Highway Mitigation Opportunities for Wildlife in Boundary County, Idaho

by

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16. Abstract

This report documents the following types of information for the highways (Hwy 95, Hwy 2 and Hwy 1) in Boundary County, Idaho, USA: 1. Identification and prioritization of wildlife-vehicle collision hotspots based on crash and carcass data, 2. A cost-benefit analyses for the implementation of wildlife fences, wildlife underpasses and overpasses, and animal detection systems, and associated prioritization of the hotspots based on the costs associated with wildlife-vehicle collisions, and 3. prioritization of the hotspots based on important wildlife habitat and corridors. In addition, the report identifies the mitigation emphasis sites which ranked worst for wildlife-vehicle collisions, highest for the associated costs, and that were considered to be located in the most important wildlife habitat and corridors. These sites were evaluated for the implementation of potential future mitigation measures, most notably wildlife fences, wildlife underpasses and overpasses and animal detection systems. Finally three options are presented for responding to the existing wildlife-vehicle collisions and potential future safe crossing opportunities for wildlife.

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EXECUTIVE SUMMARY

This report documents the identification and prioritization of highway segments in Boundary County, Idaho that may require mitigation for wildlife. The highway segments (Hwy 95, 2 and 1) cut across important wildlife habitat and corridors. This results in wildlife-vehicle collisions - which are a threat to human safety-, high costs associated with wildlife-vehicle collisions, and negative effects on wildlife.

Crash and carcass data were used to identify hotspots along the three highways. These hotspots emphasize the highway segments where mitigation measures may be required to improve human safety and reduce direct wildlife mortality. The hotspots were prioritized based on the number of wildlife-vehicle collisions, the costs associated with these wildlife-vehicle collisions and their perceived importance as wildlife habitat and corridor. The hotspots that ranked highest were reviewed for the potential implementation of mitigation measures aimed at reducing collisions with large mammals and providing safe crossing opportunities for large mammals.

Collisions with large mammals were relatively numerous along the highways in Boundary County, especially with deer (mostly white-tailed deer), and, though far fewer, elk and moose. Hotspots were identified along all three highways in Boundary County (Hwy 95, 2, and 1). The hotspots that ranked worst with regard to the number of collisions, the costs associated with these collisions, and that were also situated in important wildlife habitat or corridors were all located along Hwy 95 and Hwy 2. Note that only the wildlife-vehicle collisions hotspots were ranked for their costs associated with wildlife-vehicle collisions and their perceived importance as wildlife habitat or corridors. This means that, at least in theory, there may be other road sections that have equal or higher costs associated with wildlife-vehicle collisions (though this is not the case in our study area) and that may be situated in equally or more important wildlife habitat and corridors (this is potentially the case in our study area).

Wildlife fencing in combination with wildlife underpasses and overpasses is the most effective and robust mitigation measure to reduce collisions with large mammals and provide safe crossing opportunities for wildlife. Animal detection systems can also substantially reduce collisions with large mammals but these systems are less robust and should still be considered experimental.

The cost-benefit analyses showed that there are highway sections in Boundary County where the benefits of mitigation measures, even the most expensive ones, are greater than their costs. This signals that not implementing mitigation measures on these highway sections is more costly to society than the investment associated with implementing effective mitigation measures.

While the implementation of mitigation measures at selected road sections benefits human safety, nature conservation and is also economically attractive, implementation may be challenging. For example, the highway sections in Boundary County are characterized by relatively flat terrain and many access points (i.e. driveways). These characteristics make it challenging, though not impossible, to implement wildlife fencing, wildlife underpasses, overpasses and animal detection systems. In addition, the investments may be jeopardized if development and human disturbance increase on adjacent private lands.

The researchers formulated the following options for consideration:

1. If the objective is to reduce collisions with large mammals and provide safe crossing opportunities for large mammals, implement wildlife fencing in combination with

wildlife jump-outs, wildlife underpasses and overpasses on selected highway segments that ranked highest with regard to the number of collisions, the costs associated with these collisions and that are located in important wildlife habitat or corridors. Accept substantial work and costs associated with construction such as moving large amounts of soil to allow for a gradual approach to underpasses or overpasses. If the mitigation site is situated adjacent to private land, accept the fact that human disturbance may increase overtime and that wildlife may then reduce the use of the crossing structures. Strive to reduce the number of access points (i.e. driveways) and mitigate the remaining gaps in the fence with wildlife guards.

2. If wildlife fences in combination with wildlife underpasses and overpasses are considered too difficult to implement, too costly or too risky (e.g. potential for future increase in human disturbance), then consider implementing animal detection systems, with or without associated fencing and wildlife-jump-outs. Consider electric mats perpendicular to the fence and across the road at the gaps in the fence to discourage animals from wandering into the fenced highway corridor. Accept the high risk associated with animal detection system projects. Accept that the success parameter is to be able to answer research questions related to system reliability and effectiveness rather than an objective to reduce wildlife-vehicle collisions by a certain minimum percentage. The researchers strongly advise to evaluate the reliability and effectiveness of an animal detection system, should it indeed be implemented.
3. If the two options described above are both considered not acceptable, then consider not implementing mitigation measures and/or continue current practices. Accept that wildlife-vehicle collisions are likely to continue to occur in relatively high numbers and that these numbers are likely to continue to grow (consistent with national trend). Accept that the costs for wildlife-vehicle collisions to society may be higher than what effective mitigation measures may have cost. Accept that current practices (e.g. deer warning signs and brushing in the right-of-way) may not be effective or may only marginally effective in reducing wildlife-vehicle collisions and that brushing of the vegetation in the right-of-way may increase the barrier effect of highways and traffic for wildlife.

1. INTRODUCTION

1.1. Project Goals and Objectives

This study aims to identify and prioritize highway segments in Boundary County, Idaho that may require mitigation for wildlife. The highway segments cut across important wildlife habitat and corridors. This not only results in wildlife-vehicle collisions but also in reduced connectivity across the landscape for wildlife.

The specific objectives of this project are to:

- Identify and prioritize highway segments that may require mitigation measures aimed at reducing wildlife-vehicle collisions and providing safe crossing opportunities for wildlife based on:
    - Existing crash and carcass data;
    - Existing maps and local knowledge and experience of important wildlife habitat and corridors bisected by the highways.
- Recommend mitigation measures for wildlife at the selected locations.
- Conduct cost-benefit analyses for a range of mitigation measures for the selected highway segments.

The crash and carcass data emphasize the highway segments where mitigation measures may be required to improve human safety and reduce wildlife mortality. Maps and local knowledge and experience of important wildlife habitat and corridors emphasize where mitigation measures may be required to reduce the barrier effect of the highway segments. The same applies to the maps and local knowledge and experience of important wildlife habitat and corridors.

The species concerned, the nature of the terrain, and the land security (potential for development) all influenced the prioritization of the highway segments that may require mitigation measures. Cost-benefit analyses allow for insight in the financial aspects of wildlife-vehicle collisions and mitigation measures and are useful in the potential future decision process whether to implement mitigation measures.

1.2. Study Area

The project focused on the following highway segments in Boundary County (see also Figure 1):

- U.S. Highway 95. From the Boundary County and Bonner County county line (south end) to the Canadian border at Eastport (north end), about 46 mi (74 km) in length.
- U.S. Highway 2. From junction with Highway 95 just north of Bonners Ferry (west end) to the Idaho/Montana state line (east end), about 15 mi (24 km) in length.
- State Route 1. From its junction with Hwy 95 near Copeland (south end) to the Canadian border at Porthill (north end), about 11 mi (18 km) in length.

Note that a segment of Hwy 95 north-east of Copeland (mi marker 521.630 to 526.326) had wildlife fencing and three large mammal underpasses installed in 2003-2004 (start construction in 2003, construction completed in 2004) (Wakkinen et al., 2012). However, there was no crash or carcass hotspot located in this mitigated road section.

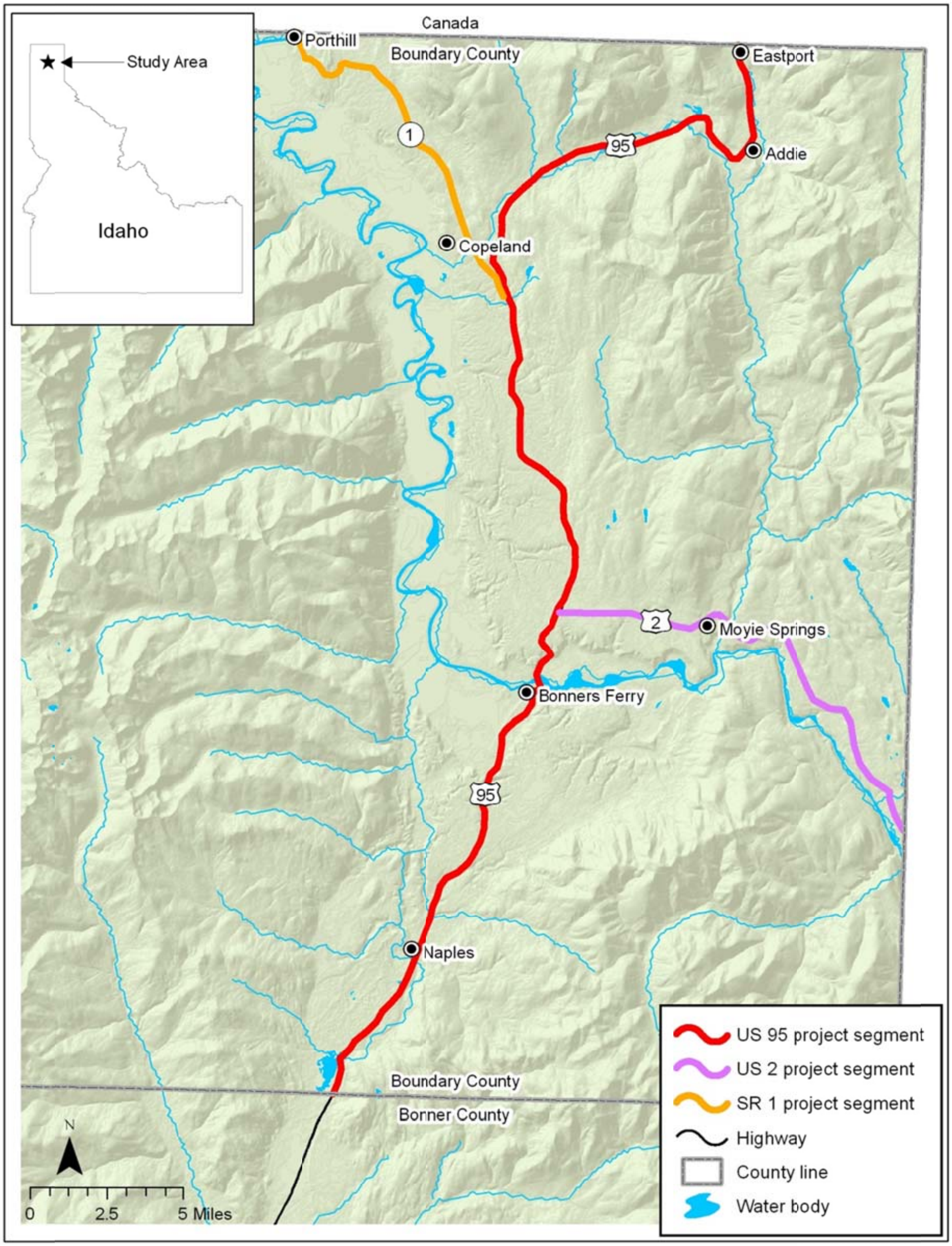

Figure 1: The three Boundary County highways included in this project.

2. WILDLIFE-VEHICLE COLLISION AREAS

2.1. Introduction

Wildlife-vehicle collision data were used to identify and prioritize highway segments that have a concentration of wildlife-vehicle collisions. These locations may require mitigation measures to reduce wildlife-vehicle collisions in order to increase human safety and reduce direct road mortality of wildlife.

2.2. Methodology

There were two types of wildlife-vehicle collision data available to the research team; crash data and carcass data. These two datasets are discussed in the following sections. The researchers chose to have the two datasets relate to the exact same time period: 1 January 2003 through 31 December 2010. This allowed for a direct comparison between the two datasets. However, the period 1 January 2007 through 31 December 2007 was excluded from both datasets as the carcass removal data were incomplete for that year. Carcass removal data were not available or questionable before 2003. Thus the crash and carcass removal data were each based on seven years of data.

2.2.1. Crash Data

Crash data are collected by the Idaho Highway Patrol and maintained by the Idaho Transportation Department. The crash data were collected to the nearest 0.1 mi (160.9 m). The researchers selected records that related to "wild animal" only. There were 290 records selected for the analysis.

2.2.2. Carcass Data

Carcass removal data are collected and maintained by the Idaho Department of Transportation. The crash data were collected to the nearest 1.0 mi (1.609 km). The researchers only selected records that related to wild mammals coyote size and up as smaller species are not likely to be consistently recorded and domestic animals are typically controlled by people or fences as it is. The deleted records related to raccoon (*Procyon lotor*), wild turkey (*Meleagris gallopavo*), striped skunk (*Mephitis mephitis*), domestic goat, and domestic cat. There were 2,033 records selected for the analysis (i.e. crash data amounted to only 14.3% of the carcass removal data). The most frequently recorded wildlife species in the carcass data was "deer" (*Odocoileus* spp.), followed by elk (*Cervus canadensis*), moose (*Alces alces*), and "bear" (*Ursus* spp.) (Figure 2 and Table 1). "Deer" almost exclusively relates to white-tailed deer (*Odocoileus virginianus*) while "bear" is likely to refer to black bear (*Ursus americanus*). However, mule deer and grizzly bear also occur in the area and a small number of the records may actually relate to these species.

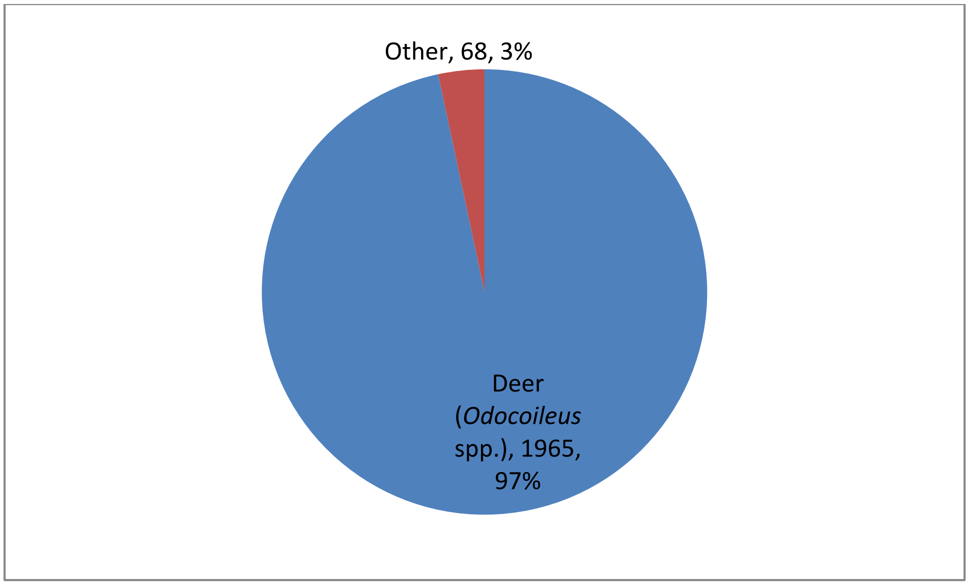

Figure 2: The number (N_{total} = 2,033) and the percentage of different species recorded as carcass data for all three highway segments combined between 1 January 2003 and 31 December 2010 (excluding 2007).

Table 1: The number and percentage of the species grouped in the "other" category of Figure 2.

Species	N	%
Elk (*Cervus canadensis*)	34	1.67
Moose (*Alces alces*)	26	1.28
Coyote (*Canis latrans*)	4	0.20
Bear (*Ursus* spp.)	4	0.20

2.2.3. Kernel Density Analyses

The researchers identified road sections with a concentration of crashes and large mammal carcasses ("hotspots") through a Kernel density (ArcGIS Release 9.3) analysis for point features. The researchers conducted two separate analyses; one for the crash data and one for the carcass removal data. For both analyses the researchers included all three road sections in Boundary County that are part of this study. As a result the hotspots that were identified are based on all the crash and carcass removal data for these roads and road sections. This means that, at least in theory, all hotspots can be located on one of these road sections, and that other road sections may have no identified hotspots.

For the Kernel density analyses the researchers divided the study area into a grid with a cell size of 82x82 ft (25x25 m). The relatively small cell size results in a relatively fine or smooth map. The locations of the crashes and carcasses are considered points and the Kernel density analysis calculates the density of crashes or carcasses in a neighborhood around each cell. Points that are close are weighted more than points that are further away. Consistent with Gomes et al. (2009) we set the search radius at 500 m. On a straight road this basically means that crashes or carcasses that are up to about 0.3 mi (500 m) away are included in the density analyses for each cell. A hotspot map was generated based on the Kernel densities that were calculated for each cell. The researchers distinguished between different density categories based on percentiles (Table 2).

Table 2: The categories used for the crash and carcass removal data hotspot maps.

	Density (n / square mile)		
Percentile categories	Crash data	Carcass data	Description
n/a	0	0	Further than 500 m from nearest crash or carcass
75-100%	0.1-27.90	0.1-103.87	The 25% of the cells with the lowest density (provided that the density is greater than 0)
50-74.9%	28.00-55.90	103.88-207.75	The next 25% of the cells with the lowest density (provided that the density is greater than 0)
25-49.9%	56.00-83.90	207.76-311.63	The next 25% of the cells with the lowest density (provided that the density is greater than 0)
5-24.9%	84.00-106.30	311.64-394.74	The next 20% of the cells with the lowest density (provided that the density is greater than 0)
<5%	106.40-112.0	394.75-415.52	The 5% of cells with the highest density (provided that the density is greater than 0)

2.2.4. Identifying Hot Spots

The researchers considered road sections with no crashes or carcasses and road sections that fell into the two lowest density categories (50-100%) (provided that the density is greater than 0) to be "background". Road sections that had higher densities ("top 50%") were considered a "hotspot". While the hotspots were identified based on the highest density categories (top 50%), the researchers started and ended a hot spot where the density category changed from the lowest category (75-100%) to the category above it (50-74.9%).

2.2.5. Prioritizing Hot Spots

For each "hotspot" the researchers investigated whether higher density categories occurred (i.e. 5-24.9% and <5%). For the crash data the researchers summed the number of crashes with wild animals, and the number of crashes with wild animals per 0.1 mi (160.9 m). Similarly, for the carcass data the researchers also summed the number of wild large mammal carcasses, and the number of wild large mammal carcasses per 0.1 mi (160.9 m) with and without distinguishing between species. The prioritization was based on the following parameters:

- The potential presence of the highest density category (<5%)
- The potential presence of the second highest density category (5-24.9%)
- The number of crashes with wild animals per 0.1 mi or the number of wild large mammal carcasses per 0.1 mi

2.2.6. Year Trend, Seasonal Distribution and Hour of Day

In addition to the identification and prioritization of road sections that have a concentration of wildlife-vehicle crashes, the selected crash data were also used to investigate possible trends over the years, months within a year, and by the hour of day. For the analyses by year the 2007 data were included, but for the analyses by month and hour of day the original dataset for the hotspot analysis (excluding 2007) was used. Finally the carcass data were used to investigate the number of carcasses by year (excluding 2007) and by month for the three most frequently reported species: deer, elk, and moose.

The crash data were also summarized per year for the entire state of Idaho from 2000 through 2011. The researchers interpreted these data for potential trends and calculated the percentage of crashes that occurred in Boundary County to those in the entire state of Idaho.

2.3. Results

2.3.1. Identifying Hot Spots

The hotspots for the three highway segments are shown in Figure 3 (carcass data) and Figure 4 (carcass removal data). The crash data had 3 road segments with a hotspot, all on Hwy 95 (Table 3). The carcass removal data had 14 road segments with a hotspot, 9 on Hwy 95, 4 on Hwy 2, and 1 on Hwy 1 (Table 4).

