MP180.5-184—and these structures may provide animals in the area with safe opportunities to cross either the highway or railroad.

Another crossing zone was located near Tunnel Creek (MP173; Fig. 10). In this area, there was a 300 m segment of road that contained 8 trails. A total of 10 trails and 3 GNESA wildlife crossings were located from MP172-174. Parcels of land on both sides of the highway in this area were identified by GNESA as potential areas for conservation. The owner of the nearby Glacier Haven Inn (MP173.5) reported to me that he had seen many ungulates cross the highway above the railroad tunnel. Several deer and elk, one wolf, and one cougar were caught on camera in this area.

A railroad tunnel ran underneath the highway near MP173, and most of the trails in this area were located directly above the tunnel. A large culvert ran underneath the highway at Tunnel Creek (Fig. 11), and a railroad bridge crossed over Tunnel Creek near the railroad tunnel.

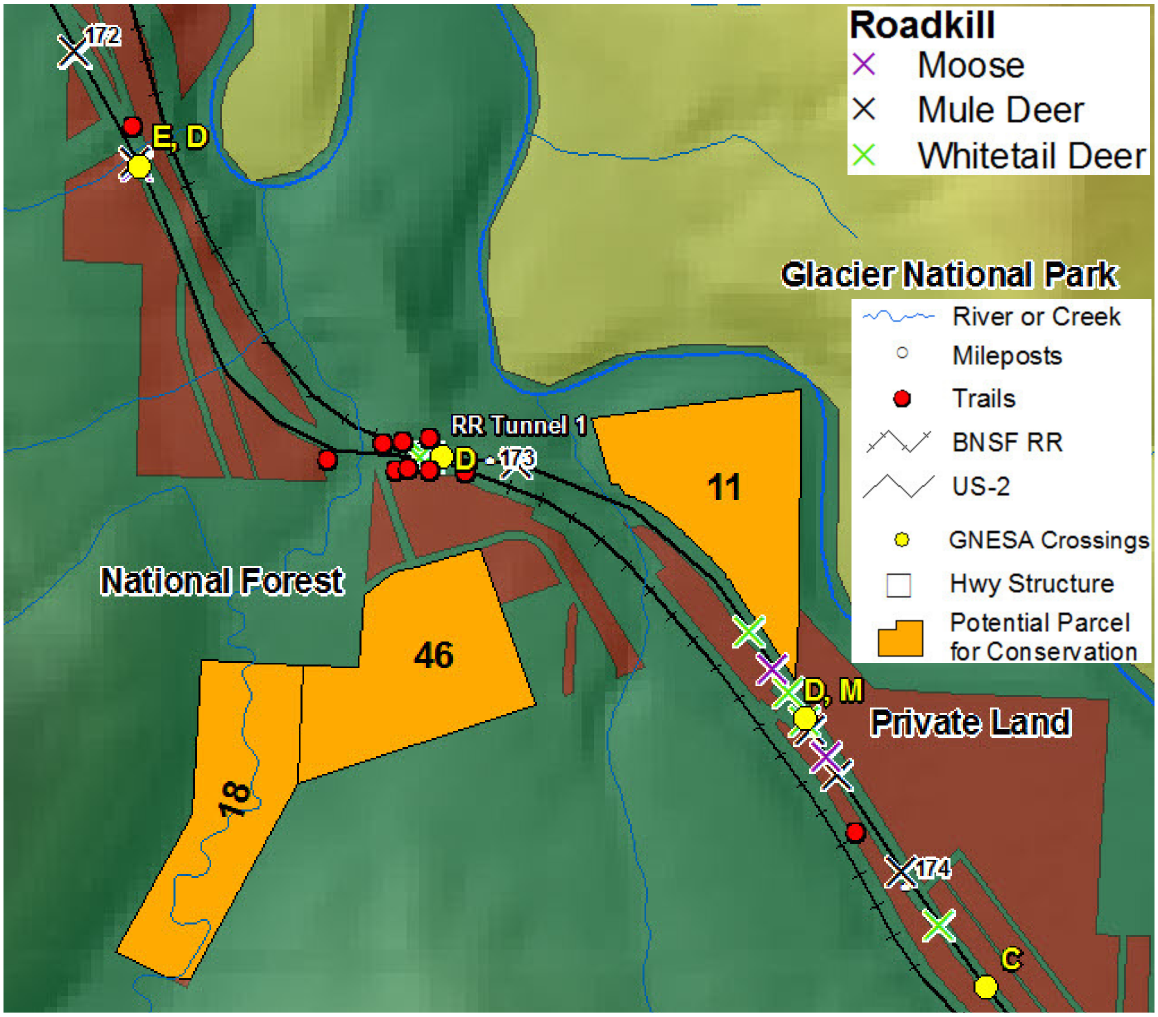

Figure 10. Trails, GNESA wildlife crossings, roadkill, potential parcels for conservation, and highway structures near Tunnel Creek (MP 173).
**Parcel 11 = Glacier River Retreat LLC. Parcels 18 and 46 = Tunnel Creek Undevelopment Com. **GNESA crossings: C = Cougar, D = Deer, E = Elk, M = Moose, and MD =Mule Deer.*

