Title

A sampling of wildlife use in relation to structure variables for bridges and culverts under I-90 between Alberton and St. Regis, Montana

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A SAMPLING OF WILDLIFE USE IN RELATION TO STRUCTURE VARIABLES FOR BRIDGES AND CULVERTS UNDER I-90 BETWEEN ALBERTON AND ST. REGIS, MONTANA

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Abstract: Habitat fragmentation, habitat loss, and human caused mortality are the major factors contributing to wildlife decline throughout the world. High-speed, heavily-used highways can divide formerly contiguous blocks of habitat and isolate wildlife populations. Underpasses and culverts have the potential to mitigate the negative impacts of roads on wildlife populations by maintaining connectivity between wildlife populations and decreasing wildlife collisions with vehicles. Using heat and motion sensitive cameras, we monitored seven underpasses and three culverts for ten months along Interstate 90 in western Montana. We documented the type and frequency of wildlife use and compared the level of use to variables associated with the structures. Wildlife use was most frequent at underpasses and limited in culverts. Ungulates were the primary users of underpasses with limited use by medium and large carnivores. We found no significant relationships between wildlife use and structural variables. This is partly due to a small sample size but could be the result of animals using structures opportunistically.

Problem Statement

Highways have the potential to fragment wildlife populations and wildlife habitat. The extent of this fragmentation is likely a function of a combination of factors associated with roads, such as traffic volume, human development, and landscape variables. Given this, interstate highways may have the highest potential for fragmentation of any highway type. Knowledge about the extent of fragmentation for wildlife populations of concern, such as large carnivores, will aid in understanding the priority and importance of mitigation efforts by state agencies to minimize wildlife fragmentation.

Wildlife can get across highways either over the road surface at risk of mortality and human safety from collisions with vehicles, or under the highway using structures such as bridges or culverts. Knowledge of if and how much existing structures are used by wildlife for crossing and which structures are used most can aid in future structure design and rebuilding in order to maximize wildlife use.

Background

Habitat fragmentation occurs when contiguous blocks of habitat are broken into pieces, with the pieces being separated from one another by unsuitable habitats. Habitat fragmentation is accompanied by habitat loss as the area of the remaining parcels sum to less than the area of the original contiguous block. Recent advances in the science of island biogeography have led to the development of ecological principles that are relevant to our management of public lands (MacArthur and Wilson 1967). First, the number of species in an area of habitat is proportional to its size. As the area of a habitat is reduced, the number of constituent species is concurrently reduced. Populations that are dramatically reduced in size and isolated from one another on small habitat “islands” are at risk of extinction. Extinction risk is elevated because small populations are less able to absorb losses caused by random environmental, genetic, and demographic changes (Gilpin and Soule 1986).

The primary causes of grizzly bear habitat fragmentation are human activities, such as highway building, and residential, recreational, and commercial developments. The negative effects of human developments and the degree of habitat fragmentation are influenced by the spatial arrangement of the developments. In the Rocky Mountain west, human developments usually occur in a linear fashion along valley floors. When development reaches a certain concentration, grizzly bears can no longer cross the valley floor or use it as habitat. These areas have been termed “habitat fracture zones” (Servheen and Sandstrom 1993).

Human transportation corridors and their associated developments can cause fragmentation of the habitats of many different species (Garland and Bradley 1984). Highways are a major contributor to habitat fragmentation, and fracture zones occur in association with highways. The negative effects of transportation corridors, and high-speed highways in particular, have been documented for numerous wildlife species. Most of the literature concerns ungulate mortality (Bashore et al. 1985, Bruinderink and Hazebroek 1996, Gleason and Jenks 1993, Romin and Bissonette 1996). Florida panther mortality and habitat fragmentation has also been documented (Belden and Hagedorn 1993). However, the effects of highways on grizzly bears are largely unknown. Gibeau and Herrero (1998) found that the Trans Canada Highway in the Bow River Valley of Alberta is a barrier to female grizzly bear movement, and a significant filter for males, despite the installation of crossing structures.