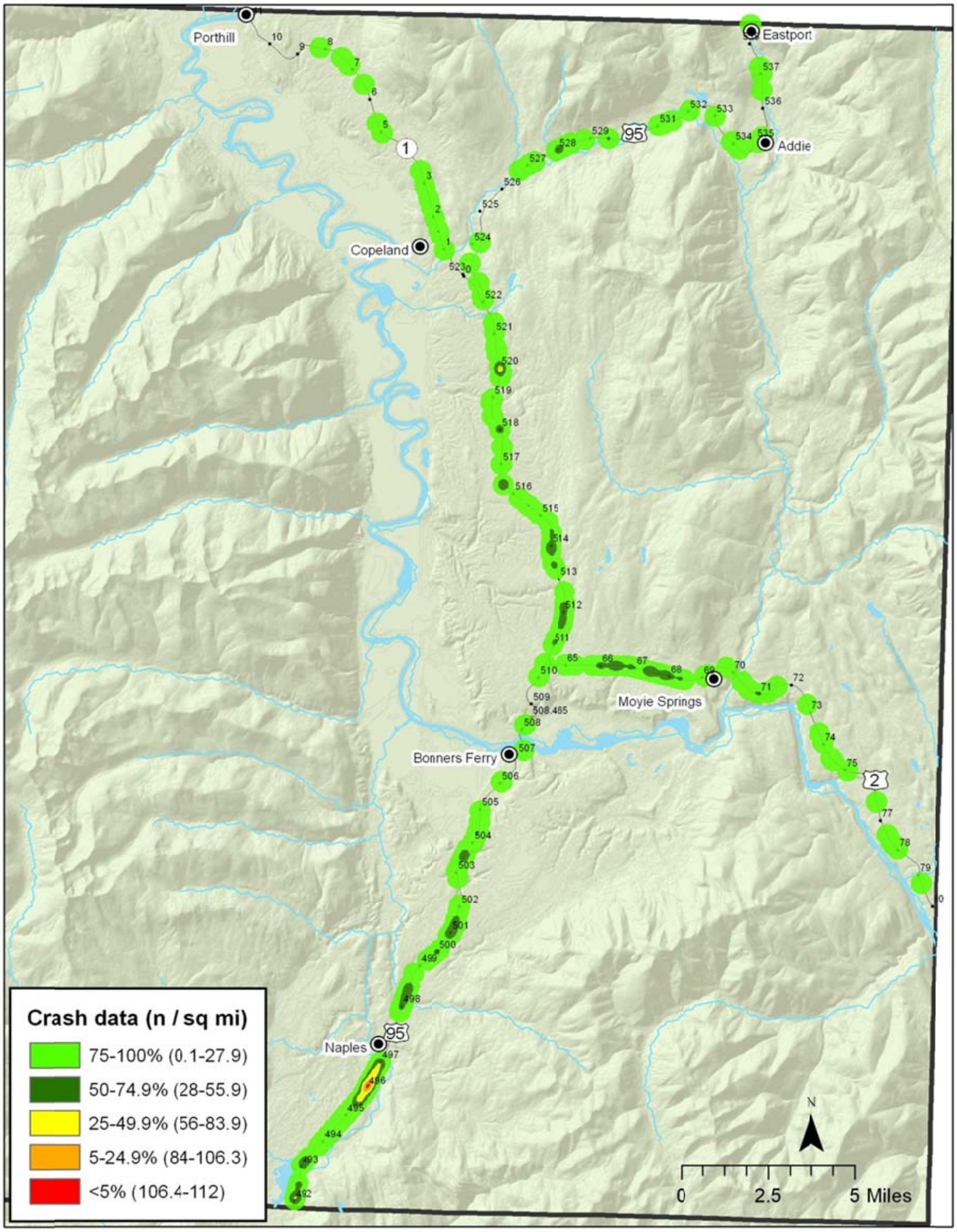

Figure 3: The hotspots based on crash data for the highways in Boundary County (2003 through 2010, excluding 2007). The numbers reflect the mi markers.

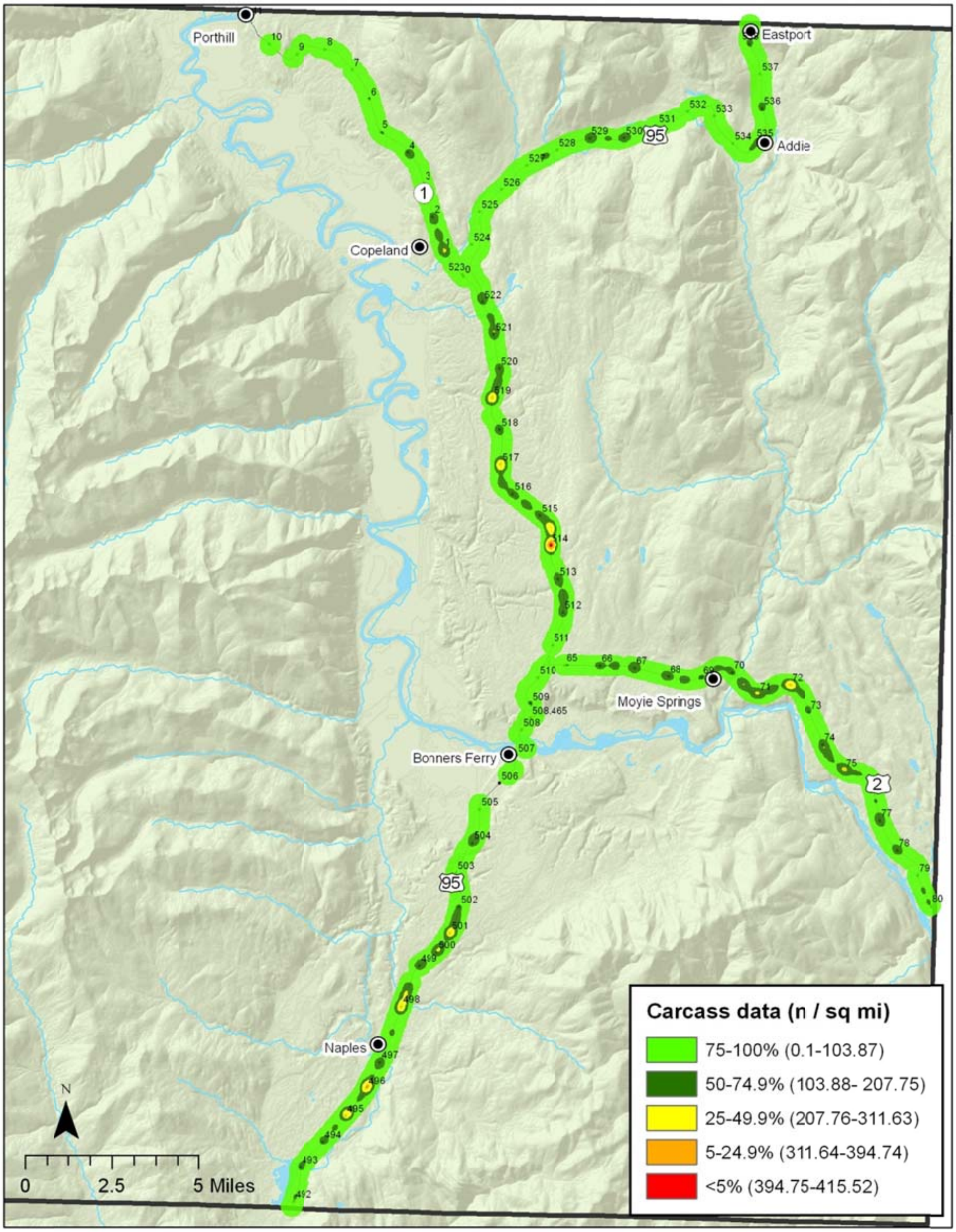

Figure 4: The hotspots based on carcass removal data for the highways in Boundary County (2003 through 2010, excluding 2007). The numbers reflect the mi markers.

Table 3: The mi markers where the categories shown on the crash data hotspot map change. LG = light green, DG = dark green, Y = yellow, O = orange, R = red.

Hwy	Color boundary	Mi marker
95	LG/DG	491.8
95	DG/Y	492
95	Y/DG	492.1
95	DG/LG	492.5
95	LG/DG	495.3
95	DG/Y	495.5
95	Y/O	495.8
95	O/R	495.9
95	R/O	496.1
95	O/Y	496.3
95	Y/DG	496.9
95	DG/LG	497.1
95	LG/DG	519.7
95	DG/Y	519.9
95	Y/DG	520
95	DG/LG	520.2

Table 4: The mi markers where the categories shown on the carcass removal data hotspot map change. LG = light green, DG = dark green, Y = yellow, O = orange, R = red.

Hwy	Color boundary	Mi marker		Hwy	Color boundary	Mi marker		Hwy	Color boundary	Mi marker
95	LG/DG	494.8		95	LG/DG	513.7		2	LG/DG	70.3
95	DG/Y	494.9		95	DG/Y	513.8		2	DG/Y	70.5
95	Y/DG	495.2		95	Y/O	513.9		2	Y/DG	70.5
95	DG/LG	495.3		95	O/R	514		2	DG/Y	70.9
				95	R/O	514.1		2	Y/DG	71.1
95	LG/DG	495.5		95	O/Y	514.2		2	DG/LG	71.6
95	DG/Y	495.8		95	Y/DG	514.3				
95	Y/O	495.9		95	DG/Y	514.3		2	LG/DG	71.8
95	O/Y	496.1		95	Y/DG	514.7		2	DG/Y	71.9
95	Y/DG	496.2		95	DG/LG	515.2		2	Y/DG	72.2
95	DG/LG	496.5						2	DG/LG	72.6
				95	LG/DG	515.8				
95	LG/DG	497.8		95	DG/Y	516.8		2	LG/DG	73.9
95	DG/Y	497.9		95	Y/DG	517.1		2	DG/Y	74.1
95	Y/DG	498.4		95	DG/LG	517.3		2	Y/DG	74.2
95	DG/LG	498.6						2	DG/LG	74.7
				95	LG/DG	518.8				
95	LG/DG	499.8		95	DG/Y	518.9		2	LG/DG	74.8
95	DG/Y	500		95	Y/DG	519.2		2	DG/Y	74.9
95	Y/DG	500.2		95	DG/LG	520.1		2	Y/DG	75.1
95	DG/LG	500.5						2	DG/LG	75.6
				95	LG/DG	520.8				
95	LG/DG	500.6		95	DG/Y	521		1	LG/DG	0.8
95	DG/Y	500.8		95	Y/DG	521.1		1	DG/Y	0.9
95	Y/DG	501.2		95	DG/LG	521.6		1	Y/DG	1.1
95	DG/LG	502						1	DG/LG	1.7

2.3.2. Prioritizing Hot Spots

The prioritization parameters and values for the hotspots for crash data and carcass removal data are summarized in Table 4 and 5. For the crash data the 495.3-497.1 hotspot received highest values for all the parameters (Table 4). For the carcass removal data the 513.7-515.2 hotspot was the only hotspot that contained the highest density category for carcasses (red category) (Table 5). However, hotspot 497.8-498.6 had a higher number of carcasses per mi, and while the number of carcasses was slightly lower in the 495.5-496.5 hotspot, it did contain a road segment with the second highest density category for carcasses (orange category). Hotspot 494.8-495.3 had the second highest number of carcasses per mi.

The researchers selected the “worst” crash hotspot (Hwy 95 mi marker 495.3-497.1) and the worst three carcass hotspots (Hwy 95 mi marker 494.8-495.3, 497.8-498.6, 513.7-515.2) for further discussion of potential mitigation measures (see Chapter 5).

Table 5: The prioritization parameters and values for the three crash data hotspots.

	Mi marker							
Hwy	Low	High	Length (mi)	Red category	Orange category	Crashes (n)	Crashes per 0.1 mi (n)	Crashes/ mi/yr
95	491.8	492.5	0.7	n	n	9	1.29	1.84
95	495.3	497.1	1.8	y	y	36	2.00	2.86
95	519.7	520.2	0.5	n	n	8	1.60	2.29

Table 6: The prioritization parameters and values for the 14 carcass data hotspots.

	Mi marker										
Hwy	Low	High	Length (mi)	Red category	Orange category	Species	Crashes (n)	Crashes/ 0.1 mi (n)	Total crashes (n)	Total crashes/ 0.1 mi (n)	Total crashes/ mi/yr (n)
95	494.8	495.3	0.5	n	n	deer	36	7.20	36	7.20	10.29
95	495.5	496.5	1	n	y	deer	48	4.80	57	5.70	8.14
						moose	9	0.90			
95	497.8	498.6	0.8	n	n	deer	71	8.87	71	8.87	12.68
95	499.8	500.5	0.7	n	n	deer	31	4.43	31	4.43	6.33
95	500.6	502	1.4	n	n	deer	60	4.29	63	4.50	6.43
						elk	3	0.21			
95	513.7	515.2	1.5	y	y	deer	105	7.00	110	7.33	10.48
						elk	4	0.27			
						bear	1	0.07			
95	515.8	517.3	1.5	n	n	deer	76	5.07	77	5.13	7.33
						elk	1	0.07			
95	518.8	520.1	1.3	n	n	deer	73	5.62	74	5.69	8.13
						elk	1	0.08			
95	520.8	521.6	0.8	n	n	deer	38	4.75	39	4.87	6.96
						elk	1	0.12			
2	70.3	71.6	1.3	n	n	deer	70	5.38	70	5.38	7.69
2	71.8	72.6	0.8	n	n	deer	48	6.00	51	6.38	9.11
						elk	3	0.38			
2	73.9	74.7	0.8	n	n	deer	40	5.00	40	5.00	7.14
2	74.8	75.6	0.8	n	n	deer	42	5.25	42	5.25	7.50
1	0.8	1.7	0.9	n	n	deer	47	5.22	47	5.22	7.46

2.3.3. Year Trend, Seasonal Distribution and Hour of Day

The number of reported wildlife-vehicle crashes in the entire state of Idaho appears to have increased over the past decade (Figure 5).

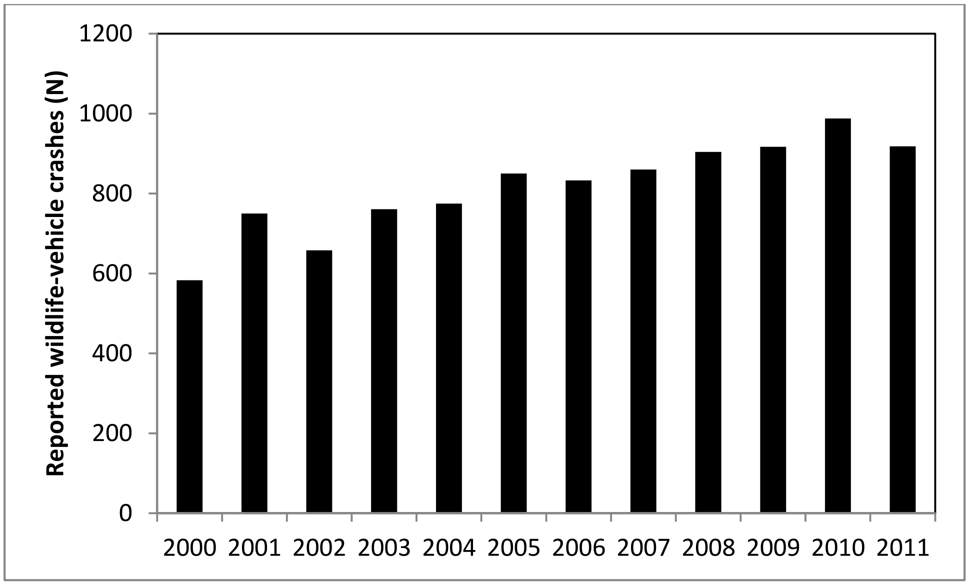

Figure 5: The number of reported wildlife-vehicle crashes per year in the entire state of Idaho (2000 through 2011).

In Boundary County the number of reported crashes with wildlife was relatively stable between 2003 and 2010 (Figure 6). However, the number of reported carcasses was more variable with highest numbers in 2008 and 2009 (Figure 7). The percentage of crashes that occurred in Boundary County (Figure 6) per year compared to those in the entire state of Idaho (Figure 5) average at 1.5% between 2003 and 2011 (yearly percentage varied between 0.8 and 1.9%).

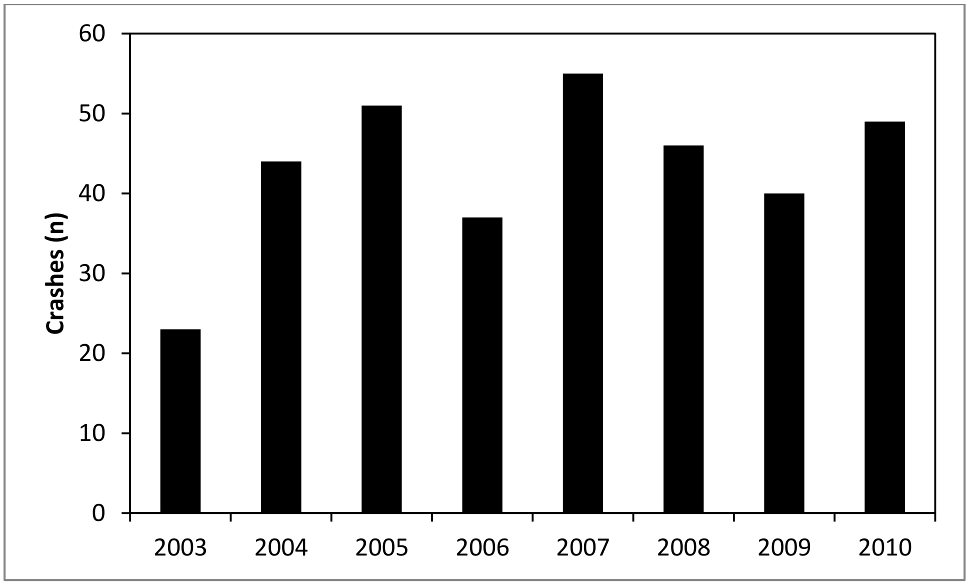

Figure 6: The number of reported wildlife-vehicle crashes per year for the highways in Boundary County (2003 through 2010).

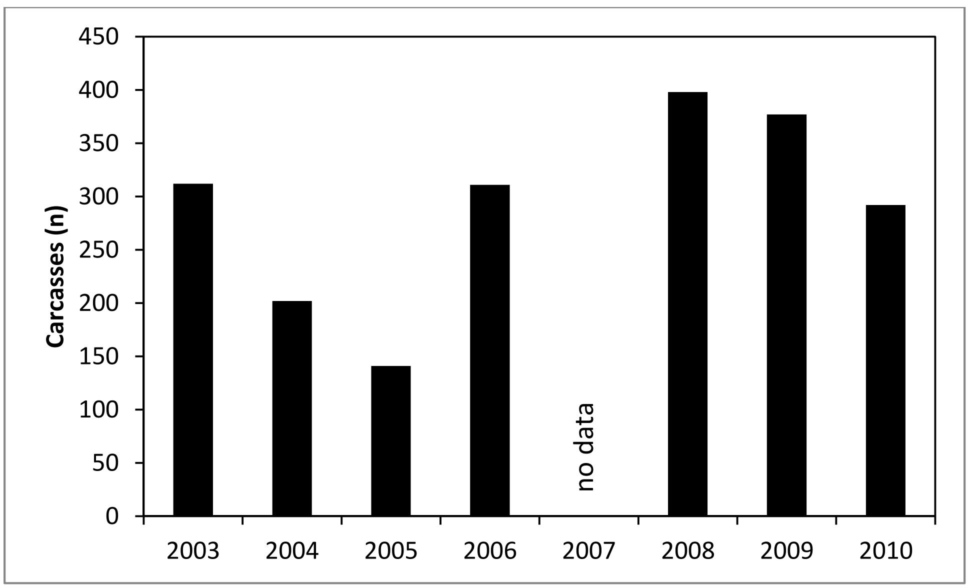

Figure 7: The number of reported carcass removals per year for the highways in Boundary County (2003 through 2010, excluding 2007).

The number of crashes per month was highest in winter (November-March) and lowest in summer (April-August) (Figure 8). The number of reported carcasses showed a similar trend for deer (Figure 9). The number of reported carcasses of elk and moose was relatively low and showed no clear seasonal trend (Figure 10 and 11).

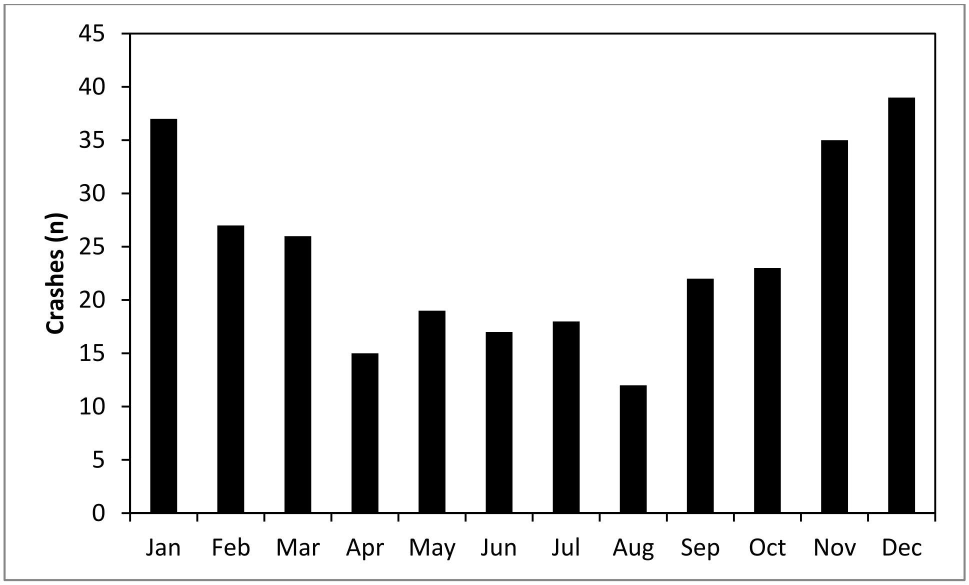

Figure 8: The number of reported wildlife-vehicle crashes per month for the highways in Boundary County (2003 through 2010, excluding 2007).