With the railroad tunnel and bridge present, animals in the area had two relatively safe options for crossing the railroad. There may be potential to modify the culvert below the highway to make it more conducive to wildlife use (Rodriguez et al. 1996). If the culvert were made larger or converted into an underpass or bridge, animals in this area could potentially cross both the highway and railroad safely. Yet, further research is needed in this area before such measures are implemented.

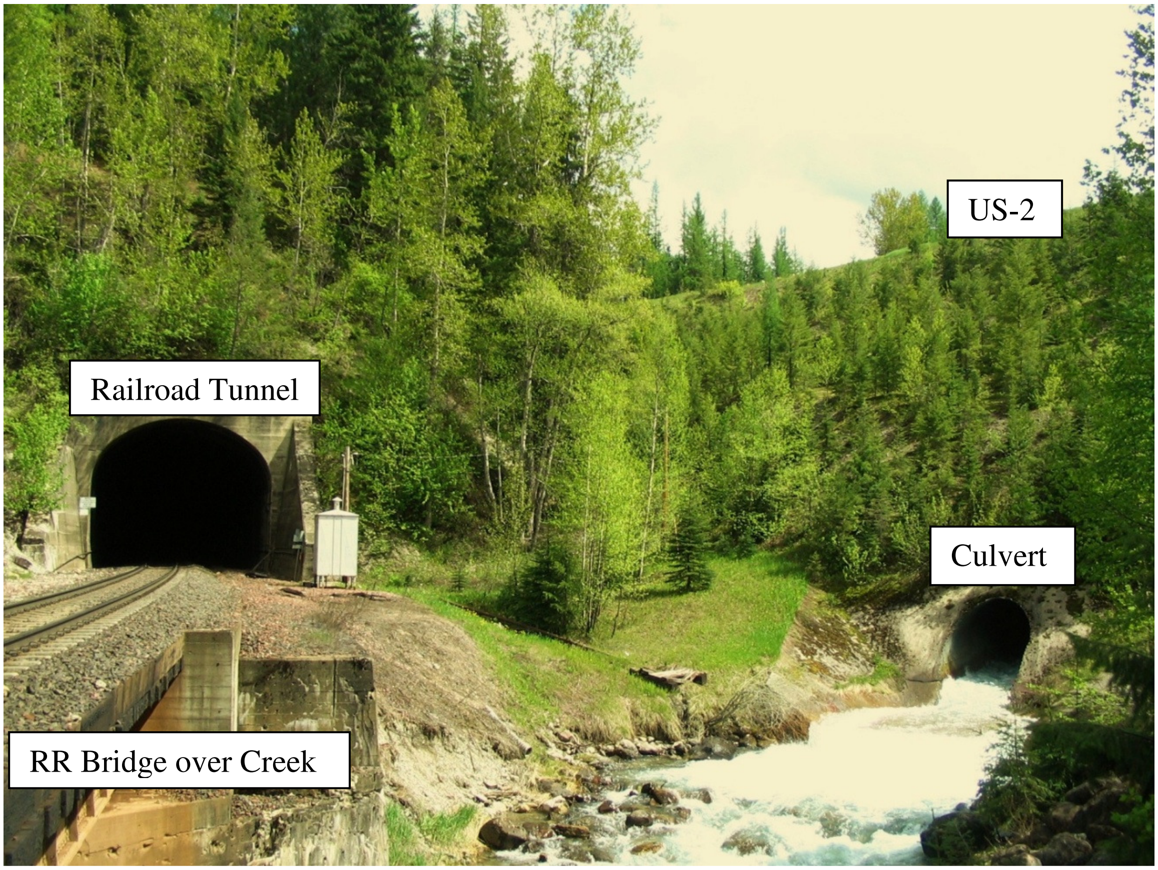

Figure 11. Railroad tunnel and large culvert located below US-2 at Tunnel Creek (MP173).

The segment of US-2 from MP189-193 is worth noting as a crossing zone due to the presence trails, GNESA wildlife crossings, highway structures, and potential parcels for conservation located in this area (Fig. 12). There were 9 trails and 4 GNESA wildlife crossing locations in this area. The two GNESA crossings between MP192-193 were described as heavily-used, year-round elk crossing locations. Near these elk crossing locations, there were: 2 wildlife trails, several parcels of land that were considered potential areas for conservation, and a highway bridge over Bear Creek.