Maintaining connectivity or “linkage” between small isolated populations could prevent many of the detrimental consequences of habitat fragmentation by preserving genetic diversity, reducing the chances of inbreeding, and dampening the effects of genetic drift. Effective linkage zones may combat the adverse effects of habitat fragmentation by allowing opportunity for movement between habitat patches. Linkage zones are defined as combinations of landscape structures that allow wildlife to move through and live within areas influenced by human actions, and their effectiveness relies largely on the level and types of human actions as well as the biology of the animal (Servheen et al. 2001a,b). Several linkage zones have been identified across Interstate 90 (I-90) in western Montana that could potentially link wildlife populations on both sides of the highway, including wolves, lynx, black bears, wolverines, and possibly grizzly bears (Servheen et al. 2001a,b).

Underpasses and culverts have the potential to mitigate the negative impacts of roads on wildlife populations by maintaining connectivity between wildlife populations and decreasing wildlife collisions with vehicles. Variables influencing wildlife use of culverts and underpasses must be identified and prioritized to maximize their effectiveness in the future. The degree and type of wildlife use of highway structures along I-90 in western Montana is unknown. This project was aimed at understanding the movements of medium to large wildlife species through the existing underpasses and culverts under a portion of I-90. Many ungulate species occur in the project area and the majority of crossing data were expected to be from ungulates. We documented the degree and frequency of wildlife using these structures and compared the level of use to structure variables.

Study Area

The study area is in the Clark Fork River Valley that is bisected by I-90, where an observable succession of human development is occurring (fig.1). The 50-mile section (between mileposts 33 and 82) of interstate being monitored is between Alberton and St. Regis and includes the Ninemile area west of Missoula, Montana. This is a four-lane highway, which has a high-posted speed limit (75 mph) and has an average traffic volume of 6,500 vehicles per day (MDOT 2003). The interstate follows the Clark Fork River drainage and the Montana Rail Link railroad.

Human settlement is primarily restricted to the valley, due to the fact that the majority of the rugged, mountainous terrain adjacent to the valley is public land. Human presence is increasing in the study area and forest and riparian habitats that were once converted into agricultural lands are now being developed as residential communities. Logging occurs throughout the surrounding mountains, and numerous localities in the area are becoming recreational attractions. Although the valley bottom is experiencing human population growth and development, the majority of the surrounding, mountainous land still possesses adequate habitat to support wildlife populations. These include threatened and sensitive carnivorous species, such as Canada Lynx (*Lynx canadensis*), wolves (*Canis lupus*), wolverines (*Gulo gulo*), and possibly grizzly bears (*Ursus arctos*). Four wildlife linkage zones to connect animals on both sides of the I-90 corridor have been identified, and three of the four linkage zones had suitable structures for monitoring (Servheen et al. 2001a, 2001b). Maintenance of linkage opportunities across I-90 is valuable to the long-term health of many wildlife species. This area offers potential for the existence of viable populations of large mammals, but the relationship of these animals to the highway and the numbers and locations of highway crossings, if any, are unknown.

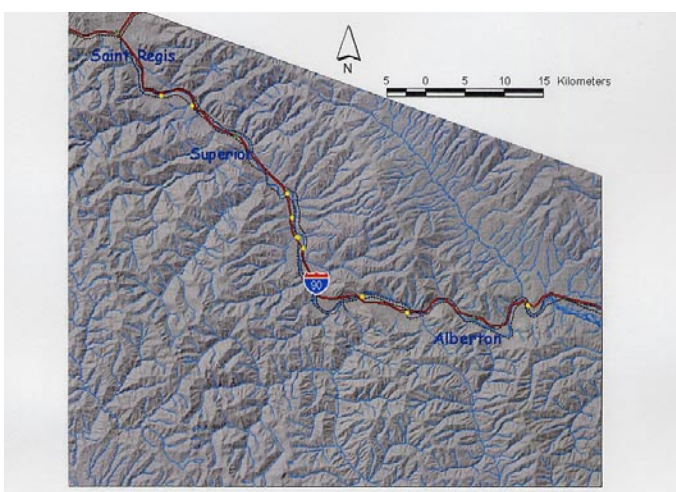

Fig. 1. The location of the study area in the Clark Fork River Valley between Alberton and St. Regis, Montana. Bridges monitored in yellow; culverts monitored in green.

Methods

The objectives of this study were to: (1) monitor and document selected underpasses and culverts on I-90 between the Ninemile area (west of Alberton) and St. Regis for wildlife activity using infrared, motion-sensitive 35mm cameras and snow tracking; (2) relate structure variables to the type and level of wildlife use; and (3) document levels and locations of wildlife mortality associated with the highway in the study area.