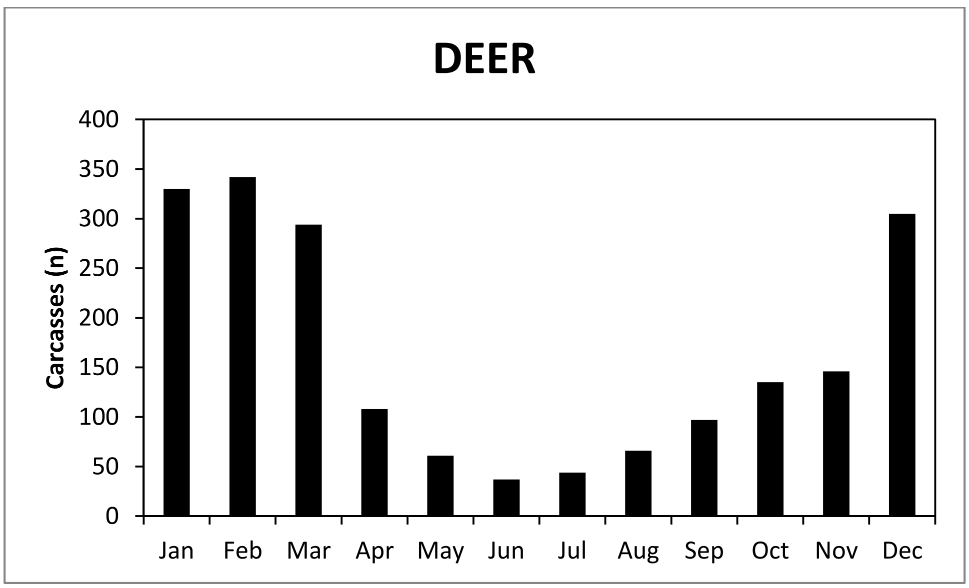

Figure 9: The number of reported deer carcass removals per year for the highways in Boundary County (2003 through 2010, excluding 2007).

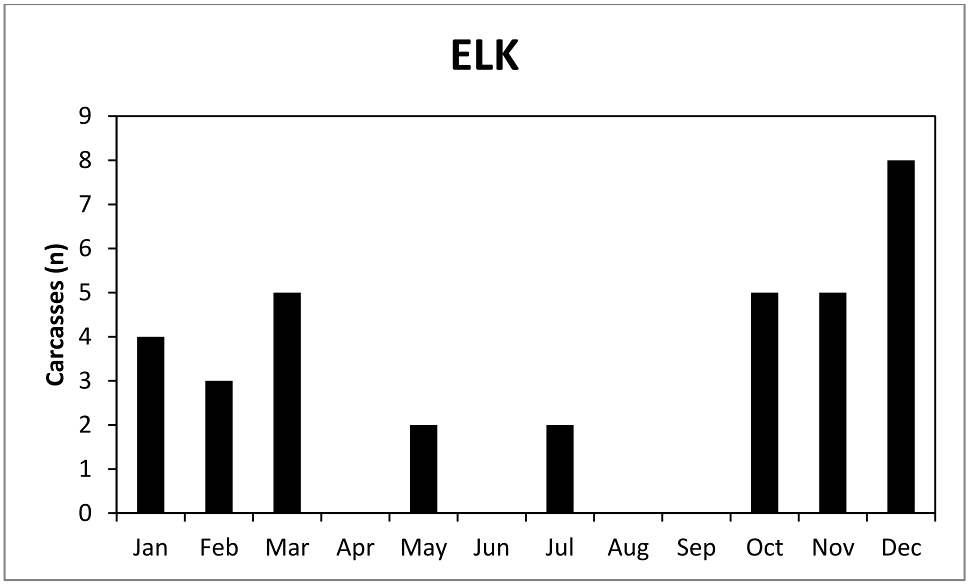

Figure 10: The number of reported elk carcass removals per year for the highways in Boundary County (2003 through 2010, excluding 2007).

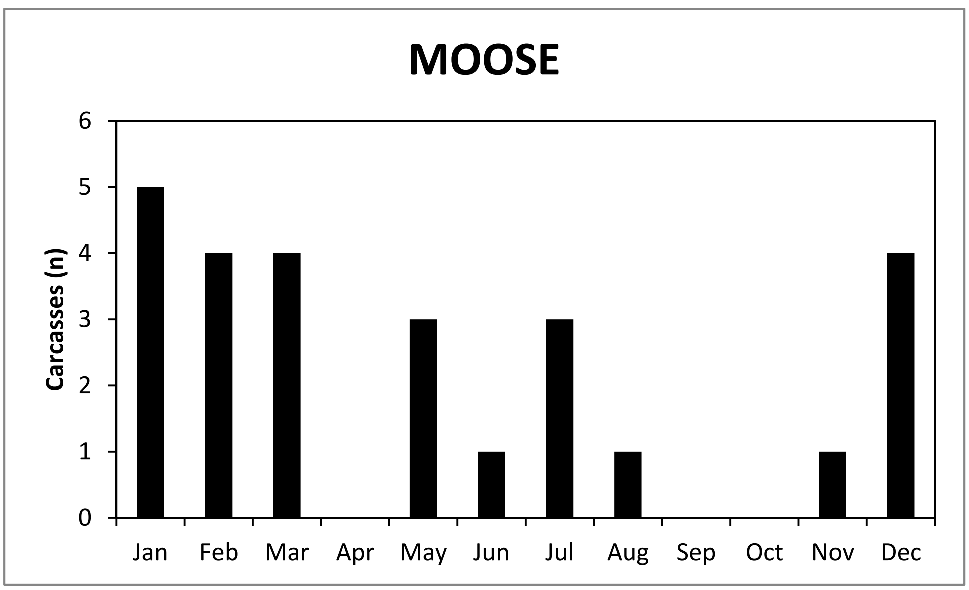

Figure 11: The number of reported moose carcass removals per year for the highways in Boundary County (2003 through 2010, excluding 2007).

The time of day wildlife-vehicle collisions occur was highest in the late afternoon, evening and early night (between 4 pm and 11 pm), with a less pronounced peak in the early morning (between 6 am and 8 am) (Figure 12). Relatively few wildlife-vehicle collisions occur during the middle of the day.

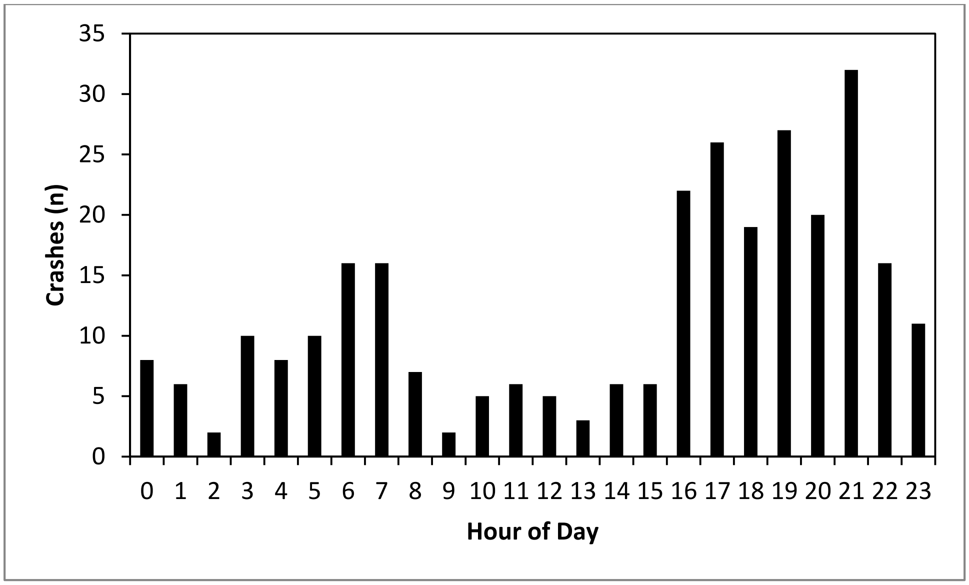

Figure 12: The number of reported wildlife-vehicle crashes per hour of day for the highways in Boundary County (2003 through 2010, excluding 2007).

2.4. Discussion

The number of reported wildlife-vehicle crashes in the entire state of Idaho appears to have increased over the past decade, perhaps justifying increased efforts to reduce these types of crashes. The carcass removal data mostly related to large ungulates, especially deer (97%) and substantially lower numbers of elk (2%) and moose carcasses (1%). The crash data showed 3 road segments with a hotspot, all on Hwy 95. The carcass removal data had 14 road segments with a hotspot, 9 on Hwy 95, 4 on Hwy 2, and 1 on Hwy 1. The deer-vehicle collisions were highest in the winter months (December-March) and wildlife-vehicle collisions occurred most often between 6-8 am and 4-11 pm.

The researchers distinguished multiple parameters that can be used to prioritize the 3 crash data hotspots and the 14 carcass data hotspots. Obviously these parameters are based on collisions with large ungulates. There are other ways through which the wildlife-vehicle collision hotspots can be prioritized as well. Two of these other possibilities are discussed in the next chapters: cost-benefit analyses (Chapter 3) and conservation based data on actual, likely or potential future corridors (Chapter 4). However, it is important to note that the approach for the current project is based on first identifying road sections with a relatively high number of wildlife-vehicle collisions. Another potential approach is to start with the identification of road sections that may require mitigation based on conservation needs rather than human safety. The outcome of these two approaches is not necessarily the same.

3. COST-BENEFIT ANALYSIS MITIGATION MEASURES

3.1. Introduction

Over 40 types of mitigation measures aimed at reducing collisions with large ungulates have been described (see reviews in Hedlund et al. 2004, Knapp et al. 2004, Huijser et al. 2008). Examples include warning signs that alert drivers to potential animal crossings, wildlife warning reflectors or mirrors (e.g., Reeve and Anderson 1993, Ujvári et al. 1998), wildlife fences (Clevenger et al. 2001), and animal detection systems (Huijser et al. 2006). However, the effectiveness and costs of these mitigation measures vary greatly. When the effectiveness is evaluated in relation to the costs for the mitigation measure, important insight is obtained regarding which mitigation measures may be preferred, at least from a monetary perspective.

3.2. Methods

For the purpose of this report the researchers conducted cost-benefit analyses for four different types and combinations of mitigation measures for the highway segments in Boundary County. The types and combinations of mitigation measures evaluated for this report included:

- Animal detection system
- Fence, gap (once every 2 km), animal detection system in gap, jump-outs
- Fence, under- and overpass (underpass once every 2 km, overpass once every 24 km), jump-outs
- Fence, under pass (once every 2 km), jump-outs

For details on the effectiveness and estimated costs of the mitigation measures per 0.62 mile (1 km) per year and other methodological aspects of the cost-benefit analyses see Huijser et al. (2009). This publication also provides a rationale for the estimated costs associated with each deer-vehicle collision ($6,617), elk-vehicle collision ($17,483), and moose-vehicle collision ($30,760). The cost for large mammal-vehicle collisions is expressed in dollars per year per 0.62 mi (1 km). The cost estimates are based on a divided four lane highway (two lanes in each direction).

For the purpose of this cost-benefit analyses the researchers used the carcass removal data only. In addition, “bear” was considered similar to “deer”, and coyote records were not included in the cost-benefit analyses as they are unlikely to cause major damage to a vehicle.

For the purpose of these analyses the researchers selected carcass removal data from the exact same time period (7 years) as described in the previous chapter: 1 January 2003 through 31 December 2010, excluding 1 January 2007 through 31 December 2007.

3.3. Results

Figures 13-15 show for which road sections the number of recorded deer, elk, and moose carcasses was high enough to meet or exceed thresholds for the implementation of four different types of mitigation measures. All highway segments had road sections where the threshold values for either all or some of the four mitigation measures were (nearly) met or exceeded.

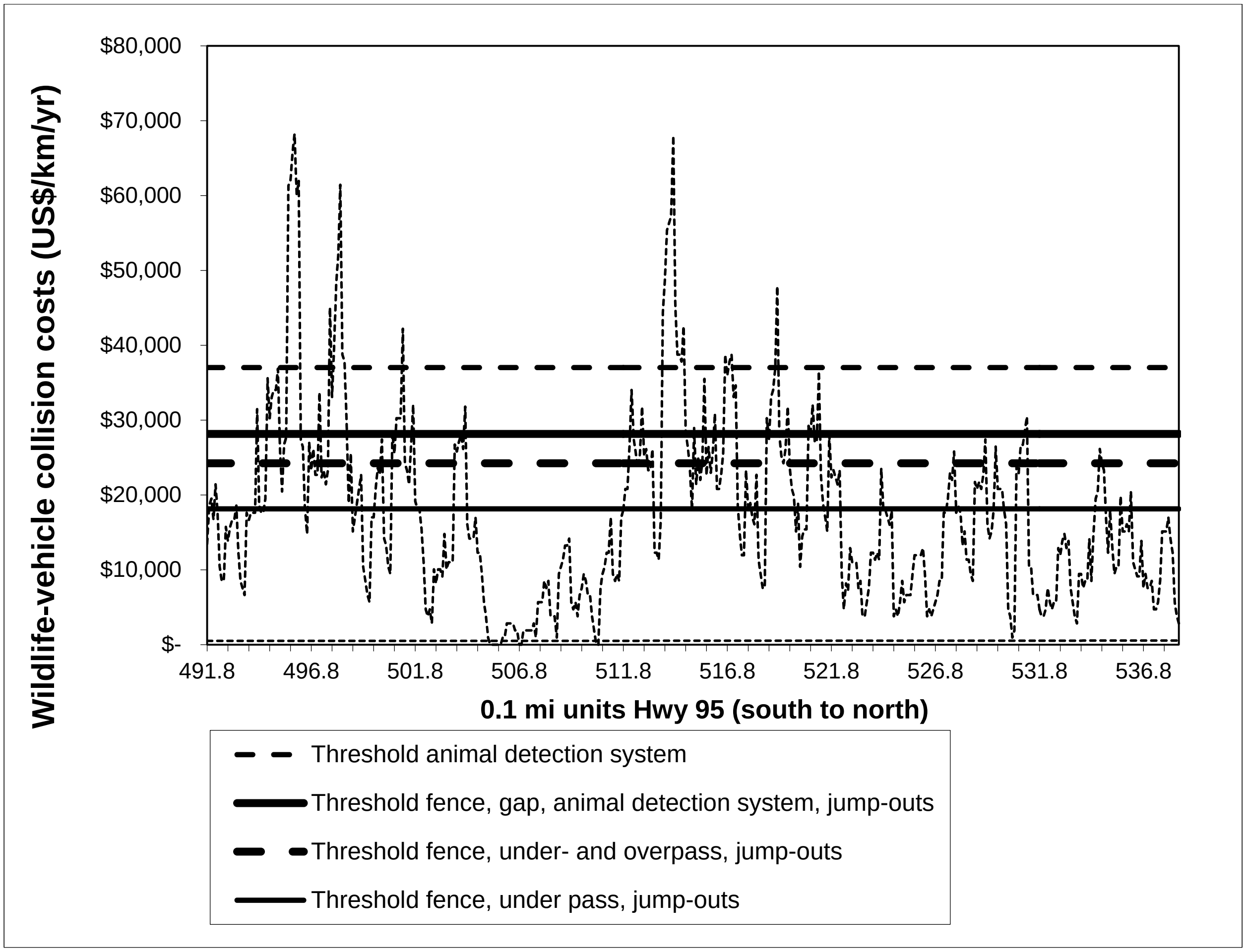

Figure 13: Hwy 95 from the Boundary County and Bonner County county line (south end, left side of graph) to the Canadian border at Eastport (north end, right side of graph). The costs (jagged line, in 2007 US$) associated with ungulate-vehicle collisions per year (annual average based on carcass removal data 2003-2010, excluding 2007), and the threshold values (at 3% discount rate) that need to be met in order to have the benefits of individual mitigation measures exceed the costs over a 75 year long time period. Note that the costs at each 0.1 mile (160.9 m) long road unit concerned and adjacent units were summed to estimate the costs per kilometer.

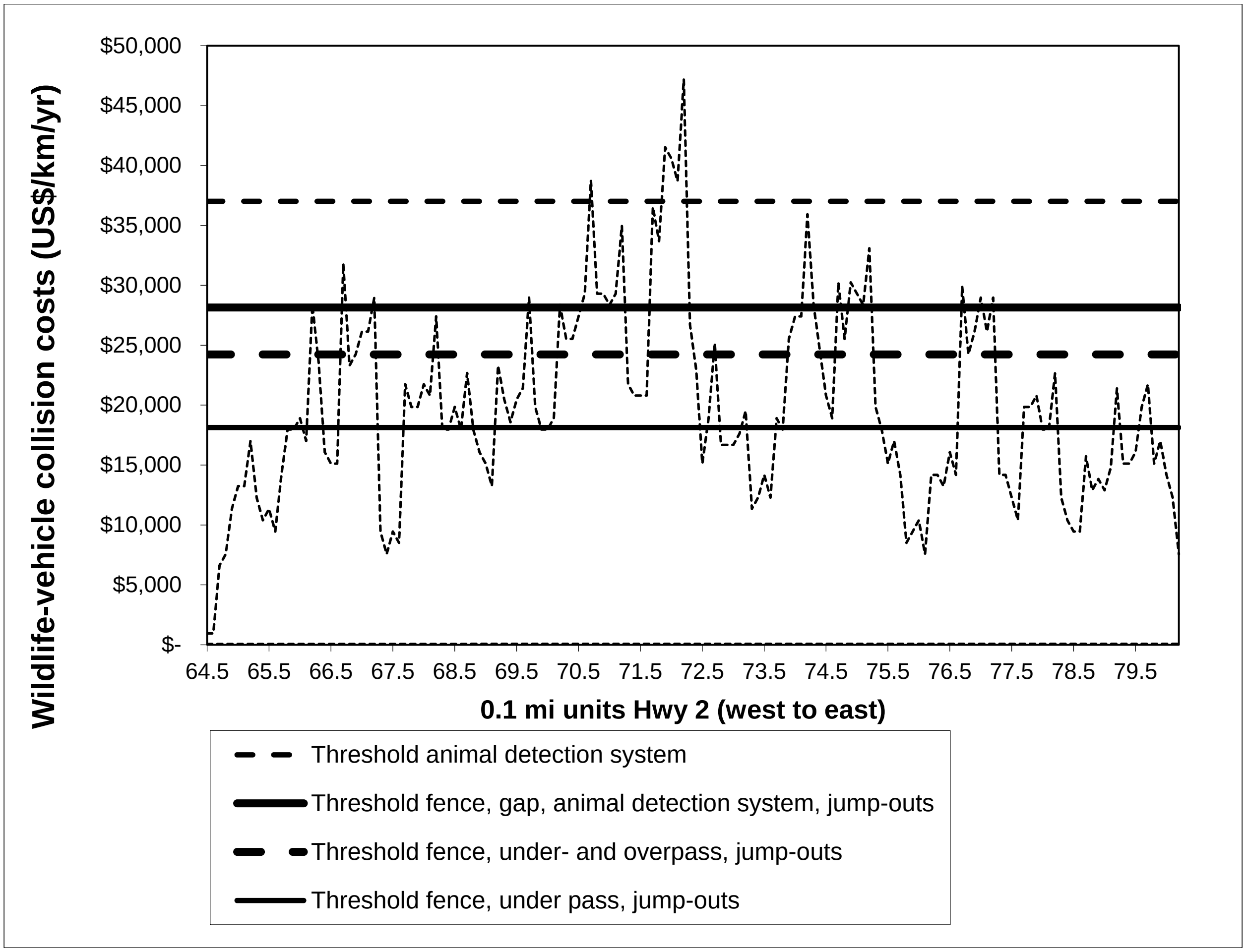

Figure 14: Hwy 2 from the junction with Hwy 95 just north of Bonners Ferry (west end, left side of graph) to the Idaho/Montana state line (east end, right side of graph). The costs (jagged line, in 2007 US$) associated with ungulate-vehicle collisions per year (annual average based on carcass removal data 2003-2010, excluding 2007), and the threshold values (at 3% discount rate) that need to be met in order to have the benefits of individual mitigation measures exceed the costs over a 75 year long time period. Note that the costs at each 0.1 mile (160.9 m) long road unit concerned and adjacent units were summed to estimate the costs per kilometer.