Although there was a fairly low density of trails in the area from MP185-189, (Fig. 13), I still believe that the segment of US-2 from MP187-188 deserves recognition as a crossing zone because it contained trail 478 (MP187) and trail 501 (MP188)—which had the third and fifth most wildlife incidents-per-day (IPD = 0.5 and 0.46, respectively). There were 7 deer, 19 elk, and 1 black bear seen on camera at trail 478. Trail 478 had the second highest elk-per-day value (EPD = 0.35). Trails 478 and 501 were both monitored with cameras only during the 2009 season. There were two Elk/Deer GNESA crossing locations 1.3 km and 2.2 km from trail 478.

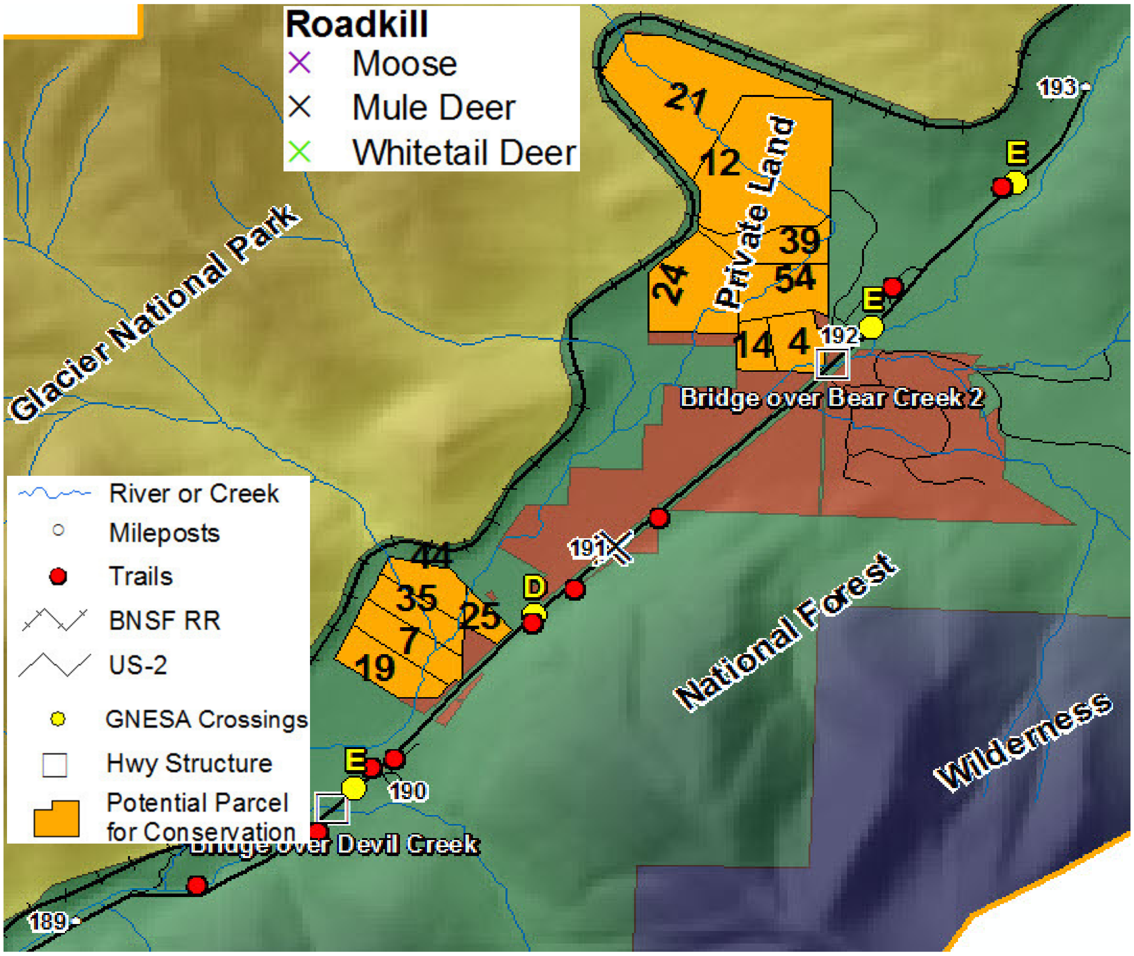

Figure 12. Trails, GNESA crossing locations, roadkill, highway structures, and potential parcels for conservation from MP189-193.
**Parcels 4, 7, 14, 19, 21, 27, 25, 35, 39, 44, and 54 = Private Landowner. Parcel 12 = CDJ Management LLC. **GNESA Crossings: D = Deer and E = Elk.*