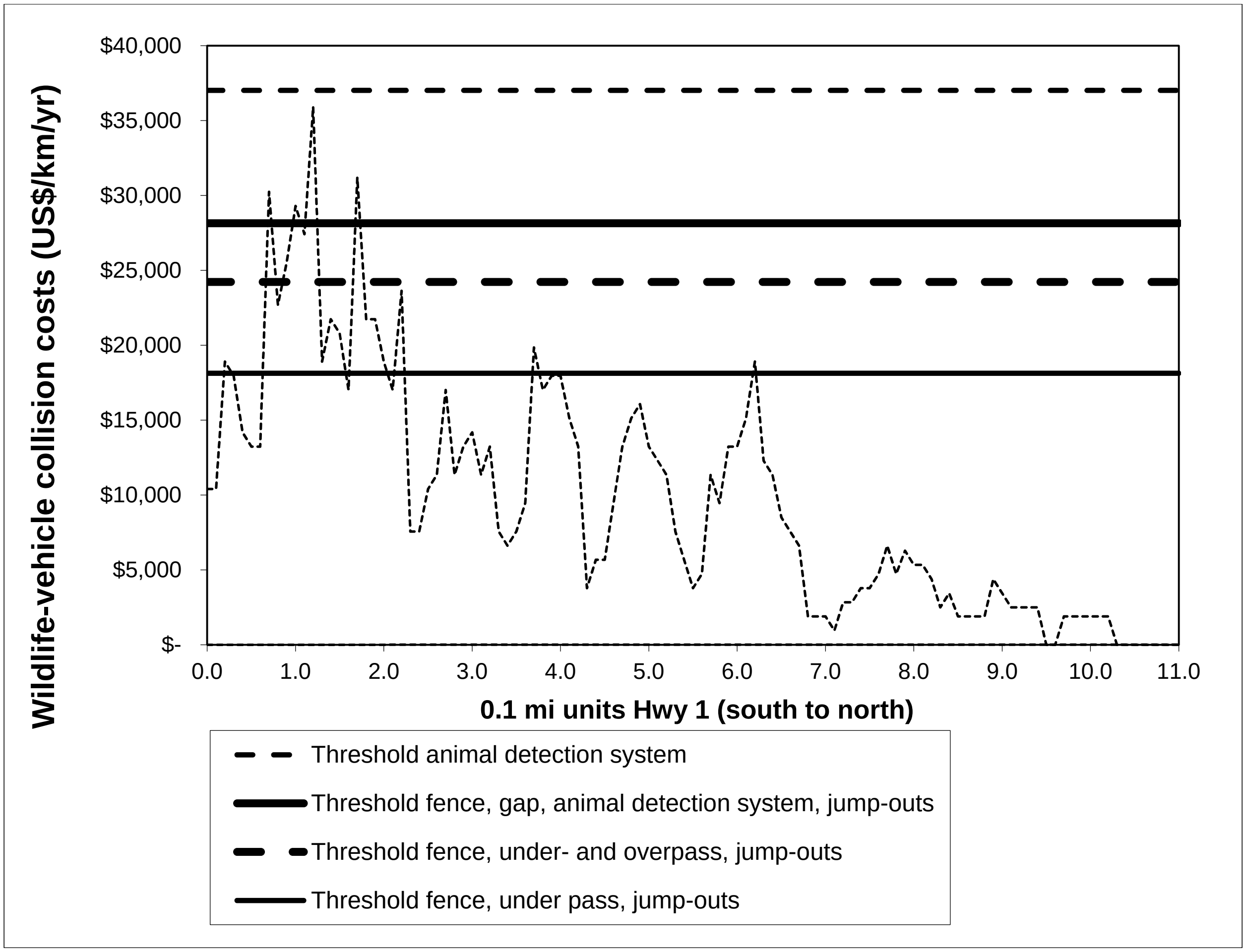

Figure 15: Hwy 1 from the junction with Hwy 95 near Copeland (south end, left side of graph) to the Canadian border at Porthill (north end, right side of graph). The costs (jagged line, in 2007 US$) associated with ungulate-vehicle collisions per year (annual average based on carcass removal data 2003-2010, excluding 2007), and the threshold values (at 3% discount rate) that need to be met in order to have the benefits of individual mitigation measures exceed the costs over a 75 year long time period. Note that the costs at each 0.1 mile (160.9 m) long road unit concerned and adjacent units were summed to estimate the costs per kilometer.

The crash and carcass hotspots that were identified in Chapter 2 were evaluated with regard to three cost parameters for wildlife-vehicle collisions (Table 7 and 8). First the researchers evaluated whether the individual hotspots had at least one 0.1 mi long road section where the costs associated with wildlife-vehicle collisions reached or exceeded the threshold for the most expensive combination of mitigation measures the researchers evaluated: stand-alone animal detection systems (threshold is $37,014/km/year). Then the researchers noted the peak value: the highest cost per km per year in a 0.1 mi road segment within each hotspot. Finally, the researchers calculated the average costs per kilometer per year associated with wildlife-vehicle collisions for each hotspot by averaging the costs for each of the 0.1 mi segments within each hotspot.

The researchers selected the “most costly” crash hotspot (Hwy 95 mi marker 495.3-497.1) and the three “most costly” carcass hotspots (Hwy 95 mi marker 495.5-496.5, 497.8-498.6, 513.7-515.2) for further discussion of potential mitigation measures (see Chapter 5).

Table 7: The prioritization parameters and values for the three crash data hotspots with regard to the costs of wildlife-vehicle collisions.

	Mi marker				
Hwy	Low	High	Peak collision costs in a 0.1 mi segment higher than highest threshold for mitigation?	Peak collision costs in a hotspot for a 0.1 mi segment ($/km/yr)	Average collision costs for the 0.1 mi segments in a hotspot ($/km/yr)
95	491.8	492.5	No	$21,409	$15,774.13
95	495.3	497.1	Yes	$68,239	$36,265.04
95	519.7	520.2	No	$36,528	$22,348.57

Table 8: The prioritization parameters and values for the 14 carcass data hotspots with regard to the costs of wildlife-vehicle collisions.

	Mi marker				
Hwy	Low	High	Peak collision costs in a 0.1 mi segment higher than highest threshold for mitigation?	Peak collision costs in a hotspot for a 0.1 mi segment ($/km/yr)	Average collision costs for the 0.1 mi segments in a hotspot ($/km/yr)
95	494.8	495.3	No	$36,866	$32,399
95	495.5	496.5	Yes	$68,239	$45,978
95	497.8	498.6	Yes	$61,444	$39,913
95	499.8	500.5	No	$27,413	$18,669
95	500.6	502	Yes	$42,200	$25,310
95	513.7	515.2	Yes	$67,991	$41,144
95	515.8	517.3	Yes	$38,757	$28,497
95	518.8	520.1	Yes	$47,871	$28,146
95	520.8	521.6	No	$36,528	$24,974
2	70.3	71.6	Yes	$38,758	$27,278
2	71.8	72.6	Yes	$47,195	$31,711
2	73.9	74.7	No	$35,921	$26,573
2	74.8	75.6	No	$33,085	$24,052
1	0.8	1.7	No	$35,921	$25,050

3.4. Discussion and Conclusions

All three highway segments had road sections where the threshold values for either all or some of the four mitigation measures were (nearly) met or exceeded. While the researchers strongly advise to use the cost-benefit analyses as a decision support tool they also urge users to recognize that these analyses are only one of the factors that may or should be considered in the decision making process.

The cost-benefit analyses were based on carcass removal data rather than carcass data, mainly because of the underreporting of the crash data (only 14.3% of the carcass removal data). However, not all carcasses are reported through carcass data collection programs to begin with (Tardif and Associates Inc. 2003, Sielecki 2004, Riley & Marcoux 2006, Donaldson & Lafon 2008). Carcass data depend on forms filled out by road maintenance crews that pick up carcasses and dispose of them (Huijser et al., 2007). Animals that die outside of the right-of-way or carcasses that may not be in sight of the drivers may not be picked up and remain unrecorded. Thus even carcass removal data should be regarded as a minimum count rather than an absolute count of the number of large animal-vehicle collisions that occur.

Locations where animal-vehicle collisions occur are not necessarily the same locations where animals are crossing the road successfully. Decisions on the types of mitigation measures, especially barriers, should not only be based on where carcasses are found, but data on successful crossings of the target species as well as other species should also be considered. It is considered good practice to not increase the barrier effect of a road (e.g. through wildlife fences) without also providing for safe crossing opportunities.

The cost-benefit analyses presented in this chapter are based on a four lane divided highway. However, the highways in Boundary County are typically two lanes. If mitigation measures are put in place without widening the road then the thresholds are likely lower than projected in this chapter; there are likely more and longer road sections where the costs associated with wildlife-vehicle collisions meet or exceed the thresholds. If the road is completely reconstructed and widened at the same the mitigation measures are installed there can be overall cost savings, but the costs for the crossing structures will increase compared to those for a two lane road.

The cost-benefit analysis is relatively conservative and does not include passive use values. For a full understanding what is and what is not included in the cost-benefit analyses and how the analyses were conducted please see Huijser et al. (2009). It is also important to know that the costs and benefits are expressed in 2007 US$. Since the costs associated with deer-vehicle collisions and with mitigation measures change continuously and can even vary substantially depending on the geographic region, the cost-benefit analyses should be regarded as indicative. The researchers would also like to point out that the cost-benefit analyses does not include all parameters that should be considered when making a decision on the implementation of potential mitigation measures. The researchers strongly advise to use the cost-benefit analyses as a decision support tool but also urge users to recognize that it is only one of the factors that may or should be considered in the decision making process. Examples of other factors that should be considered are the need for different wildlife species to have a certain degree of connectivity across the landscape, including roads, so that their population can be expected to persist in the region over a certain amount of time.

4. IMPORTANT HABITAT AND CORRIDORS

4.1. Introduction

The researchers enquired with members of the Kootenai Valley Resource Initiative (KVRI) about the potential availability of data of animals seen alive on or near the road or of documents that may contain information on actual animal movements across the different roads, or projected animal movement corridors based on habitat, topography, and/or landownership and land use. These data help identify locations where safe crossing opportunities may have to be provided for and for which species, and where barriers (e.g. wildlife fences, should be avoided).

4.2. Methods

The information that the researchers were able to access is described in the following paragraphs.

4.2.1. Land Ownership

The researchers acquired a land ownership map for the areas with public land, including enclosed or adjacent land owned by timber companies and other private landowners. The map was acquired from the Idaho Panhandle National Forest website (Idaho Panhandle National Forest, 2012). The map is shown as background in Figures 16-19.

4.2.2. The Nature Conservancy Potential Wildlife Corridors

The researchers acquired a map with potential or perceived wildlife corridors from the Nature Conservancy (Personal Communication Kennon McClintock, The Nature Conservancy). The potential or perceived wildlife corridors and where they cross the three highways in Boundary County are shown in Figure 16 and Table 7.

Table 9: The mi markers where the potential or perceived wildlife corridors (The Nature Conservancy) bisect the three highways in Boundary County.

Hwy	Mi markers
95	492.5-495.6
95	511.6-517.1
2	72.4-75.3
1	7.4-11.3 (i.e. US-Canadian border)

4.2.3. Idaho State Wide Wildlife Linkage Zones

The researchers accessed the Idaho Highway Wildlife Linkage Wiki for maps that show wildlife linkage areas along state and federal highways (Idaho Transportation Department, 2012). These wildlife linkage areas were identified by staff of the Idaho Transportation Department, Idaho Fish and Game Department, and partner organizations in a series of workshops between 2004 and 2008. The road sections that cross the Idaho Highway Wildlife Linkage areas are shown in Figure 16 and Table 8.

The State of Idaho has published a "comprehensive wildlife conservation strategy" (Idaho Department of Fish and Game. 2005). The two areas that are part of our study area are the Okanogan Highlands Section and the Flathead Valley Section. The medium and large mammal species listed as having the greatest need for conservation are caribou (*Rangifer tarandus*), mountain goat (*Oreamnos americanus*), fisher (*Martes pennanti*), wolverine (*Gulo gulo*), Canada lynx (*Lynx canadensis*), gray wolf (*Canis lupus*) and grizzly bear (*Ursus arctos*). Therefore safe crossing opportunities for medium and large mammals in this region should preferably be suitable for these species.

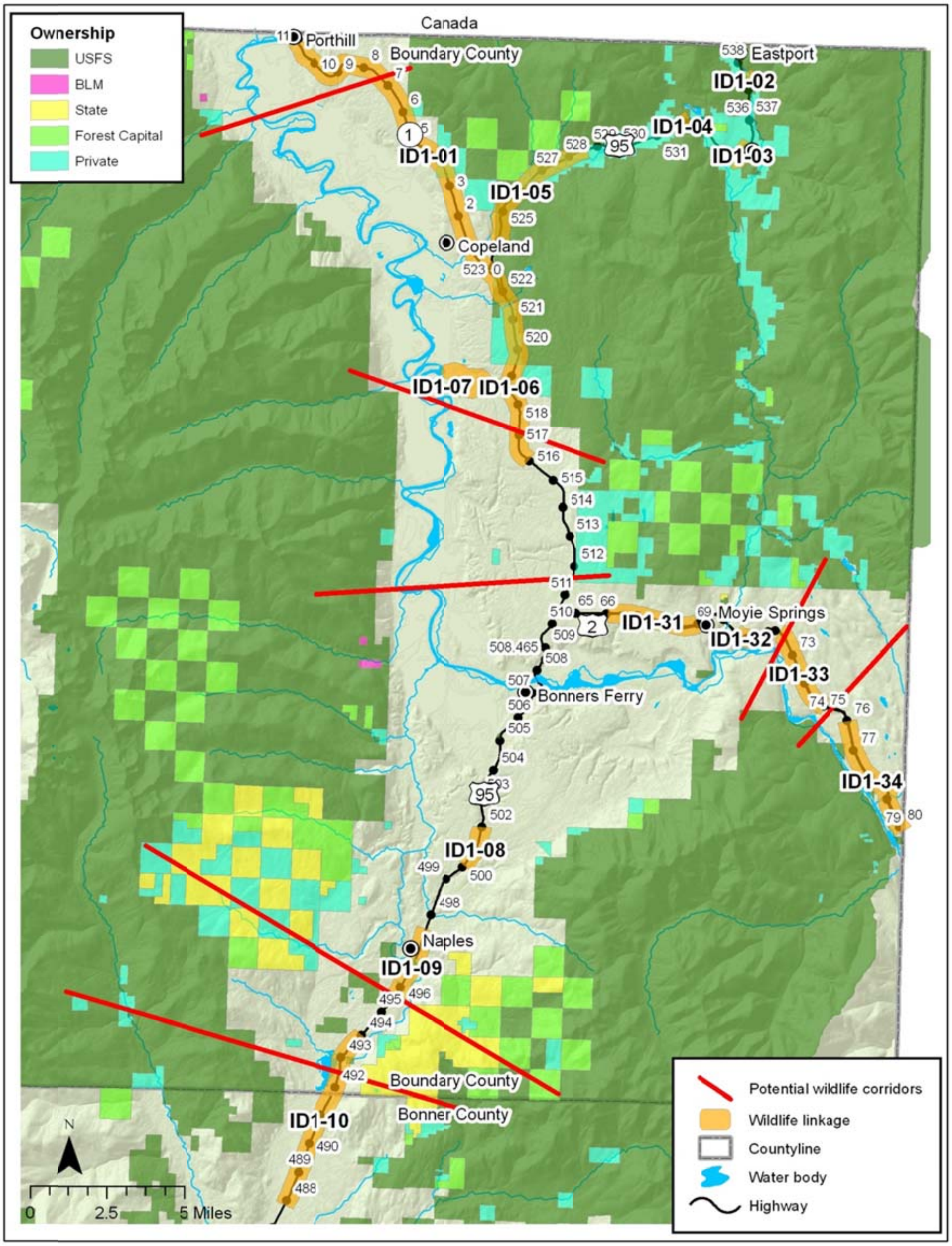

Figure 16: Landownership, potential wildlife corridors based on data from The Nature Conservancy (red lines), and road sections that bisect potential wildlife linkage areas based on data from the State of Idaho (orange road segments). Note: landownership is only shown for the areas with public land, including enclosed or adjacent land owned by timber companies and other private landowners.

Table 10: The mi markers where Idaho Highway Wildlife Linkage areas cross the three highways in Boundary County.

Hwy	Mi markers	ID in original data
95	491.8-494	ID1-10
95	495.5-497.7	ID1-09
95	500.1-502.0	ID1-08
95	516.1-521.5	ID1-06
95	518.5-518.9	ID1-07
95	521.6-523.2	ID1-01
95	523.7-528.6	ID1-05
95	531.5-532.2	ID1-04
95	534.4-535.2	ID1-03
95	537.2-537.6	ID1-02
2	66.1-69.0	ID1-31
2	70.6-71.1	ID1-32
2	72.2-75.1	ID1-33
2	76.1-80.2 (Montana border)	ID1-34
1	0-10.9	ID1-01

4.2.4. American Wildlands Wildlife Corridors

The researchers accessed the wildlife corridor database from American Wildlands (Personal Communication Rebecca Lloyd, Yellowstone to Yukon Conservation Initiative). The wildlife corridors, including target species, are shown in Figure 17 and Table 9. Safe crossing opportunities for medium and large mammals in this region should preferably be suitable for the species listed in Table 9.

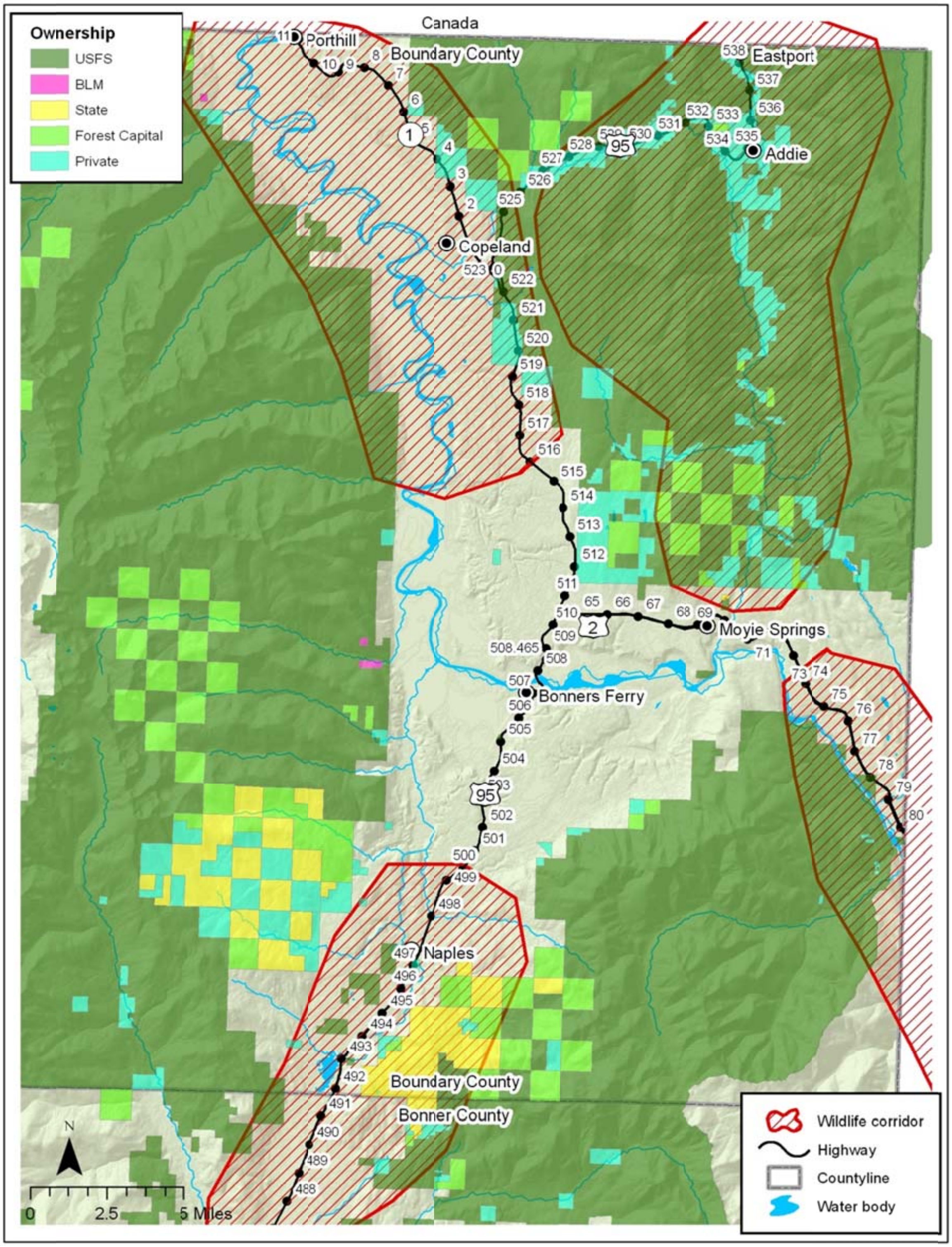

Figure 17: Wildlife Corridors based on data from American Wildlands.

Table 11: The mi markers where wildlife corridors for selected species cross the three highways in Boundary County (based on data from American Wildlands).

Hwy	Mi markers	Target species
95	491.8-500.1	Mule deer, elk, wolverine, Canada lynx, wolf, black bear, grizzly bear
95	516-525.6	Mule deer, elk, black bear, grizzly bear
95	527.2-538.5 (Canadian Border)	Black bear
2	73.6-80.2 (Montana Border)	Mule deer, elk, moose, Canada lynx, black bear, grizzly bear
1	0-11.2 (Canadian Border)	Mule deer, elk, black bear, grizzly bear

4.2.5. Local Knowledge and Experience: Marty Hoffman

The researchers interviewed Marty Hoffman with regard to animals seen dead and alive along the highways in Boundary County. Marty Hoffman drives these highways on almost a daily basis for his job and is observant to wildlife. The road sections marked by Marty Hoffman are shown in Figure 18 and Table 10.

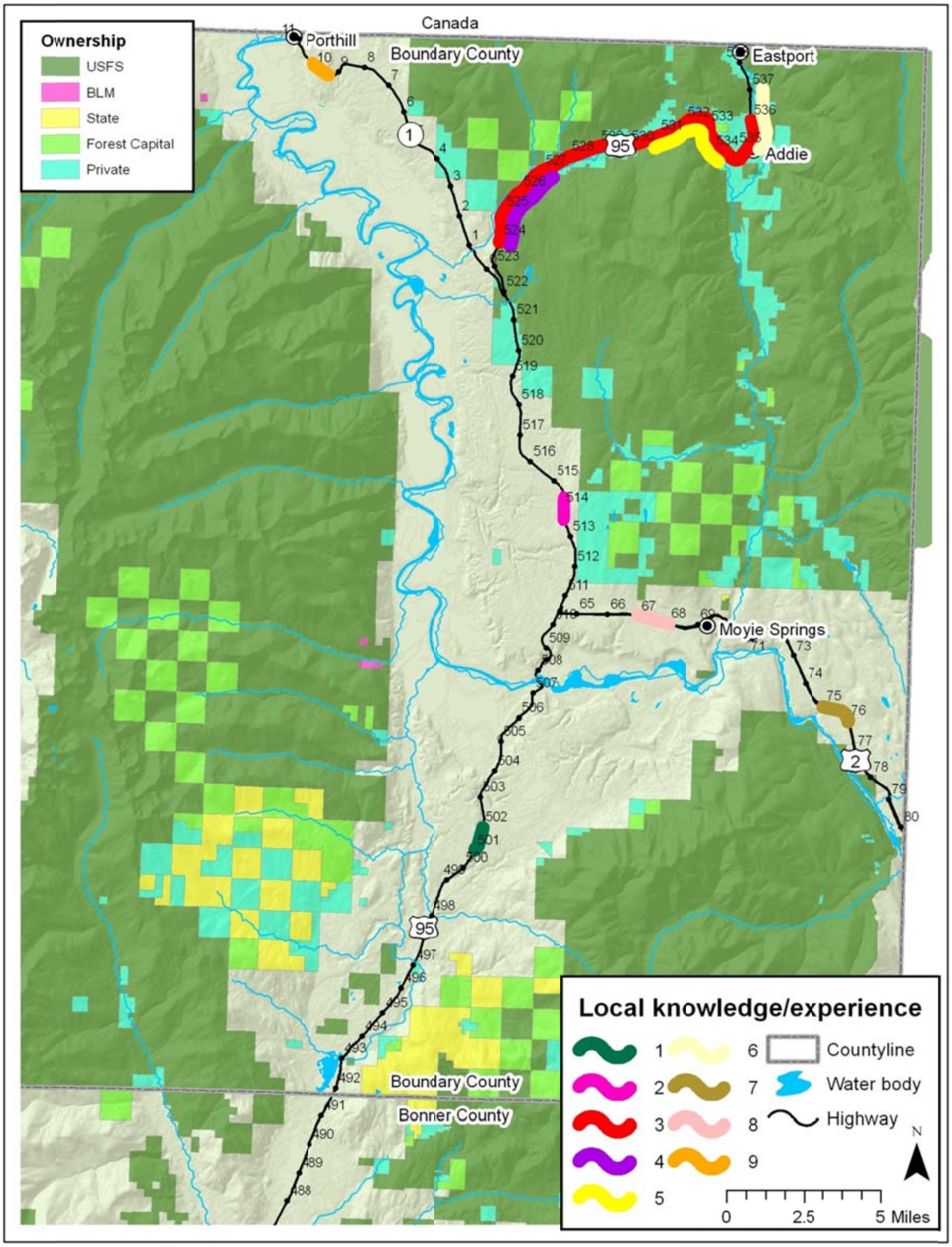

Figure 18: Road sections with a concentration of wildlife (dead or alive) based on local knowledge and experience from Marty Hoffman.

Table 12: The mi markers where a concentration of wildlife has been observed by Marty Hoffman (Local knowledge and experience).

Highway	Mi marker	Comments
U.S. Hwy 95	501-502	Elk and white-tailed deer.
U.S. Hwy 95	514	Lots of white-tailed deer (dead and alive).
U.S. Hwy 95	524-527	Elk, white-tailed deer and mule deer
U.S. Hwy 95	524-536	Lots of white-tailed deer
U.S. Hwy 95	531-534	Moose
U.S. Hwy 95	535-537	White-tailed deer
U.S. Hwy 2	75-76	Sometimes about 20 elk and 15 white-tailed deer
U.S. Hwy 2	67-68	About 15 elk
S.R. 1	9.5-10.0	30 elk seen regularly as well as white-tailed deer and mule deer (about 3-5 deer per day). 1 bobcat seen at mi marker 9.75.

4.2.6. Black Bear crossing Probability: Jesse Lewis

The researchers accessed a map that shows highway crossing probability for black bear along a segment of Highway 95 between Copeland and Eastport (Lewis et al., 2011; Personal Communication Jesse Lewis, Department of Fish, Wildlife, and Conservation Biology Colorado State University). The wildlife corridors are shown in Figure 19.

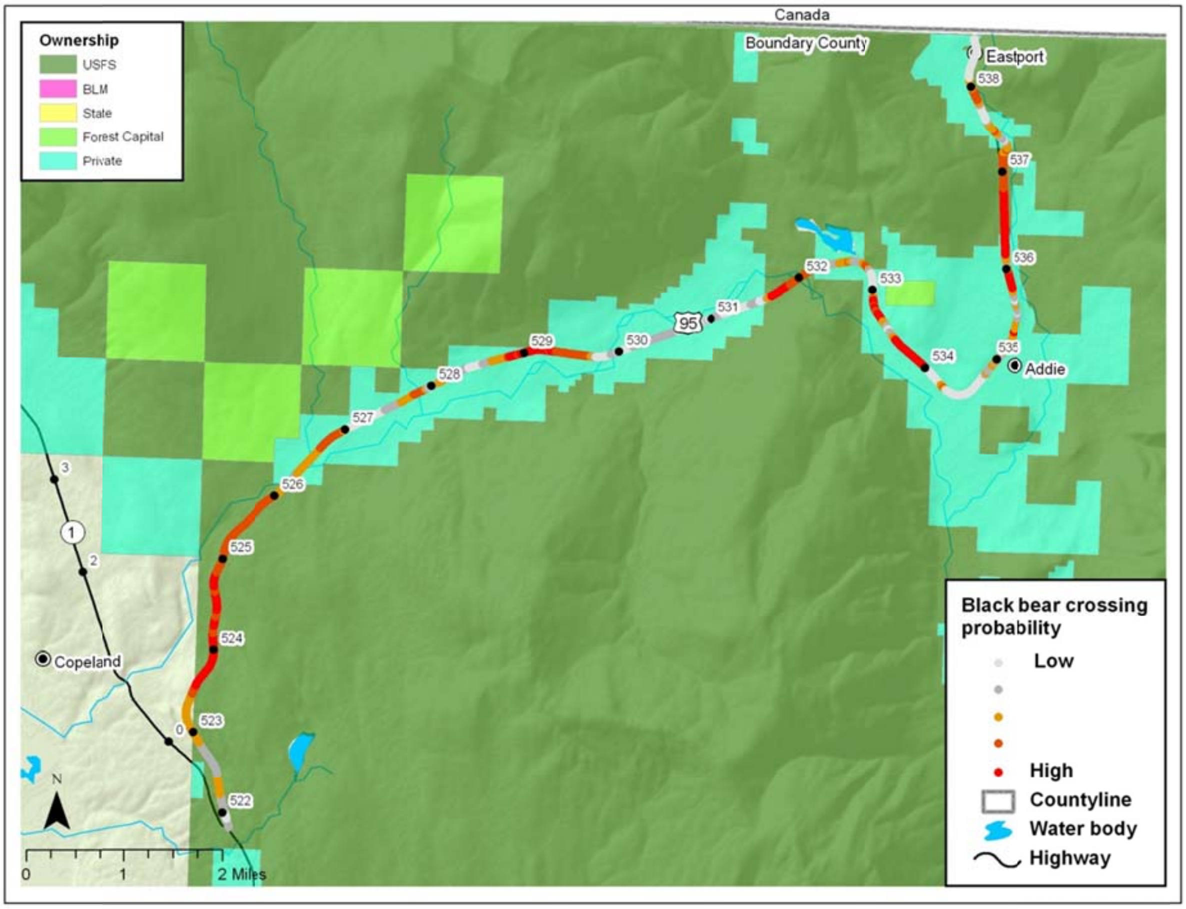

Figure 19: Highway crossing probability for black bear along a segment of Highway 95 between Copeland and Eastport (based on Lewis et al., 2011).

4.2.7. Prioritization of Crash and Carcass Hotspots Based on Habitat and Corridors

The researchers reviewed the three crash data hotspots and the 14 carcass data hotspots and noted whether the individual hotspots were located (either in their entirety or partly) in the habitat or corridor areas described in the previous sections (Table 11 and 12). Since the road length of the hotspot indfluenced the likelihood that the hotspot was either completely or only partly located in the described habitat or corridors, the researchers assigned the same value to these categories (value =1). If the hotspot was not located in the described habitat or corridors, the researchers assigned the value 0. The higher the tatal score in Table 11 and 12 the higher the ranking is of the hotspot with regard to habitat and corridors. The researchers interpreted higher values as relatively important habitat or corridors for wildlife that are generally agreed upon.

The researchers selected the most important crash hotspot (Hwy 95 mi marker 495.3-497.1) and the three most important carcass hotspots. However, since there was a three-way tie for the second most important carcass hotspot the researchers ended up selecting four carcass hotspots

(Hwy 95 mi marker 495.5-496.5, 515.8-517.3, Hwy 2 mi marker 73.9-74.7, 74.8-75.6) for further discussion of potential mitigation measures (see Chapter 5).

Table 13: The prioritization parameters and values for the three crash data hotspots based on habitat and corridors. Yes = hotspot is entirely within habitat or corridor (1 point); Partly = hotspot is partly within habitat or corridor (1 point); No = hotspot is entirely outside habitat or corridor (0 points). Black bear crossings = high probability only.

	Mi marker		Habitat and Corridor Parameters					
Hwy	Low	High	Nature Conservancy corridor	Idaho wildlife linkage zone	American Wildlands Corridors	Marty Hoffman	Black bear crossings	Total score
95	491.8	492.5	No	Yes	Yes	No	No	2
95	495.3	497.1	Partly	Partly	Yes	No	No	3
95	519.7	520.2	No	No	Yes	No	No	1

Table 14: The prioritization parameters and values for the 14 carcass data hotspots based on habitat and corridors. Yes = hotspot is entirely within habitat or corridor (1 point); Partly = hotspot is partly within habitat or corridor (1 point); No = hotspot is entirely outside habitat or corridor (0 points). Black bear crossings = high probability only.

	Mi marker		Habitat and Corridor Parameters					
Hwy	Low	High	Nature Conservancy corridor	Idaho wildlife linkage zone	American Wildlands Corridors	Marty Hoffman	Black bear crossings	Total score
95	494.8	495.3	Partly	No	Yes	No	N/A	2
95	495.5	496.5	Partly	Yes	Yes	No	N/A	3
95	497.8	498.6	No	No	Yes	No	N/A	1
95	499.8	500.5	No	Partly	Partly	No	N/A	2
95	500.6	502	No	Yes	No	Partly	N/A	2
95	513.7	515.2	Partly	No	No	Partly	N/A	2
95	515.8	517.3	Partly	Partly	Partly	No	N/A	3
95	518.8	520.1	No	Partly	Yes	No	N/A	2
95	520.8	521.6	No	No	Yes	No	N/A	1
2	70.3	71.6	No	Partly	No	No	NA	1
2	71.8	72.6	Partly	Partly	No	No	N/A	2
2	73.9	74.7	Yes	Yes	Yes	No	N/A	3
2	74.8	75.6	Partly	Partly	Yes	Partly	N/A	4
1	0.8	1.7	No	Yes	Yes	No	N/A	2

5. MITIGATION EMPHASIS SITES

5.1. Locations of Mitigation Emphasis Sites

The crash and carcass hotspot that ranked worst with regard to crash and carcass data (Chapter 2), that had the highest costs for wildlife-vehicle collisions (Chapter 3) and that were considered most important wildlife habitat and corridors (Chapter 4) are summarized in Table x. These locations are considered the mitigation emphasis sites for which the researchers suggested specific mitigation measures.

For crash hotspots there was only one hotspot selected (Hwy 95 mi marker 495.3-497.1). This one hotspot was the worst or highest ranking hotspot with regard to human safety, costs associated with wildlife-vehicle collisions and was considered the most important habitat or corridor.

For carcass hotspots the three worst or highest ranking sites were selected based on human safety (Chapter 2), costs associated with wildlife-vehicle collisions (Chapter 3) and the most important habitat or corridors (Chapter 4). The highest ranking hotspot received three points (Table x). The second highest ranking hotspot received two points and the third received 1 point. In case of a tie the hotspots all received the points associated with the rank rather than averaging the available points.

Table 15: The prioritization parameters and values for the selected carcass data hotspots.

	Mi marker						
Hwy	Low	High	Length (mi)	Human safety	Wildlife-vehicle collision costs	Habitat and corridors	Total
95	494.8	495.3	0.5	1	0	0	1
95	495.5	496.5	1	0	3	2	5
95	497.8	498.6	0.8	3	1	0	4
95	513.7	515.2	1.5	2	2	0	4
95	515.8	517.3	1.5	0	0	2	2
2	73.9	74.7	0.8	0	0	2	2
2	74.8	75.6	0.8	0	0	3	3

6. WILDLIFE MITIGATION RECOMMENDATIONS

6.1. Recommended Mitigation Measures

Although there have been many mitigation measures suggested to reduce wildlife-vehicle collisions (WVCs), only a few of measures have the potential to substantially reduce WVCs (Huijser et al. 2008, 2009; Clevenger & Huijser 2011). Only wildlife fencing (including wildlife jump-outs) and animal detection systems have shown to be able to reduce WVCs with large mammals substantially (>80%). It is important to note however, that animal detection systems should still be considered experimental whereas the estimate for the effectiveness of wildlife fencing in combination with wildlife underpasses and overpasses is much more robust. Large boulders in the right-of-way as an alternative to wildlife fencing appear to have potential as a barrier to ungulates and may be an alternative to wildlife fencing. However, this measure should also still be considered experimental and would be mostly targeted at ungulates rather than other species groups. For a summary of the pros and cons of selected mitigation measures, including wildlife fencing, animal detection systems and large boulders in the right-of-way, see Table 12.

Closing and removing the road, or tunneling or elevating the road over long sections (e.g. hundreds of meters to tens of kilometers) is more effective in reducing WVCs that the measures described above. In addition, they allow for better habitat connectivity. However, road closure and road removal are considered unacceptable, and tunneling or elevating the road is extremely costly and are typically only an option if the nature of the terrain, the physical environment, requires it. Therefore the authors of the report did not include road closure and removal or tunneling or elevating the road in the recommendations.

The effectiveness of other mitigation measures in reducing WVCs is relatively low (<50%), impractical, not applicable, or unknown (Huijser et al. 2008). The authors of this report consider animal detection systems and wildlife fencing, in combination with wildlife underpasses and overpasses, to be the primary recommended mitigation measures for the reduction of WVCs along the highways in Boundary County. However, animal detection systems should still be considered experimental whereas the performance estimates for wildlife fencing and underpasses and overpasses are much more robust. Also, care must be taken to reduce false detections, for example if pedestrians are present in the right-of-way, and animal detection systems are less effective if a high percentage of the traffic is not local or if drivers are unlikely to respond to warning signals (perhaps drivers of large vehicles are less likely to reduce speed than drivers of small vehicles). For suggestions on implementation of wildlife fences, wildlife crossing structures and animal detection systems see Huijser et al. (2008) and Clevenger & Huijser (2011).

While brushing of the right-of-way vegetation has been implemented along various road segments in Boundary County the researchers do not advise brushing as the primary strategy to reduce wildlife-vehicle collisions. Brushing may only marginally reduce collisions with larger ungulates (see review in Huijser et al., 2008) and it may discourage animals from approaching and crossing the road. The researchers are of the opinion that it is good practice to only increase the barrier effect of roads and traffic to wildlife if also appropriate safe crossing opportunities are provided.

Table 16. Pros and cons of selected mitigation measures.

Mitigation measure	Pros	Cons
Wildlife fencing including wildlife jump-outs	87% reduction in WVCs expected when combined with wildlife underpasses and overpasses.	Barrier for wildlife; combine with safe crossing opportunities. Affects landscape aesthetics and sense of connectedness of the drivers to the surrounding areas. Potential animal intrusions at access roads/points, and fence ends. Potential mortality source for certain species under certain conditions (e.g. grouse, bighorn sheep). May provide drivers with a sense of security that may lead to higher speeds. Excluding r-o-w vegetation may lead to displacement or population reduction in species that depend on r-o-w vegetation (e.g. white-tailed deer, elk).
Large boulders	Substantial reduction in WVCs for most ungulates expected (e.g. deer, elk, and moose, but not for e.g. bighorn sheep and mountain goat). Not a barrier for species that can climb over the boulders. Less effect on landscape aesthetics than wildlife fencing	Not all species protected against WVCs. Barrier for most ungulates; combine with safe crossing opportunities. Potential animal intrusions at access roads/points, and end of boulder rows. Excluding r-o-w vegetation may lead to displacement or population reduction in species that depend on r-o-w vegetation (e.g. white-tailed deer, elk). Experimental measure.
Animal detection systems	87% reduction in WVCs for large mammals expected, but this estimate in WVC reduction may change substantially as more data become available. Have the potential to provide wildlife with safe crossing opportunities anywhere along the mitigated roadway, in contrast to underpasses and overpasses which are typically limited in number and width. Are less restrictive to wildlife movement than fencing or crossing structures. They allow animals to continue to use existing paths to the road or to change them over time No road work or traffic control needed for installation (in contrast to wildlife underpasses and overpasses).	Not suitable for very high traffic volumes. Detects large animals only. Animals are allowed to cross at grade; the design of the measure allows drivers to still be exposed to risk. The number of at grade crossings may not be sufficient to ensure long term population viability for all species. When combined with wildlife fencing, wildlife is directed to road at fence ends or at gaps, and this may cause road managing agencies to be liable in case of a collision, especially if the animal detection system may not have been working properly. Species that depend on r-o-w vegetation may use the at grade crossing to access that

	Likely to be less expensive than wildlife crossing structures, especially once they are mass produced Can be installed over long road sections (multiple km) or at gaps in fence. This measure is somewhat mobile (except for foundations) and can be used at other locations should animals start crossing somewhere else.	vegetation and end up in between the fences. This may be mitigated by boulder fields in r-o-w and electric mats on road, which may only function in summer. Some of the systems are not operational during the day. Curves, drops and rises in the right-of-way, access roads, pedestrians, winter conditions (including snow spray from snow plow and snow accumulation, can cause problems with the installation, maintenance and operation. The presence of poles and equipment in the right-of-way is a potential hazard to vehicles that run off the road. Animal detection systems can be aesthetically displeasing. Experimental measure.
Wildlife underpasses and overpasses	87% reduction in WVCs expected when combined with wildlife fencing. Well used by a wide variety of species. Can provide cover (e.g., vegetation, living trees, tree stumps) and natural substrate (e.g., sand, water) allowing better continuity of habitat than e.g. at grade crossing opportunities. Likely to have greater longevity and lower maintenance and monitoring costs than e.g. animal detection systems	The number, type, and dimensions of crossing opportunities may not be sufficient to ensure long term population viability for all species. This measure requires substantial road work and traffic control. This measure is not mobile.