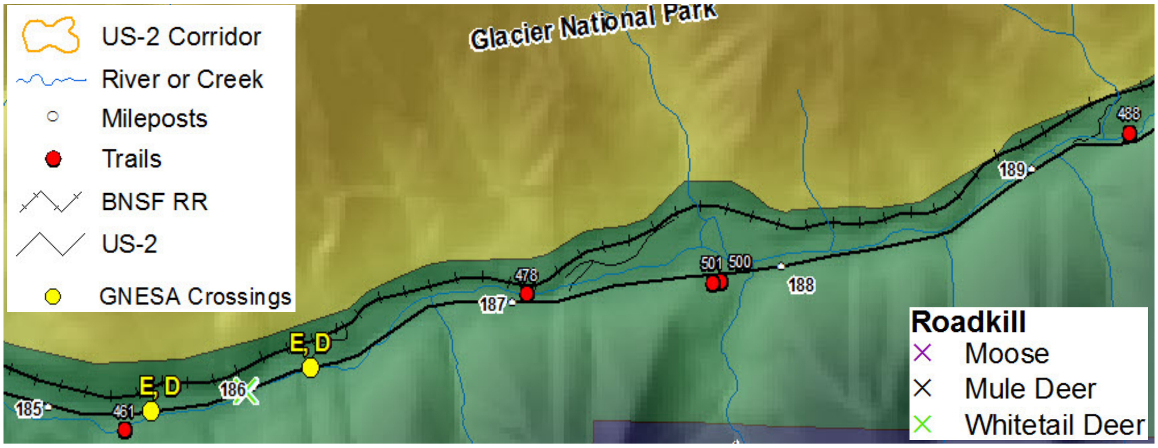

Figure 13. Trails 478 and 501, and nearby GNESA wildlife crossings, trails, and roadkill. **GNESA Crossings: D = Deer and E = Elk*

Lastly, the segment of US-2 from MP167-171 is a crossing zone because contained 13 trails and 2 GNESA wildlife crossing locations (Fig. 14). There was also a railroad bridge over US-2 at MP167.5, and two trails were located within 50 m of the bridge.

Land ownership by GNP had a significant positive correlation to the presence of trails in all plausible models of the three logistic regression analyses. The percentage of trails within GNP was greater than the percentage of random points in GNP. The best approximating models for 250m model and the 500m model both consisted of the same five variables: GNP, DistCov, DistRip, DistRR, and PopDens. Also, all plausible models for each full model contained the distance to riparian and distance to vegetative cover variables—both of which had a significant negative coefficients. In other words, trail locations tended to have a shorter distance to riparian areas and a shorter distance from the highway to the edge of cover than did random point locations. Also, based on coefficients (B) from multiple logistic analyses and on summary statistics for trails and random points (Table 8 *above*), it appeared that trail locations, compared to random point locations, were further from the BNSF railroad.