6.2. Distance between Safe Crossing Opportunities

When wildlife fencing is installed alongside a road, the barrier effect of the road corridor is increased. Depending on the species concerned, a wildlife fence may be an absolute or a nearly complete barrier. Such barriers in the landscape are to be avoided as they isolate animal populations, and smaller and more isolated populations have reduced population survival probability. Therefore, when a wildlife fence is installed, safe crossing opportunities for wildlife should be provided for as well. This section discusses the distance between safe crossing opportunities.

The spacing of safe crossing opportunities for wildlife can be calculated in more than one way and is dependent on the goals one may have. Examples of possible goals are:

- Provide permeability under or over the road for ecosystem processes, including but not restricted to animal movements. Ecosystem processes include not only biological processes, but also physical processes (e.g. water flow).

- Allowing a wide variety of species to change their spatial distribution drastically, for example in response to climate change.
- Maintaining or improving the population viability of selected species based on their current spatial distribution. This includes striving for larger populations with a certain degree of connectivity between populations (allowing for successful dispersal movements).
- Providing the opportunity for individuals (and populations) to continue seasonal migration movements (e.g. big horn sheep, white-tailed deer).
- Allowing individuals, regardless of the species, that have their home ranges on both sides of the highway to continue to use these areas. This may result in a road corridor that is permeable for wildlife, at least to a certain degree, and at least for the individuals that live close to the road.

A further complication is that individuals that disperse, that display seasonal migration, or that live in the immediate vicinity of a road may display differences in behavior with regard to where and how they move through the landscape, how they respond to roads, traffic, and associated barriers (e.g. wildlife fencing), and their willingness to use safe crossing opportunities. For example, dispersing individuals may be far away from the areas where one is used to seeing them, they may not move through habitat that we may expect them to be in, they typically travel long distances, much further and quicker compared to resident individuals, but successful dispersers may also stay away from roads and traffic, and other types of human disturbance. Safe crossing opportunities may not be encountered by dispersing individuals as they are new in the area and are not familiar with their location, and when confronted with a road or associated wildlife fence they may return or change the direction of their movement before they encounter and use a safe crossing opportunity. Furthermore, if dispersing individuals do encounter a safe crossing opportunity, they may be more hesitant to use them compared to resident individuals that not only know about their location, but that also have had time to learn that it is safe to use them. Since dispersal can be a relatively rare phenomenon, one may not be able to afford a dispersing individual to fail. Therefore, despite the fact that dispersers travel much further than resident individuals, designing safe crossing opportunities for dispersers does not automatically mean that one can allow for a greater distance between safe crossing opportunities.

Full scale population viability analyses can be very helpful to compare the effectiveness of different configurations of safe crossing opportunities. For this report the authors choose a simpler approach. For selected ungulate and carnivore species the diameter of their home ranges were estimated (Tables 13 and 14).

The distance between safe crossing opportunities was set to be equal to the diameter of the home range of the species concerned (Figure 40). This allowed individuals that have the center of their home range on the road to have access to at least one safe crossing opportunity. However, individuals that may have had their home range on both sides of the road do not necessarily have access to a safe crossing opportunity (Figure 41). Finally, this approach assumed homogenous habitat and distribution of the individuals and circular home ranges, while in reality habitat and habitat quality may vary greatly, causing variations in density of individuals and irregular shapes home ranges.

The authors of this report would like to emphasize that this approach does not necessarily result in viable populations for every species of interest, and that not every individual that approaches the road and associated wildlife fence, will encounter and use a safe crossing opportunity. In addition, the approach described above is not necessarily the only approach or the approach that addresses the barrier effect of the road corridor and associated fencing sufficiently for all species concerned. However, the authors do think that the approach chosen is consistent, practical, based on the available data (or lack thereof), and likely to result in considerable permeability of the road corridor and associated wildlife fencing for a wide array of species.

Table 17. Home range size and diameter estimates for selected carnivore species. The estimates relate to female individuals where possible, and local or regional data weighed relatively heavily in the final estimation of the home range size.

Species	Home range (ha) and diameter (m)	Source(s)
Focal species		
Fisher (*Martes pennanti*)	75,000 ha 23,885 m	47,700 ha for females for females, 219,000 ha for males (Weir & Corbould, 2010)
Wolverine (*Gulo gulo)*	20,000 ha 15,962 m	16,700 ha (range 7,600-26,900 ha) for females (Banci & Harestad, 1990), 10,500 for adult females (Whitman et al., 1986), 38,800 for females (review in Lindstedt et al., 1986), 32,500-40,500 ha for females (Krebs et al., 2007)
Bobcat (*Lynx rufus)*	2,500 ha 5,643 m	1,780 ha for adult female (Knowles, 1985), 1,930 ha for females (review in Lindstedt et al., 1986), 3,120 ha for females (Litvaitis et al., 1986)
Canada lynx (*Lynx canadensis)*	15,000 ha 13,823 m	2,800 ha (range 1,110-4,950 ha) for adults (Brand et al., 1976), 9,000 ha (range 5,800-12,100 ha for adult females (Squires & Laurion, 2000), 20,600 ha (range 7,700-40,800 ha) for females (Apps, 2000)
Cougar (*Puma concolor)*	4,000 ha 7,138 m	3,500 ha (range 1,900-5,100 ha) for adult females in summer and 2,600 ha (range 1,400-4,300 ha) in winter (Spreadbury et al., 1996), 6,730 ha for females (review in Lindstedt et al., 1986), 9,700 ha (range 3,900-22,700 ha) for adult females in summer and 8,700 (range 3,100-23,900 ha) in winter (Ross & Jalkotzy, 1992)
Red fox (*Vulpes vulpes*)	1,500 ha 4,371 m	1,611 ha (range 277-3,420 ha) (Jones & Theberge, 1982), 350 ha (Frey & Conover, 2006)
Coyote (*Canis latrans)*	2,500 ha 5,643 m	1,130 ha (range 280-3,200 ha) (Gese et al., 1988), 2,010 ha (range 1,600-2,420 ha) for females (review in Lindstedt et al., 1986), 2,420 ha (range 880-5,460 ha) for adult females (Andelt & Gipson, 1979), 3,186 ha (range 670-9,140 ha) for females (review in Laundré & Keller, 1984)
Wolf (*Canis lupus*)	50,000 ha 25,238 m	6,250 ha (range 700-6,800 ha) (review in Lindstedt et al., 1986). 73,900 ha (Latham, 2009)
Black bear (*Ursus americanus)*	4,000 ha 7,138 m	1,960 ha for females (Young & Ruff 1982), 5,960 ha (range 2,300-16,000 ha) for adult females (McCoy, 2005)
Grizzly bear (*Ursus arctos*)	25,000 ha 17,846 m	22,700 ha (range 3,500-88,400 ha) for adult females (Gibeau et al., 2001), 28,500 ha (112-482 ha) for adult females (Servheen, 1983)

Table 18. Home range size and diameter estimates for the selected ungulate species. The estimates relate to female individuals where possible, and local or regional data weighed relatively heavily in the final estimation of the home range size.

Species	Home range (ha) and diameter (m)	Source(s)
Selected other species		
White-tailed deer (*Odocoileus virginianus)*	70 ha 944 m	70.5 ha for adult females in summer (Leach & Edge, 1994), <80 in summer (Mundinger, 1981), 60-70 ha for females in summer (review in Mackie et al. 1998), 89 ha (range 17-221 ha) for females in summer and 115 ha (range 19-309 ha) in winter (review in Mysterud et al., 2001)
Mule deer (*Odocoileus hemionus)*	300 ha 1,955 m	301 ha on average for males and females in winter (D'Eon & Serrouya, 2005), 90-320 ha for adult females in summer and 80-500 ha in winter (review in Mackie et al. 1998), 617 ha (range 25-4,400 ha) for females in summer and 1,267 ha (range 32-9,070 ha) in winter (review in Mysterud et al., 2001)
Elk (*Cervus canadensis*)	5,000 ha 7,981 m	3,769 ha (range 820-9,520 ha) for females in summer and 181 ha (range 152-210 ha) in winter (review in Mysterud et al., 2001), 5,296 ha for adult females in summer and 10,104 ha in winter (Anderson et al., 2005), 8,360-15,720 ha for elk populations (Van Dyke et al., 1998)
Moose (*Alces alces)*	2,500 ha 5,643 m	2,612 ha (range 210-10,300 ha) for females in summer and 2,089 ha (range 200-11,300 ha) in winter (review in Mysterud et al., 2001)
Mountain goat (*Oreamnos americanus*)	300 ha 1,955 m	280 ha for adult males, 480 ha for adult females (Singer & Doherty, 1985)
Bighorn sheep (*Ovis canadensis*)	900 ha 3,386 m	541 ha for females (review in Demarchi et al., 2000), 920 ha (range 650-1,140 ha) for females in summer and 893 (range 880-1,320 ha) in winter (review in Mysterud et al., 2001), 640-3,290 ha (review in Demarchi et al., 2000)

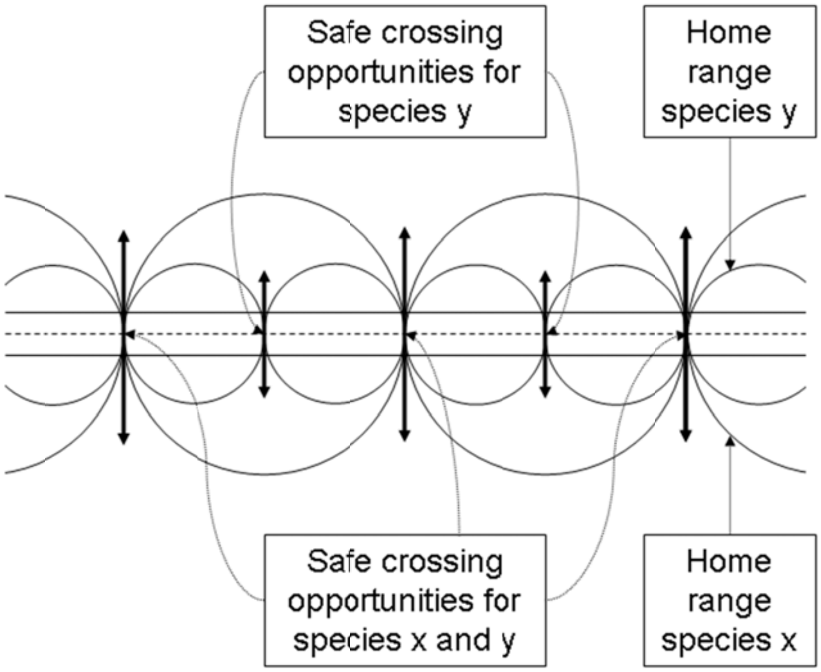

Figure 20. Schematic representation of home ranges for two theoretical species projected on a road and the distance between safe crossing opportunities (distance is equal to the diameter of their home range).

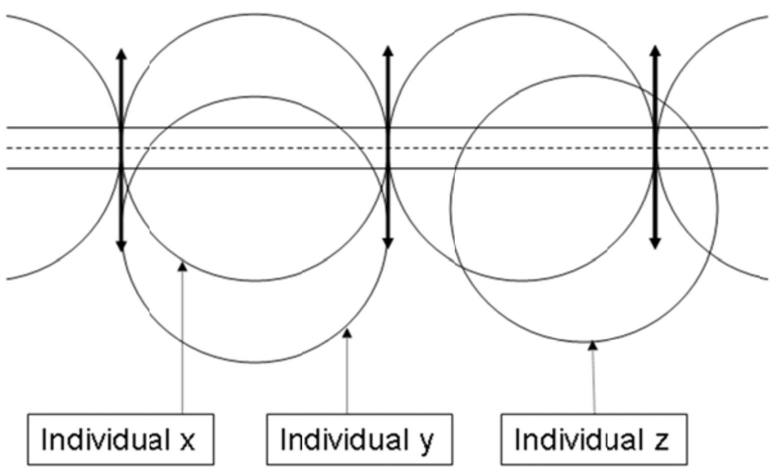

Figure 21. Schematic representation of home range for an individual (x) that has the center of its home range on the center of the road (access to two safe crossing opportunities), an individual (y) that has the center of its home range slightly off the center of the road exactly in between two safe crossing opportunities (no access to safe crossing opportunities), and an individual (z) that has the center of its home range slightly off the center of the road but not exactly in between two safe crossing opportunities (access to one safe crossing opportunity).

6.3. Safe Crossing Opportunity Types

The authors of this report distinguished six different types of safe crossing opportunities for potential implementation on and along the roads in the study area (Table 15) (Figure 22-30). Note that there are other types of crossing structures, e.g. for arboreal species, amphibians, but these are not included in this report because this report focuses on median and large mammals (coyote size and larger) and these species are also able to pass through or over the wildlife fence. In addition, the six types of crossing structures listed are likely to be used by e.g. amphibians, reptiles, (semi-)arboreal species, and small mammals, given certain environmental conditions or modifications. For example, if wet habitat is present or created on or nearby an overpass or underpass, amphibians and other semi-aquatic species are more likely to use the crossing opportunity. Similarly, aquatic or semi-aquatic species are likely to use a crossing opportunity if the underpass is combined with a stream or river crossing. Stream characteristics and stream dynamics must be carefully studied to ensure that the conditions inside the crossing structure are and remain similar to that of the stream up- and downstream of the structure. Such parameters include e.g. water velocity, variability in water velocity, erosion of substrate inside the crossing structure, or up- and downstream of the structure, and the implications of high and low water events, including debris and potential maintenance issues. If terrestrial animals are to use the underpass as well, a minimum path width of 0.5 m is recommended for small and medium mammals, and 2-3 m for large mammals (Clevenger & Huijser, 2011). Furthermore, small mammals increase their use of wildlife underpasses and overpasses if cover (e.g. tree stumps, branches and rocks) is provided for continuous travel through or over the crossing structure. Nonetheless, one may choose to provide additional safe crossing opportunities specifically designed for e.g. amphibians, reptiles, semi-arboreal species, and small mammals (soil and air humidity, cover, woody vegetation that spans across or under the road or canopy connectors such as ropes or other material) (e.g. Kruidering et al. 1995).

While Table 19 classifies crossing structures based on their dimensions, there is no generally agreed upon definition of different types of crossing structures. One may also choose to modify the dimensions of an underpass based on the species of interest and the physical environment at the location of the underpass.

Table 20 provides an overview of the suitability of the six different types of safe crossing opportunities for the medium and large mammal species that are known to occur in the area or that have been mentioned by various sources in Chapter 4. When evaluating the suitability, the authors assumed no human co-use of the crossing opportunities. The suitability of the different types of safe crossing opportunities is not only influenced by the size of the species and their habitat, but also by behavior. Most animal detection systems only detect large mammals and are therefore by definition not suitable for medium and small species. Because the suitability of the different safe crossing opportunities depends on the species, and large landscape connectors (e.g. tunneling or elevated road sections) are rare, providing a variety of different types of safe crossing opportunities generally provides habitat connectivity for more species than implementing only one type of crossing structure, even if that structure is relatively large.

For some species there is little or no information on what type and dimension of crossing structure is considered suitable. However, for some species the researchers can make an educated guess. For example, woodland caribou may be similar to other large cervids such as elk and moose, suggesting that wildlife overpasses and overspan bridges are the most suitable type of crossing structure for this species.

Should at grade crossing opportunities be implemented in combination with wildlife fencing, extreme care must be taken to discourage wildlife from wandering off in between the fences in the fenced road corridor. Bringing the fence close to the road at these locations, with or without the use of boulder fields may help, and an electric mat (ElectroMAT™, ElectroBraid™) that is embedded in the road surface, or laid on top of the road, may also be considered to discourage animals from walking off to the sides on the roadway (ElectroBraid 2008a). Reports on the manufacturer's website suggest that the electric matt holds up when exposed to snowplows and that it can function throughout the winter (ElectroBraid 2008b). Nonetheless, such at grade crossing opportunities should be seen as experimental and their effectiveness should be carefully evaluated before implementing them on large scale.

Table 19. Dimensions of the safe crossing opportunities recommended for implementation on or along the roads in the study area.

Safe Crossing Opportunity	Dimensions (as seen by the animals)		Safe Crossing Opportunity	Dimensions (as seen by the animals)
Wildlife overpass	50 m wide		Medium mammal underpasses	0.8-3 m wide, 0.5-2.5 m high
Open span bridge	12 m wide, ≥5 m high		Small-medium mammal pipes	0.3-0.6 m in diameter
Large mammal underpass	7-8 m wide, 4-5 m high		Animal Detection system	n/a

Figure 22. Wildlife overpass on the Trans-Canada Highway (© Marcel Huijser).

Figure 23. Wildlife overpass across a 2-lane road (US Hwy 93) on the Flathead Indian Reservation, Montana, USA (© Marcel Huijser).

Figure 24. An open span bridge along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (across Spring Creek, south of Ravalli) (© Marcel Huijser).

Figure 25. A large mammal underpass (7-8 m wide, 4-5 m high) along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (south of Ravalli) (© Marcel Huijser).

Figure 26. A medium mammal box culvert (1.2 m wide, 1.8 m high) along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (south of Ravalli) (© Marcel Huijser).

Figure 27. A medium mammal culvert (2 m wide, 1.5 m high) along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (south of Ravalli) (© Marcel Huijser).

Figure 28. A small-medium mammal pipe ("badger pipe") in The Netherlands (© Marcel Huijser).

Figure 29. An animal detection system (infrared break-the-beam system manufactured by Calonder Energy, Switzerland) at a gap in a wildlife fence near 't Harde, The Netherlands (© Marcel Huijser).

Figure 30. An animal detection system (microwave radio signal break-the-beam system manufactured by Sensor Technologies & Systems, Scottsdale, AZ) installed along a 1 mile (1,609 m) section of US Hwy 191 between Big Sky and West Yellowstone in Yellowstone National Park (© Marcel Huijser).

Table 20. Suitability of different types of mitigation measures for selected species. ● Recommended/Optimum solution; ○ Possible if adapted to local conditions; ⊗ Not recommended; ? Unknown, more data required; — Not applicable (Clevenger & Huijser, 2011; Clevenger, unpublished data).

	Wildlife overpass	Open span bridge	Large mammal underpass	Medium mammal underpass	Small-medium mammal underpass	Animal detection system
Ungulates						
Deer spp.	●	●	●	⊗	⊗	●
Elk	●	●	○	⊗	⊗	●
Moose	●	●	○	⊗	⊗	●
Woodland caribou	?	?	?	⊗	⊗	●
Mountain goat	●	●	○	⊗	⊗	●
Bighorn sheep	●	●	○	⊗	⊗	●
Carnivores						
Fisher	●	●	○	⊗	⊗	⊗
Wolverine	●	?	?	?	⊗	⊗
Bobcat	●	●	●	●	●	⊗
Canada lynx	●	?	?	?	⊗	⊗
Cougar	●	●	●	⊗	⊗	⊗
Coyote	●	●	●	●	●	⊗
Wolf	●	●	○	⊗	⊗	⊗
Black bear	●	●	●	⊗	⊗	●
Grizzly bear	●	○	○	⊗	⊗	●

6.4. Buffer Zones, Gaps, and Mitigation Zones

If wildlife road mortality in the crash or carcass hotspots is reduced through the installation of e.g. wildlife fencing and safe crossing opportunities for wildlife, wildlife that is attracted to the right-of-way vegetation or that wants to cross the highway may still gain access to the highway at fence ends. Such behavior may result in a change in location of wildlife-vehicle collisions rather than a substantial reduction in wildlife-vehicle collisions. Therefore wildlife fencing and safe crossing opportunities should have buffer zones with wildlife fencing that extend beyond the actual location of the mortality clusters. The researchers suggest buffer zones of 0.62 mi (1 km) from each end of a crash or carcass hotspot. This distance is based on the home range for white-tailed deer. The researchers estimate that this distance is substantial enough to be a discouragement to most large ungulates, especially white-tailed deer, that approach the road at a crash or carcass hotspot, to travel to a fence end rather than using safe crossing opportunities within the fenced road sections.

6.5. Site Specific Recommendations for Mitigation Measures

The researchers recommend wildlife fencing in combination with wildlife underpasses and overpasses as the most robust and effective combination of mitigation measures that substantially reduce collisions with large mammals and that provide safe crossing opportunities for wildlife. However, the topography of the terrain may not always lend itself very well for wildlife underpasses and overpasses. Furthermore since concrete wildlife underpasses and overpasses have a long life span (about 75 years) it is important that wildlife species continue to be able to access the structures well into the future. Thus landownership and planning or zoning regulations with regard to development and other potential changes in the habitat and human disturbance are often a factor when deciding on the location for or type of mitigation measures. That is why the researchers also suggest considering animal detection systems, either as a stand-alone mitigation measure or combined with wildlife fencing. It is important to realize though that the implementation of animal detection systems should still be considered experimental. Animal detection system projects should be associated with research into their reliability and effectiveness and the success parameter of the animal detection system project should be based on being able to answer the research question. Because of its experimental nature the success parameter of an animal detection system project should not be based on reducing collisions with large mammals with a certain percentage. If reducing collisions with large mammals with a certain percentage is the success parameter though, then the researchers advise the implementation of wildlife fencing in combination with wildlife underpasses and overpasses, despite having to overcome potential problems with the topography and landownership. Another consideration is the costs associated for different mitigation measures. While the investment costs for wildlife fencing and wildlife underpasses and overpasses can be considered high, their benefits are likely to exceed their costs at selected road sections in Boundary County (see Chapter 3). The same is true for animal detections systems but the costs for these systems are currently estimated to be higher than the costs for wildlife fencing and wildlife underpasses and overpasses as the projected life span of the animals detection systems is only 10 years rather than 25 years (wildlife fencing) or 75 years (concrete crossing structures) (Huijser et al., 2009).

The researchers listed the mitigation emphasis sites and summarized the target species for the Okanogan Highlands and the Flathead Valley region (Idaho Department of Fish and Game, 2005) and the target species for smaller scale wildlife habitat and corridors identified by American Wildlands (see Chapter 4) (Table 21). Based on the target species and the species specific recommendations in Table 20 the researchers then formulated recommendations for different types and dimensions of wildlife overpasses and underpasses (see also Table 19) that may be implemented in combination with wildlife fencing. The researchers indicated between brackets on what species the crossing structure type and dimension is based. For example, if grizzly bear is considered a target species, then the researchers recommend a wildlife overpass whereas if only deer and black bear are a concern at a particular location a large mammal underpass would be sufficient. Note that there are uncertainties about the appropriate type and dimensions of crossing structures for the following species: caribou, wolverine and Canada lynx. However, for these species wildlife overpasses or overspan bridges are likely a safer choice than large mammal underpasses.

Table 21: The target species and recommendations for mitigation measures in the mitigation emphasis sites (selected crash and carcass hotspots). * Crash hotspot; the other hotspots are carcass hotspots.

	Mi marker					
Hwy	**Low**	**High**	**Species involved with collisions**	**Target species Idaho State wildlife linkage zones**	**Target species American Wildlands corridors**	**Recommended mitigation measures and species that would need this type and dimension of crossing structure at a minimum at that location or in that area**
95*	495.3	497.1	?	Caribou, mountain goat, fisher, wolverine, Canada lynx, wolf and grizzly bear	Mule deer, elk, wolverine, Canada lynx, wolf, black bear, grizzly bear	Wildlife overpass (grizzly bear) or open span bridge (elk, caribou, mountain goat, fisher, wolf, and perhaps also Canada lynx and wolverine) or large mammal underpass (deer, black bear)
95	494.8	495.3	Deer		Mule deer, elk, wolverine, Canada lynx, wolf, black bear, grizzly bear	Wildlife overpass (grizzly bear) or open span bridge (elk, caribou, mountain goat, fisher, wolf, and perhaps also Canada lynx and wolverine) or large mammal underpass (deer, black bear)
95	495.5	496.5	Deer and moose		Mule deer, elk, wolverine, Canada lynx, wolf, black bear, grizzly bear	Wildlife overpass (grizzly bear) or open span bridge (elk, moose, caribou, mountain goat, fisher, wolf, and perhaps also Canada lynx and wolverine) or large mammal underpass (deer, black bear)
95	497.8	498.6	Deer		Mule deer, elk, wolverine, Canada lynx, wolf, black bear, grizzly bear	Wildlife overpass (grizzly bear) or open span bridge (elk, caribou, mountain goat, fisher, wolf, and perhaps also Canada lynx and wolverine) or large mammal underpass (deer, black bear)
95	513.7	515.2	Deer and elk			Wildlife overpass (grizzly bear) or open span bridge (elk, caribou, mountain goat, fisher, wolf, and perhaps also Canada lynx and wolverine) or large mammal underpass (deer)
95	515.8	517.3	Deer and elk		Mule deer, elk, black bear, grizzly bear	Wildlife overpass (grizzly bear) or open span bridge (elk, caribou, mountain goat, fisher, wolf, and perhaps also Canada lynx and wolverine) or large mammal underpass (deer, black bear)
2	73.9	74.7	Deer		Mule deer, elk, moose, Canada lynx, black bear, grizzly bear	Wildlife overpass (grizzly bear) or open span bridge (elk, caribou, mountain goat, fisher, wolf, and perhaps also Canada lynx and wolverine) or large mammal underpass (deer, black bear)
2	74.8	75.6	Deer		Mule deer, elk, moose, Canada lynx, black bear, grizzly bear	Wildlife overpass (grizzly bear) or open span bridge (elk, caribou, mountain goat, fisher, wolf, and perhaps also Canada lynx and wolverine) or large mammal underpass (deer, black bear)

The recommendations for mitigation measures in Table 21 are solely based on the target species and do not take the terrain of landownership into consideration. Most of the land along the highways is privately owned with a high number of access points (i.e. driveways) while there are only some highway segments that bisect or are positioned close to state or federal lands where the potential for development and associated human disturbance is lower. Other characteristics of the highway segments are that large sections are in valley bottoms that are relatively flat, making it more challenging to implement wildlife underpasses and overpasses. Figures 31-47. show satellite images from the mitigation emphasis sites including the 0.1 mile markers.

Table 22: The target species and recommendations for mitigation measures in the mitigation emphasis sites (selected crash and carcass hotspots). * Crash hotspot; the other hotspots are carcass hotspots.

	Mi marker				
Hwy	**Low**	**High**	**Combined**	**Observations**	Suggestions and considerations
95*	495.3	497.1	Combined (494.8-497.1)	The landscape is mostly forested with dispersed houses, clearings and grassland. Possibilities for overpasses and underpasses are limited because of mostly flat terrain. Possibilities for wildlife fencing, boulders and animal detection systems limited because of the many driveways. There is a small lake (Stampede Lake) on west side of the highway (around mi marker 496.1-496.2) which is perhaps an attractant to moose in addition to the creek (Deep Creek) that is paralleling the highway on the east side. Mi marker 497.1 (near Naples) is a natural end to the mitigation zone with an existing large bridge over the railroad, low volume road and creek (Deep Creek).	There are some locations that are marginally suitable for a large mammal underpass or an overspan bridge (e.g. around mi marker 494.9, 495.3, 496.1 and 496.5). However, given the presence of moose the researchers suggest one or more wildlife overpasses and overspan bridges as a minimum rather than only large mammal underpasses. The driveways may result in many gaps in the wildlife fence. The number of gaps can be reduced by combining driveways and having short frontage roads before the driveways go through a gap in the fence and connect to Hwy 95. The gaps can be made less permeable to wildlife (specifically ungulates) through wildlife guards (similar to cattle guards). Animal detection systems could be implemented here too, but vehicles and people on the driveways would result in many detections that are not related to wildlife ("false detections) that may affect driver confidence in the system and thus the effectiveness of the system. This problem may be much reduced by installing vehicle detection loops in the driveways that would cancel detections by the animal detection system that are caused by vehicles. Animal detection systems may also be installed at gaps in the fence or at fence ends. Consider including electric mats that are integrated into the road surface and right-of-way to encourage wildlife to cross the road straight and reduce the probability that they wander into the fenced road corridor and are caught in between the fences.
95	494.8	495.3			
95	495.5	496.5			
95	497.8	498.6		The landscape is dominated by forest and grasslands, proving both food and cover, especially for white-tailed deer. Possibilities for underpasses and overpasses limited because of mostly flat terrain. Possibilities for wildlife fencing, boulders and animal detection systems are limited because of the many driveways. The slope on the east side (mi marker 498.1) appears unstable, complicating potential construction. There is a small road fill around mi	While the topography suggests potential for an overpass around mi marker 497.9 the slope on the east side appears unstable, complicating potential construction. A large mammal underpass may be possible around mi marker 498.1. See previous hotspot for considerations related to wildlife fencing and animal detection systems.

				marker 498.1 associated with a stream crossing.	
95	513.7	515.2		The landscape is dominated by forest and agricultural crops, proving both food and cover, especially for white-tailed deer. Possibilities for overpasses and underpasses are limited because of mostly flat terrain. Possibilities for wildlife fencing, boulders and animal detection systems limited because of the many driveways.	There is a marginally suitable location for a large mammal underpass (e.g. around mi marker 514.1). See previous hotspots for other general considerations.
95	515.8	517.3		The landscape is dominated by forest and agricultural crops, proving both food and cover, especially for white-tailed deer. A haystack near mi marker 417.0 may be an additional attractant to ungulates. Possibilities for overpasses and underpasses are limited because of mostly flat terrain. Possibilities for wildlife fencing, boulders and animal detection systems limited because of the many driveways.	See previous hotspots for general considerations.
2	73.9	74.7	Combined (73.9-75.6)	The landscape is mostly forested with dispersed houses, clearings and grassland. Possibilities for overpasses and underpasses are limited because of mostly flat terrain. Possibilities for wildlife fencing, boulders and animal detection systems limited because of the many driveways.	There is a marginally suitable location for a large mammal underpass (e.g. around mi marker 75.6). See previous hotspots for other general considerations.
2	74.8	75.6			

Figure 31. The Hwy 95 494.8-497.1 hotspot showing the 0.1 mi markers on a satellite image background.

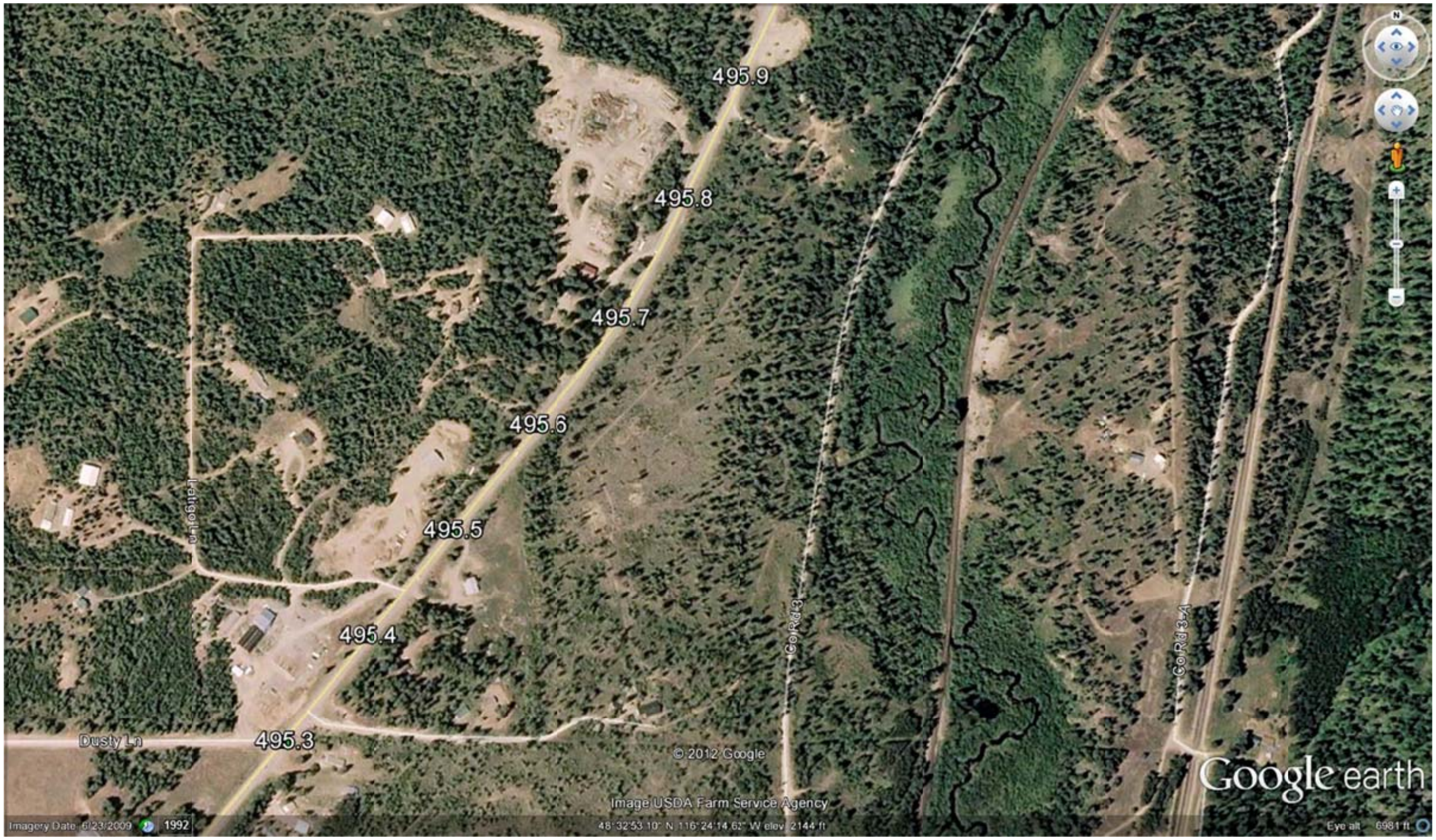

Figure 32. The Hwy 95 494.8-497.1 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 33. The Hwy 95 494.8-497.1 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 34. The Hwy 95 494.8-497.1 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 35. The Hwy 95 494.8-497.1 hotspot showing the 0.1 mi markers on a satellite image background.

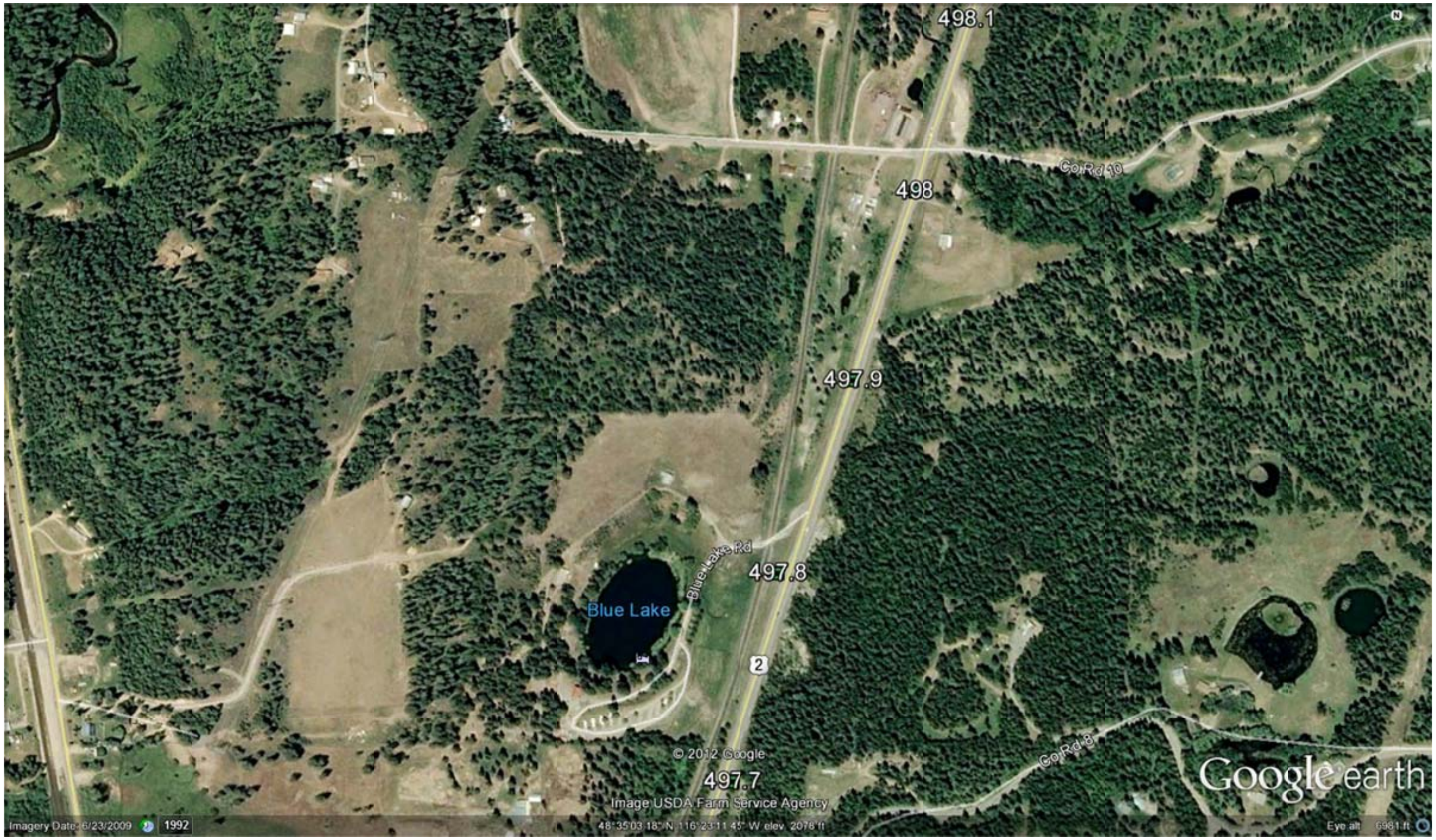

Figure 36. The Hwy 95 497.8-498.6 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 37. The Hwy 95 497.8-498.6 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 38. The Hwy 95 497.8-498.6 hotspot showing the 0.1 mi markers on a satellite image background.

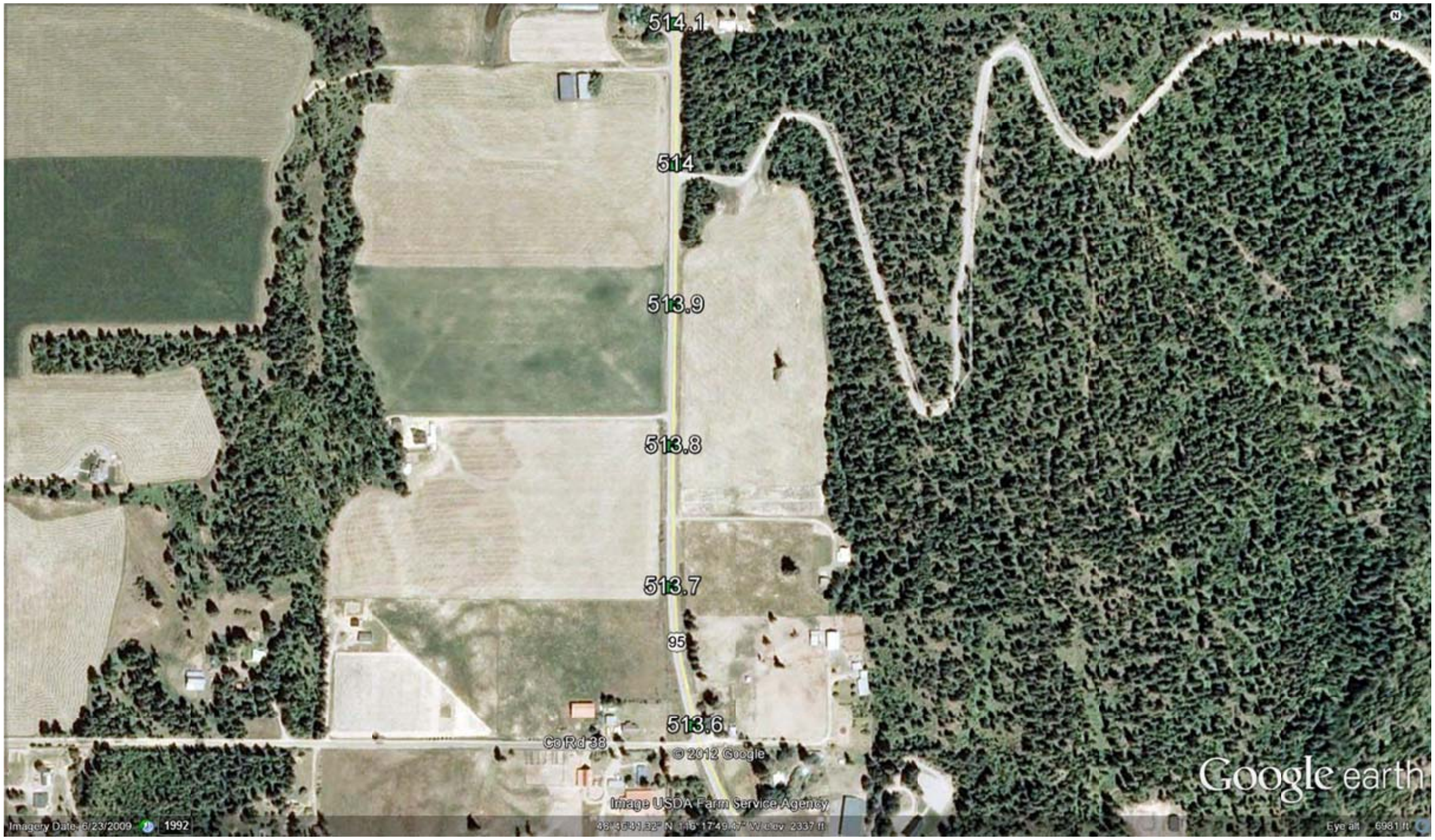

Figure 39. The Hwy 95 513.7-515.2 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 40. The Hwy 95 513.7-515.2 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 41. The Hwy 95 513.7-515.2 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 42. The Hwy 95 515.8-517.3 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 43. The Hwy 95 515.8-517.3 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 44. The Hwy 95 515.8-517.3 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 45. The Hwy 2 73.9-75.6 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 46. The Hwy 2 73.9-75.6 hotspot showing the 0.1 mi markers on a satellite image background.