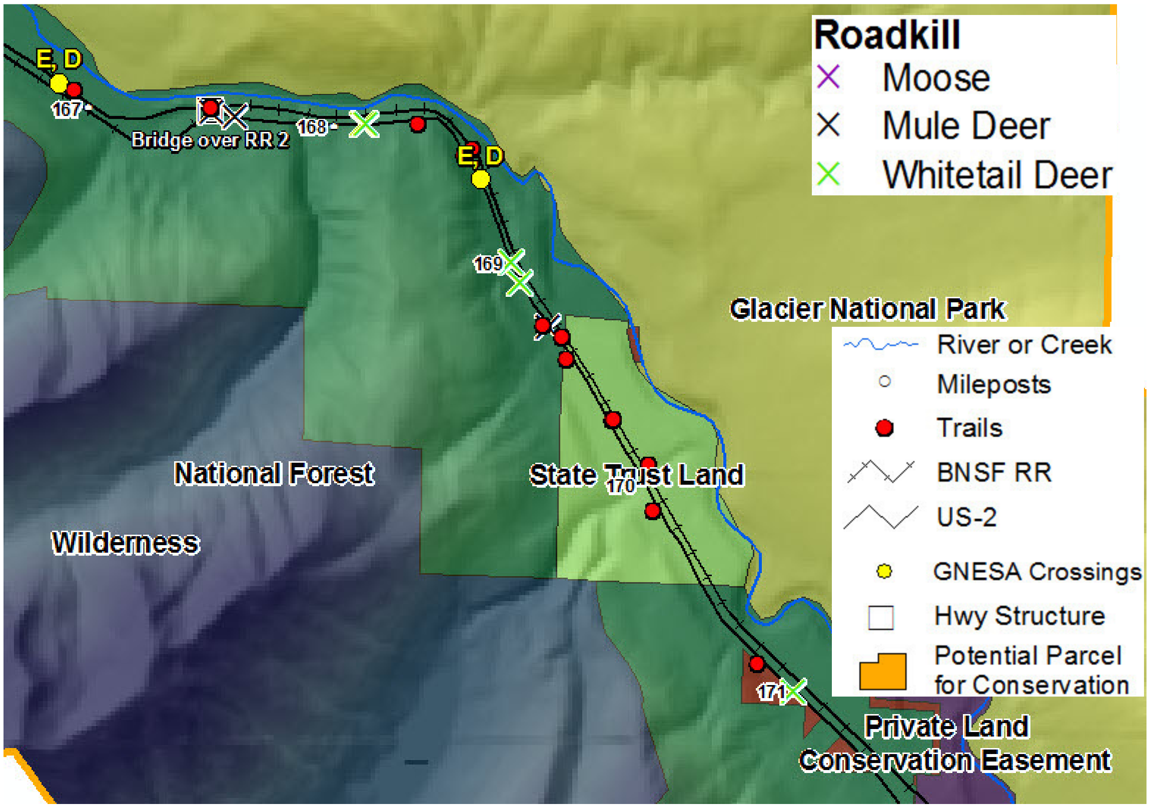

Figure 14. Trails, GNESA crossing locations, roadkill, and highway structures from MP167-171.
** GNESA Crossings: D = Deer and E = Elk.*

The average elevation standard deviation (or, terrain ruggedness) was higher for trails than for random points at the 250 m and 500 m scale, but lower for trails than for random points at the 50 m scale. One possible explanation for this may be that more rugged terrain at the 250 m and 500 m scales could be associated with less human activity, disturbance, or development. This makes sense when considering that the mean population density and mean road density were greater for trails than for random points. Terrain ruggedness may be lower for trails than for random points at the 50 m scale because lower terrain ruggedness at the 50 m may make it easier for animals to approach the highway. Another explanation may be that since the mean distance from trail locations to the center of the highwas was less than 50 m, the flatness of the roadway may have impacted the terrain ruggedness of several 50 m trail buffers; yet, no collinearity was shown to exist between the variables for distance to cover and elevation standard deviation. Trail locations had a higher population density than random point locations at all three scales. This was likely because many trails were located near, but not in, human communities. In particular, there was an area of trail clustering just west of Pinnacle, MT and another area of trail clustering just east of Essex, MT.

I marked trails regardless of whether there was a corresponding trail on the other side of the highway. Of the 88 major trails I identified, 49 (56%) had a trail within 500 m on the opposite side of the highway and 39 (44%) did not. There was nearly always at least one minor trail within 500 m of a major trail on the opposite side of the highway. The presence of a trail or trails did not necessarily mean that animals crossed the highway in that location. Also, wildlife incidents caught on camera were likely more representative of wildlife activity near the highway then of actual wildlife highway crossings. Upon reviewing the camera data, I was unable to document instances where a camera incident on one side of the highway corresponded to a camera incident of the same species (or, individual animal) on the other side of the highway within a ~10 minute period. This may because animals were either not crossing the highway, or because they were using trails immediately after crossing the highway. In other words, animals may have used trails to approach the highway for crossing and then entered vegetative cover on the other side wherever possible. Despite the uncertainty of animal crossing behavior, I nevertheless believe that trail locations and the camera results found in this study provide critical baseline information about wildlife activity along US-2, and are therefore useful for the prioritization of future research and mitigation measures in the US-2 corridor. The results of this study—including all maps, shapefiles, and datasets—will be made available to the Great Northern Environmental Stewardship Area working group (GNESA) and its partners.

RECOMMENDATIONS

I identified 4 crossing zones in the study area. Crossing zones were located in the following areas: MP167-171, MP172-174, MP179-184, and MP189-193. I believe that these areas should be prioritized for future research and mitigation measures, especially if time, money, or other resources are limited. However, the results of this study provide mostly preliminary, baseline information; and thus, future research should examine the entire study area if possible. Further research in the US-2 corridor is advisable before highway mitigation measures, especially major mitigation measures such as wildlife crossing structures, are implemented. Information from the results of this study and of potential future studies could be used to implement low-cost mitigation measures such as temporary passive wildlife signs—or, species-specific wildlife signs that are only used during periods when the given species is most likely to be crossing a highway in a particular location. While permanent wildlife signs are probably ignored by motorists (Sullivan and Messmer 2003), temporary passive signs have been shown to decrease wildlife-vehicle collisions and reduce motorist speeds (Sullivan et al. 2004).

For future research, there are several different methods that would be beneficial. First, continuing to monitor trails with cameras would provide valuable information with relatively little labor. I suggest the use of more than 6 cameras so that more trails can be monitored per session and per season than I was able to monitor. Continued camera surveys would help provide a more complete picture of wildlife activity on roadside trails in the study area. Cameras could be used for at least 6 months of the year (April/May-September/October) to monitor the 88 major trails that I identified in this study.