Figure 47. The Hwy 2 73.9-75.6 hotspot showing the 0.1 mi markers on a satellite image background.

7. CONCLUSIONS

The researchers identified highway sections that are a wildlife-vehicle collision hotspot. The hotspots were prioritized based on the number of wildlife-vehicle collisions, the costs associated with these wildlife-vehicle collisions and their perceived importance as wildlife habitat and corridor. The hotspots that ranked highest were reviewed for the potential implementation of mitigation measures aimed at reducing collisions with large mammals and providing safe crossing opportunities for large mammals.

Collisions with large mammals were relatively numerous along the highways in Boundary County, especially with deer (mostly white-tailed deer) and, though far fewer, elk and moose. Hotspots were identified along all three highways in Boundary County (Hwy 95, 2, and 1). The hotspots that ranked worst with regard to the number of collisions, the costs associated with these collisions and that were also situated in important wildlife habitat or corridors were located along Hwy 95 and Hwy 2. Note that only the wildlife-vehicle collisions hotspots were ranked for their costs associated with wildlife-vehicle collisions and their perceived importance as wildlife habitat or corridors. This means that, at least in theory, there may be other road sections that have equal or higher costs associated with wildlife-vehicle collisions (not the case in our study area) and that may be situated in equally or more important wildlife habitat and corridors (potentially the case in our study area).

Wildlife fencing in combination with wildlife underpasses and overpasses is the most effective and robust mitigation measure to reduce collisions with large mammals and provide safe crossing opportunities for wildlife. Animal detection systems can also substantially reduce collisions with large mammals but these systems are less robust and should still be considered experimental.

The cost-benefit analyses showed that there are highway sections in Boundary County where the benefits of mitigation measures, even the most expensive ones, are greater than their costs. This means that not implementing mitigation measures on these highway sections is more costly to society than the investment associated with implementing effective mitigation measures.

While the implementation of mitigation measures at selected road sections benefits human safety, nature conservation and is also economically attractive, implementation may be challenging. For example, the highway sections in Boundary County are characterized by relatively flat terrain and many access points (i.e. driveways). These characteristics make it challenging, though not impossible, to implement wildlife fencing, wildlife-jump-outs, wildlife underpasses, overpasses and animal detection systems. In addition, the investments may be jeopardized if development and human disturbance increase on adjacent private lands.

The researchers formulated the following options for consideration:

1. If the objective is to reduce collisions with large mammals and provide safe crossing opportunities for large mammals, implement wildlife fencing in combination with wildlife jump-outs, wildlife underpasses and overpasses on selected highway segments that ranked highest with regard to the number of collisions, the costs associated with these collisions and that are located in important wildlife habitat or corridors. Accept substantial work and costs associated with construction such as moving large amounts of soil to allow for a gradual approach to underpasses or overpasses. If the mitigation site is

situated adjacent to private land, accept the fact that human disturbance may increase overtime and that wildlife may then reduce the use of the crossing structures. Strive to reduce the number of access points (i.e. driveways) and mitigate the remaining gaps in the fence with wildlife guards.

2. If wildlife fences in combination with wildlife underpasses and overpasses are considered too difficult to implement, too costly or too risky (e.g. potential for future increase in human disturbance), then consider implementing animal detection systems, with or without associated fencing and wildlife-jump-outs. Consider electric mats perpendicular to the fence and across the road at the gaps in the fence to discourage animals from wandering into the fenced highway corridor. Accept the high risk associated with animal detection system projects. Accept that the success parameter is to be able to answer research questions related to system reliability and effectiveness rather than an objective to reduce wildlife-vehicle collisions by a certain minimum percentage. The researchers strongly advise to evaluate the reliability and effectiveness of an animal detection system, should it indeed be implemented.
3. If the two options described above are both considered not acceptable, then consider not implementing mitigation measures and/or continue current practices. Accept that wildlife-vehicle collisions are likely to continue to occur in relatively high numbers and that these numbers are likely to continue to grow (consistent with national trend). Accept that the costs for wildlife-vehicle collisions to society may be higher than what effective mitigation measures may have cost. Accept that current practices (e.g. deer warning signs and brushing in the right-of-way) may not be effective or may only marginally effective in reducing wildlife-vehicle collisions and that brushing of the vegetation in the right-of-way may increase the barrier effect of highways and traffic for wildlife.

8. FREQUENTLY ASKED QUESTIONS

1. Q: Wildlife fencing is an integral part of the proposed mitigation measures. Aren't those fences bad for wildlife rather than good?

   A: Indeed fences can be a barrier for wildlife and some types of fence can even wound or kill wildlife. Fencing and other barriers in the landscape contribute to habitat fragmentation and block daily, seasonal or dispersal movements by individuals of different wildlife species. However, the fencing as proposed in this report uses the barrier effect of fencing for two specific purposes that benefit wildlife rather than hurt wildlife:
   - Wildlife fencing along roads discourages large mammals from entering the roadway and thus reduces direct wildlife mortality on the road as a result of collisions with vehicles.
   - Wildlife fencing directs wildlife that approaches the road to safe crossing opportunities such as wildlife overpasses and underpasses, thus encouraging animals to use safe crossing opportunities when they move across the landscape and encounter roads.

2. Q: Wildlife underpasses and overpasses are an integral part of the proposed mitigation measures. Do wildlife even use these structures to get to the other side of the road?

   A: If the crossing structures are located at the correct locations, and if they are of the right type with the right dimensions, and correct design features given the target species wildlife use of crossing structures can be very substantial. For example, in 2010 there were at least 12,000 confirmed wildlife crossings through about 30 crossing structures along US Hwy 93 North on the Flathead Indian Reservation in Montana (Huijser et al., 2011). Similarly over 185,000 wildlife crossings have been documented over 12 years at the wildlife crossing structures along the Trans Canada Highway in Banff National Park, Alberta, Canada (Clevenger et al., 2009). While wildlife use of wildlife crossing structures can be very high it is much more challenging to investigate whether these numbers are "high enough" to satisfy certain conservation or human safety goals. There should be enough "movement" or "connectivity" between populations on both sides of the road so that the target species have viable populations over long time periods. Population viability analyses can provide insight in how many structures may be required to maintain viable populations in a region. However, such population viability analyses require detailed data and funding to conduct the research. Note: photos of different wildlife species using different types of wildlife underpasses and one overpass along US Hwy 93 North can be viewed and downloaded from the internet: http://www.mdt.mt.gov/other/research/external/project_photos/us93info/

3. Q: Aren't wildlife crossing structures a good place for predators to wait until prey passes by and aren't these crossing structures then essentially prey traps and perhaps even population sinks for some species?

A: A review of the literature found that "evidence for the existence of prey-traps is scant, largely anecdotal and tends to indicate infrequent opportunism rather than the establishment of patterns of recurring predation" (Little et al., 2002). More recent research into this issue found no evidence that kill sites (where carnivores had killed ungulates) were closer to roads after wildlife fencing and crossing structures were installed (Ford & Clevenger 2010). In addition, data from wildlife cameras at crossing structures were analyzed to investigate whether presence of prey was followed by presence of predators more often and closer in time as crossing structures were longer in place (Ford & Clevenger 2010). Again, no evidence was found that crossing structures act as prey traps.

9. REFERENCES

Andelt, W.F. & P.S. Gipson. 1979. Home range, activity, and daily movements of coyotes. Journal of Wildlife Management 43 (4): 944-951.

Anderson D.P., J.D. Forester, M.G. Turner, J.L. Frair, E.H. Merrill, D. Fortin, J.S. Mao & M.S. Boyce. 2005. Factors influencing female home range sizes in elk (Cervus elaphus) in North American landscapes. Landscape Ecology 20: 257–271.

Apps, C.D. 2000. Space-use, diet, demographics, and topographic associations of lynx in the southern Canadian Rocky Mountains: a study. pp 351-371. In: Ruggiero, L.F., K.B. Aubry, S.W. Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey & J.R. Squires. Ecology and conservation of lynx in the United States. General Technical Report RMRS-GTR-30WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Banci, V. & A.S Harestad. 1990. Home range and habitat use of wolverines (*Gulo gulo)* in Yukon, Canada. Holarctic Ecology 13 (3): 195-200.

Brand, C.J., L.B. Keith, & C.A. Fischer. 1976. Lynx responses to changing snowshoe hare densities in central Alberta. Journal of Wildlife Management 40 (3): 416-428.

Clevenger, A.P., B. Chruszcz & K. Gunson. 2001. Highway mitigation fencing reduces wildlife–vehicle collisions. Wildlife Society Bulletin 29: 646–653.

Clevenger, T. & M.P. Huijser. 2011. Handbook for Design and Evaluation of Wildlife Crossing Structures in North America. Department of Transportation, Federal Highway Administration, Washington D.C., USA. Available from the internet: http://www.westerntransportationinstitute.org/documents/reports/425259_Final_Report.pdf

Demarchi, R.A., C.L. Hartwig, & D.A. Demarchi. 2000. Status of the Rocky Mountain bighorn sheep in British Columbia. Wildlife Society Bulletin B-99: 56 pp.

D'Eon, R. G. & R. Serrouya. 2005. Mule deer seasonal movements and multiscale resource selection using global positioning system radiotelemetry. Journal of Mammalogy 86: 736-744.

Donaldson, B.M., & N.W. Lafon. 2008. Testing an integrated PDA-GPS system to collect standardized animal carcass removal data. FHWA/VTRC 08-CR10. Virginia Transportation Research Council, Charlottesville, Virginia, USA.

ElectroBraid. 2008a. http://www.electrobraid.com/wildlife/highway_fence.html

ElectroBraid. 2008b. http://www.electrobraid.com/wildlife/reports/Wasilla_ElectroMAT.pdf

Ford, A.T. & A.P. Clevenger. 2010. Validity of the prey-trap hypothesis for carnivore-ungulate interactions at wildlife-crossing structures. Conservation Biology 24(6): 1679–1685.

Frey, S.N. & M.R. Conover. 2006. Habitat use by meso-predators in a corridor environment. Journal of Wildlife Management 70(4):1111–1118.

Gibeau, M.L., S. Herrero, B.N. McLellan & J.G. Woods. 2001. Managing for grizzly bear security areas in Banff National Park and the Central Canadian Rocky Mountains. Ursus 12: 121-129.

Gomes L., C. Grilo, C. Silva &A. Mira. 2009. Identification methods and deterministic factors of owl roadkill hotspot locations in Mediterranean landscapes. Ecological Research 24(2): 355-370

Hedlund, J.H., P.D. Curtis, G. Curtis & A.F. Williams. 2004. Methods to reduce traffic crashes involving deer: what works and what does not. Traffic Injury Prevention 5: 122–131.

Huijser, M.P. 2000. Life on the edge. Hedgehog traffic victims and mitigation strategies in an anthropogenic landscape. PhD thesis, Wageningen University, Wageningen. Available from the internet. URL: http://edepot.wur.nl/121248

Huijser, M.P., P.T. McGowen, W. Camel, A. Hardy, P. Wright, A.P. Clevenger, L. Salsman & T. Wilson. 2006. Animal vehicle crash mitigation using advanced technology. Phase I: review, design and implementation. SPR 3(076). FHWA-OR-TPF-07-01, Western Transportation Institute – Montana State University, Bozeman, Montana, USA.

Huijser, M.P., J. Fuller, M.E. Wagner, A. Hardy & A.P. Clevenger. 2007. Animal–vehicle collision data collection. A synthesis of highway practice. NCHRP Synthesis 370. Project 20-05/Topic 37-12. Transportation Research Board of the National Academies, Washington, D.C., USA.

Huijser, M.P., P. McGowen, J. Fuller, A. Hardy, A. Kociolek, A.P. Clevenger, D. Smith & R. Ament. 2008. Wildlife-vehicle collision reduction study. Report to Congress. U.S. Department of Transportation, Federal Highway Administration, Washington D.C., USA. Available from the internet: http://www.tfhrc.gov/safety/pubs/08034/index.htm

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

Huijser, M.P., T.D.H. Allen, J.P. Purdum & W. Camel. 2011. Wildlife Crossing Monitoring and Research on the Flathead Indian Reservation between Evaro and Polson, Montana. Annual Report 2011. Western Transportation Institute, College of Engineering, Montana State University, Bozeman, MT, USA. Available from the internet: http://www.mdt.mt.gov/other/research/external/docs/research_proj/wildlife_crossing/phaseii/annual_2011.pdf

Idaho Department of Fish and Game. 2005. Idaho Comprehensive Wildlife Conservation Strategy. Idaho Conservation Data Center, Idaho Department of Fish and Game, Boise, ID. http://fishandgame.idaho.gov/cms/tech/CDC/cwcs.cfm

Idaho Panhandle National Forest. 2012. Land ownership. http://www.fs.fed.us/ipnf/

Idaho Transportation Department. 2012. Idaho Highway Wildlife Linkage Wiki. https://www.socialtext.net/idahohighwaywildlifelinkage/

Jones, D.M. & J.B. Theberge. 1982. Summer home range and habitat utilization of the red fox V*ulpes vulpes* in a tundra habitat northwest British Columbia, Canada. Canadian Journal of Zoology 60 (5): 807-812.

Knapp, K., X. Yi, T. Oakasa, W. Thimm, E. Hudson & C. Rathmann. 2004. Deer–vehicle crash countermeasure toolbox: a decision and choice resource. Final report. Report Number DVCIC – 02. Midwest Regional University Transportation Center, Deer–Vehicle Crash Information Clearinghouse, University of Wisconsin-Madison, Madison, Wisconsin, USA.

Knowles, P.R. 1985. Home range size and habitat selection of bobcats (*Lynx rufus*) in north-central Montana. Canadian Field-Naturalist 99 (1): 6-12.

Krebs, J., E.C. Lofroth, & I. Parfitt. 2007. Multiscale habitat use by wolverines in British Columbia, Canada. Journal of Wildlife Management 71(7): 2180–2192.

Kruidering, A.M., G. Veenbaas, R. Kleijberg, G. Koot, Y. Rosloot & E. Van Jaarsveld. 2005. Leidraad faunavoorzieningen bij wegen. Rijkswaterstaat, Dienst Weg-en Waterbouwkunde, Delft, The Netherlands.

Latham, A.D.M. 2009. Wolf ecology and caribou-primary prey-wolf spatial relationships in low productivity peatland complexes in northeastern Alberta. PhD Thesis. University of Alberta, Edmonton, Alberta, Canada.

Laundré, J.W. & B.L. Keller. 1984. Home range size of coyotes: A critical review. Journal of Wildlife Management 48 (1): 127-139.

Leach, R.H. & W.D. Edge. 1994. Summer home range and habitat selection by white-tailed deer in the Swan Valley, Montana. Northwest Science 68 (1): 31-36.

Lewis, J.S., J.L. Rachlowa, J.S. Hornea, E.O. Gartona, W.L. Wakkinen, J. Haydenc & P. Zagerd. 2011. Identifying habitat characteristics to predict highway crossing areas for black bears within a human-modified landscape. Landscape and Urban Planning 101: 99–107.

Lindstedt, S.L, B.J. Miller, & S.W. Buskirk. 1986. Home range, time, and body size in mammals. Ecology 67 (2): 413-418.

Little, S.J., R.G. Harcourt & A.P. Clevenger. 2002. Do wildlife passages act as prey-traps? Biological Conservation 107(2): 135-145.

Litvaitis, J.A., J.A. Sherburne, & J.A. Bissonette. 1986. Bobcat habitat use and home range size in relation to prey density. Journal of Wildlife Management 50 (1): 110-117.

Mackie, R.J., D.F. Pac, K.L. Hamlin & G.L. Dusek. 1998. Ecology and management of mule deer and white-tailed deer in Montana. Montana Fish, Wildlife and Parks, Wildlife Division, Helena, Montana, USA.

McCoy, K. 2005. Effects of transportation and development on black bear movement, mortality, and use of the Highway 93 corridor in northwest Montana. MSc. Thesis, University of Montana, Missoula, MT.

Mundinger, J.G. 1981. White-tailed deer reproductive biology in the Swan Valley, Montana. Journal of Wildlife Management 45 (1): 132-139.

Mysterud, A., F.J. Pérez-Barbería & I.J. Gordon. 2001. The effect of season, sex and feeding style on home range area versus body mass scaling in temperate ruminants. Oecologia 127: 30-39.

Reeve, A.F. & S.H. Anderson. 1993. Ineffectiveness of Swareflex reflectors at reducing deer–vehicle collisions. Wildlife Society Bulletin 21: 127–132.

Riley, S.J., & A. Marcoux. 2006. Deer–vehicle collisions: an understanding of accident characteristics and drivers' attitudes, awareness and involvement. Research report RC-1475. Department of Fisheries and Wildlife, Michigan State University, East Lansing, Michigan, USA.

Ross, P.I. & M.G. Jalkotzy. 1992. Characteristics of a hunted population of cougars in southwestern Alberta. Journal of Wildlife Management 56 (3): 417-426.

Servheen, C. 1983. Grizzly bear food habits, movements, and habitat selection in the Mission Mountains, Montana. Journal of Wildlife Management 47 (4): 1026-1035.

Sielecki, L.E. 2004. WARS 1983–2002—Wildlife Accident Reporting and Mitigation in British Columbia: Special Annual Report. Ministry of Transportation, Engineering Branch. Environmental Management Section. Victoria, British Columbia, Canada.

Singer, F.J. & J.L. Doherty. 1985. Movements and habitat use in an unhunted population of mountain goats *Oreamnos americanus*. Canadian Field Naturalist 99 (2): 205-217.

Spreadbury, B.R, K. Musil, J. Musil, C. Kaisner, & J. Kovak. 1996. Cougar Population Characteristics in Southeastern British Columbia. Journal of Wildlife Management 60 (4): 962-969.

Squires, J.R. & T. Laurion. 2000. Lynx home range and movements in Montana and Wyoming: preliminary results. In: Ruggiero et al., eds. Ecology and conservation of lynx in the United States. pp 337-349. In: Ruggiero, L.F., K.B. Aubry, S.W. Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey & J.R. Squires. Ecology and conservation of lynx in the United States. General Technical Report RMRS-GTR-30WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Tardif, L. -P., & Associates Inc. 2003. Collisions involving motor vehicles and large animals in Canada. Final report. L-P Tardif and Associates Inc., Nepean, Ontario, Canada.

Ujvári, M., H.J. Baagøe & A.B. Madsen. 1998. Effectiveness of wildlife warning reflectors in reducing deer–vehicle collisions: a behavioural study. Journal of Wildlife Management 62:1094–1099.

Van Dyke, F.G., W.C. Klein, & S.T. Stewart. 1998. Long-term range fidelity in Rocky Mountain elk. Journal of Wildlife Management 62 (3): 1020-1035.

Wakkinen, W., J. Lewis, B. Moore & J. Hayden. 2012. Copeland Highway 95 improvement project. Wildlife monitoring report. Idaho Department of Fish and Game, Boise, Idaho, USA.

Weir, R.D. & F.B. Corbould. 2010. Factors Affecting Landscape Occupancy by Fishers in North-Central British Columbia. Journal of Wildlife Management 74(3): 405-410.

Whitman, J.S., W.B. Ballard, & C.L. Gardner. 1986. Home range and habitat use by wolverines in southcentral Alaska. Journal of Wildlife Management 50 (3): 460-463.

Young, B.F. & R.L. Ruff. 1982. Population dynamics and movements of black bears in east central Alberta. Journal of Wildlife Management 46 (4): 845-860.