Roadside snow tracking would also be a useful method for assessing wildlife activity along US-2. Snow tracking surveys should be conducted 24-72 hours after each snowfall so that wildlife tracks are fresh and easily identifiable (e.g. Singleton and Lehmkuhl 1999). Areas with high densities of wildlife snow tracks could be compared to trail locations to determine if a spatial relationship exists. Also, since snow tracking surveys provide species-specific data, it would be interesting to spatially compare species data from camera surveys and snow tracking surveys. Collaring (GPS or radio-telemetry) and monitoring animals in the US-2 corridor would provide further information about the crossing locations of specific animals. These crossing locations could then be compared to trail locations, camera data, and snow tracking data.

Based on the results of my camera surveys, I suspect that ungulates—namely deer and elk—are most responsible for creating the trails that I identified. Thus, I think it would be worthwhile to assess whether there is any difference between ungulates and non-ungulates in terms of the spatial relationship between trail locations, snow track locations, and highway crossing locations of collared animals.

Roadkill data for the US-2 corridor needs to be improved. There were only 61 roadkill incidents reported in the 9 year span from 1998-2007, and these data were collected incidentally and opportunistically. A more systematic approach to documenting roadkill would allow for more significant spatial analyses of roadkill incidents. Although roadkill data does not necessarily delineate areas where wildlife cross the highway most frequently, these data can help specify where wildlife tend to unsuccessfully cross the highway. Roadkill data could be collected by researchers who drive the length of the highway on a regular basis. Also, a citizen science program could be implemented in which highway signs encourage motorists to call a number or visit a website to report any roadkill they see. A citizen science program could also encourage motorists to report any live animals they see on or near the highway.

Traffic volumes will likely continue to increase on US-2, and it will become increasingly important to study and monitor wildlife activity in the US-2 corridor so that proper measures can be taken to promote the safety of wildlife and motorists alike.

LITERATURE CITED

Aresco, M. J. 2003. Highway mortality of turtles and other herpetofauna at Lake Jackson, Florida, USA, and the efficacy of a temporary fence/culvert system to reduce roadkills. In: Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. Irwin CL, Garrett P,McDermott KP. Center for Transportation and the Environment, North Carolina State University,Raleigh, NC: pp. 433-449.

Akaike, H. 1973. Information theory as an extension of the maximum likelihood principle. Pages 267-281 *in* B.N. Petrov, and F. Csaki, (eds.) Second International Symposium on Information Theory. Akademiai Kiao, Budapest.

Akaike, H. 1978. On the likelihood of a time series model. The Statistician 27: 217-235.

Alexander, S. M. and N. M. Waters. 2000. The effects of highway transportation corridors on wildlife: a case study of Banff National Park. Transportation Research Part C 8: 307-320.

Barnum, S. A. 2003. Identifying the best locations along highways to provide safe crossing opportunities for wildlife. Report Number CDOTDTD-UCD-2003-9. Colorado Department of Transportation Research Branch, Denver.

Barnum, S., K. Rinehart, and M. Elbroch. 2007. Habitat, highway featuers, and animal-vehicle collision locations as indicators of wildlife crossing hot spots. UC Davis: Road Ecology Center. Retrieved from: http://www.escholarship.org/uc/item/3d35b16n

Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management 59: 228-237.

Bertwistle, J. 1999. The effects of reduced speed zones on reducing bighorn sheep and elk collisions with vehicles on the Yellowhead highway in Jasper National Park. Pages 89-97 in G.L. Evink, P. Garrett, and D. Zeigler editors. Proceedings of the third international wildlife ecology and transportation. FL-ER-73-99. Florida Department of Transportation, Tallahassee.

Bissonette, J., C. Kassar, and L. Cook. 2008. Assessment of costs associated with deer–vehicle collisions: human death and injury, vehicle damage, and deer loss. Human–Wildlife Conflicts 2(1):17–27.

Burnham, K. P. and D. R. Anderson. Model selection and multimodel inference: A practical information-theoretic approach, second edition. Springer-Verlag, New York, New York 2002.

Case, R. M. 1978. Interstate highway road killed animals: a data source for biologists. Wildlife Society Bulletin 6:8-13.

Clevenger, A. P. and N. Waltho. 1999. Dry drainage culvert use and design considerations for
small- and medium-sized mammal movement across a major transportation corridor. Pp.
263-277 *In* G.L. Evink, P. Garrett, and D. Zeigler (eds.) Proceedings of the Third International Conference on Wildlife Ecology and Transportation. FL-ER-73-99. Florida
Department of Transportation, Tallahassee, Florida.

Clevenger, A. P. and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology 14: 47- 56.

Clevenger, A. P. and N. Waltho. 2005. Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biological Conservation 121: 453 – 464.

Clevenger, A. P, A. Hardy, and K. E. Gunson. 2006. Analyses of wildlife-vehicle collision data: Applications for guiding decision-making for wildlife crossing mitigation and motorist safety. A report prepared for the Dr. John Bissonette and the National Cooperative Highway Research Program, Utah State University.

Conover, M. R., W. C. Pitt, K. K. Kessler, T. J. DuBow, and W. A. Sanborn. 1995. Review of human injuries, illnesses, and economic losses caused by wildlife in the United States. Wildlife Society Bulletin 23: 407-414.

Epps, C. W., P. J. Palsboll, J. D. Wehausen, G. K. Roderick, R. R. Ramey, and D. R. McCullough. 2005. Highways block gene flow and cause a rapid decline in genetic diversity of desert bighorn sheep. Ecology Letters 8:1029-1038.

Forman, R. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter. 2003. Road ecology: science and solutions. Island Press, Washington DC, USA.

Forman, R. T. 2000. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology. 14(1): 31-35.

Foster, M. L. and S. R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23: 95-100. 111

Gagnon, J. W., T. C. Theimer, N. L. Dodd, A. Manazo, and R. E. Schweinsburg. 2007. Effects of traffic on elk use of wildlife highway underpasses Arizona. Journal of Wildlife Management 71:2324–2328.

Hoctor, T. S., M. H. Carr, and P. D. Zwick. 2000. Identifying a linked reserve system using a regional landscape approach: the Florida ecological network. Conservation Biology 14: 984-1000.

Kintsch, J. 2005. Linking Colorado's landscapes. In *Proceedings of the 2005 International Conference on Ecology and Transportation*, Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 138-142.

Lewis, J. S. 2007. The effects of human influences on black bear habitat selection and movement patterns within a highway corridor. Thesis. University of Idaho. Moscow, ID, USA.

Mace, R., J. S. Waller, T. Manley, J. Lyon, H. Zuuring. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains Montana. The Journal of Applied Ecology 33(6): 1395-1404.

Menard, S. 1995. Applied logistic regression analysis. Sage University Paper Series 106. Sage, Thousand Oaks, California, USA.

Ng, S. J., J. W. Dole, R. M. Sauvajot, S. P. D. Riley, and T. J. Valone. 2004. Use of highway undercrossings by wildlife in southern California. Biological Conservation 115: 499-507.

Pojar, T. M., R. A. Prosence, D. F. Reed, and R. H. Woodward. 1975. Effectiveness of a lighted, animated deer crossing sign. Journal of Wildlife Management 39:87-91.

Ripley, B. D. 1981. Spatial statistics. John Wiley and Sons, NewYork, USA.

Rodriguez, A, G. Crema, and M. Delibes. 1996. Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. Journal of Applied Ecology 33(6): 1527-1540

Saunders, D. A., R. J. Hobbs, C. R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5: 18-32.

Scheick, B. and M. Jones. 1999. Locating wildlife underpasses prior to expansion of Highway 64 in North Carolina. In *Proceedings of the third International Conference on Wildlife Ecology and Transportation*.

Seiler, A. 2005. Predicting locations of moose-vehicle collisions in Sweden. Journal of Applied Ecology 42:371–382

Servheen, C., J. S. Waller, and W. Kasworm. 1998. Fragmentation effects of high-speed highways on grizzly bear populations shared between the United States and Canada. Pp. 97-103. in Proceedings of the International Conference on Wildlife Ecology and Transportation, 1998. Tallahassee, Florida.

Shaffer, M. L. and F. B. Samson. 1985. Population size and extinction: a note on determining critical population sizes. The American Naturalist 125:144-152.

Singer, F. J. and J. L. Doherty. 1985. Managing mountain goats at a highway crossing. Wildlife Society Bulletin 13:469-477.

Singleton, P.H. and J.F. Lehmkuhl. 1999. Assessing wildlife habitat connectivity in the Interstate 90 Snoqualmie Pass corridor, Washington. Pages 75-84 in G.L. Evink, P. Garrett, and D. Zeigler, editors. ICOET 2001 Proceedings 148 A Time for ActionProceedings of the Third International Conference on Wildlife Ecology and Transportation. FL-ER-73-99. Florida Department of Transportation, Tallahassee, Florida. 330 pp.

Sullivan, T. L. and T. A. Messmer T. A. 2003. Perceptions of deer-vehicle collision management by state wildlife agency and department of transportation administrators. Wildlife Society Bulletin 31:163-73.

Sullivan, T. L., A. F. Williams, T. A. Messmer, L. A. Nelson, and S. Y. Kyrychenko, S.Y. 2004. Effectiveness of temporary warning signs in reducing deer-vehicle collisions during mule deer migrations. Wildlife Society Bulletin 32(3): 907-915

Switalski, T. A., L. Broberg, and A. Holden. 2007. Wildlife Use of Open and Decommissioned Roads on the Clearwater National Forest, Idaho. In Proceedings of the 2007 International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Debra Nelson, and K.P. McDermott. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University, 2007. pp. 627-632.

Waller, J. S. and C. Servheen. 2005. Effects of transportation infrastructure on grizzly bears in northwestern Montana. Journal of Wildlife Management 69(3): 985-1000.

Weir, R. D., H. Davis, C. Hoodicoff, and K. W. Larsen. 2004. Life on a highway: sources of mortality in an endangered British Columbian badger population. In: T.D. Hooper, ed. Proc. Species at Risk 2004 Pathways to Recovery Conference. 2–6 March, 2004, Victoria, B.C.

APPENDIX

Appendix A. Roadkill incidents.

Species	MP	Date	Dist to Trail (m)	Dist to GNESA crossing (m)	GNESA Species
Whitetail Deer	153.1	1/29/2007	2935	1050	E, D
Whitetail Deer	153.7	1/17/2007	2111	115	E, D
Whitetail Deer	153.7	2/17/2007	2139	144	E, D
Mule Deer	154.1	7/5/2007	1578	427	E, D
Whitetail Deer	155.3	7/2/2007	130	204	MD, G, E
Mule Deer	155.5	6/29/2007	215	139	MD, G, E
Mule Deer	156.6	5/22/2007	106	194	MD
Mule Deer	158.2	5/8/2007	75	3	MD
Whitetail Deer	158.3	3/16/2008	30	92	MD
Whitetail Deer	159.7	6/29/2007	1005	109	E
Mule Deer	159.9	6/4/2007	741	192	E
Beaver	162.3	11/23/2006	513	431	E, D
Whitetail Deer	163.0	10/3/2007	1113	1313	E, D
Whitetail Deer	163.3	8/13/2007	684	881	E, D
Whitetail Deer	163.5	5/6/2007	362	552	E, D
Mule Deer	167.5	7/5/2007	27	966	E, D
Mule Deer	167.6	6/27/2007	163	1112	E, D
Whitetail Deer	168.1	11/3/2005	318	790	E, D
Whitetail Deer	168.1	11/3/2005	342	812	E, D
Whitetail Deer	169.0	5/1/2007	445	543	E, D
Whitetail Deer	169.1	12/10/2006	299	689	E, D
Mule Deer	169.3	6/27/2007	40	1004	E, D
Whitetail Deer	171.0	6/11/2007	281	1877	E, D
Whitetail Deer	172.0	4/13/2007	234	333	E, D
Mule Deer	172.0	4/29/2008	242	340	E, D
Moose	172.2	6/21/2007	100	6	E, D
Mule Deer	172.2	5/29/2007	92	15	E, D
Whitetail Deer	172.9	3/23/2007	35	33	D
Mule Deer	173.0	4/23/2008	135	196	D
Whitetail Deer	173.0	4/29/2008	42	53	D
Moose	173.4	Unknown	207	109	D, M
Whitetail Deer	173.5	4/28/2008	582	268	D, M
Moose	173.5	Unknown	469	154	D, M
Whitetail Deer	173.6	4/4/2008	394	79	D, M
Whitetail Deer	173.6	4/14/2008	394	79	D, M
Mule Deer	173.7	6/4/2007	287	29	D, M
Whitetail Deer	173.7	5/11/2007	312	3	D, M
Mule Deer	173.8	6/13/2007	153	164	D, M
Mule Deer	174.0	4/2/2008	159	368	C
Whitetail Deer	174.0	4/29/2008	325	199	C
Mule Deer	175.0	11/15/2006	656	476	WD, M
Moose	175.0	Unknown	1011	124	WD, M
Moose	175.0	Unknown	934	204	WD, M
Moose	175.5	12/23/2006	143	1257	WD, M

Species	**MP**	**Date**	**Dist to Trail (m)**	**Dist to GNESA (m)**	**GNESA Species**
Whitetail Deer	178.8	12/6/2006	355	761	E, D
Mule Deer	180.0	10/11/2007	406	289	BB
Whitetail Deer	180.1	12/15/1998	145	355	MD
Whitetail Deer	180.1	12/15/1998	145	355	MD
Whitetail Deer	180.1	12/15/1998	230	457	BB
Whitetail Deer	180.1	12/15/1998	182	504	BB
Mule Deer	180.5	12/18/2000	62	1081	BB
Mule Deer	180.5	12/18/2000	67	253	MD
Mule Deer	181.0	1/19/2007	335	543	MD
Mule Deer	181.0	1/19/2007	280	489	MD
Mule Deer	181.5	2/17/2007	77	243	MD
Mule Deer	181.5	2/17/2007	28	207	E, G
Mule Deer	186.0	12/18/2006	700	358	E, D
Whitetail Deer	186.0	12/18/2006	691	367	E, D
Mule Deer	191.0	5/30/2007	242	466	D
Mule Deer	191.0	5/30/2007	234	495	D

**GNESA Species: B = Bear, BB = Black Bear, C = Cougar, D = Deer, E = Elk, G = Mountain Goat, M = Moose, MD = Mule Deer, WD = Whitetail Deer.*