Infrared motion and heat sensor cameras were mounted at seven bridges and three culverts within the study area. We used TrailMaster TM550 and TM35-1 units in culverts and a combination of TrailMaster units and DeerCam Scouting Cameras at underpasses (Lenexa, KS & Park Falls, WI). We selected structures according to accessibility, established animal trails, human use, and equipment security. Each structure was given an ungulate use rating and a small, medium, and large carnivore use rating, and an omnivore/carnivore use rating according to the following formula so that they may be compared:

$$\text{Use Rating} = (\sum \#\text{of photographs})/(\sum \#\text{of functional camera days})$$

Snow tracking was opportunistically conducted at each structure we monitored whenever adequate conditions arose, and five track transects were established along the highway adjacent to structures we were monitoring to understand wildlife crossings close to bridges and culverts. We used published track measurements to identify wildlife species (Halfpenny and Biesiot 1986).

Past studies have examined a variety of factors affecting wildlife use of existing structures, including distance to hiding cover, surrounding terrain, degree of human development, traffic volume, time of day, and structural openness. Of these variables, landscape components, such as hiding cover and topography, as well as human influences are believed to play significant roles in the probability and frequency of underpass use (Bruinderink and Hazebroek 1996, Clevenger et al. 2002, Gleason and Jenks 1993, Haas 2001, Rodriguez et al. 1997).

We described each selected site in terms of location, structure, vegetation cover, and human activities (table 1). Landscape features documented for each structure include: distance to adequate hiding cover; surrounding topography; structural dimensions such as length, width, and height of each bridge or culvert; and human influence including type of human activity, and land ownership (table 2).

Table 1.
Crossing structure descriptions and general description of the surrounding area for each

Structure ID	Structure Type	Feature Spanned	LAND USE & GENERAL CHARACTERISTICS
81.5	Underpass	Clark Fork R.	Fishing access; light residential area w/ houses to the north & south, near wolf roadkill locations; deer trail parallel to I-90 on both sides & continues underneath bridge; high human activity directly underneath bridge on east side
69	Underpass	County road & railroad	Small housing development to the southwest; agriculture to the east; paved county road w/ low traffic; deer trail between pastures that parallels I-90 & leads underneath bridge
66.3	Underpass	Clark Fork R.	Steep terrain; canyons; kayaker launch on east side of bridge
58.5	Underpass	Clark Fork R.	Rest area to the west on both sides of I-90; USFS campground to the west; county road runs parallel to I-90 here
57.5	Underpass	Railroad	Low human activity; vegetative cover continuous below underpass; USFS campground to the east
53.7	Underpass	Clark Fork R.	Residential area to the west; vegetative cover continuous below road surface
39.8	Underpass	Clark Fork R. & county road	Agriculture; residences to the east; animal trails below underpass parallel to I-90; USFS campground to the southwest
57.5 C	Culvert	Intermittent stream	Low human activity; vegetative cover on both ends of culvert; USFS campground to the east
55.6 C	Culvert	Spring stream	Rapidly expanding residential development to the north; commercial activity to the north; landfill to the southeast; vegetative cover at both ends of culvert
42.4 C	Culvert	Intermittent stream	Light residential; residence directly north of culvert; railroad to the southwest

Distance to adequate hiding cover (>50%) from the entrance to each structure was determined in the field using a two-meter high vegetation cover pole (Bookhout 1996). ArcView GIS 3.3 was used to provide topographical information within 500m of each structure (ESRI Redlands, CA). The standard deviation of elevation and aspect were derived using a 500m buffer and DEM's for the area. Traffic volume data and structural dimensions were supplied by MDOT and analyzed (figure 3). Each culvert and underpass was given a Structural Openness (SO) rating (Foster and Humphrey 1995, Yanes et al. 1995; Henke et al. 2001) using the formula:

$$SO = \frac{(OW*OH)}{LOC}$$

OW = opening width
OH = opening height
LOC = length of crossing

We expected the structural openness rating to be a negligible factor in use differences between underpasses, but important among culverts when comparing the use ratings at each structure.

Additionally, each structure was given a Land Ownership (LO) rating (% private, % Plum Creek Timber Company, % state, % USFS). This was calculated, using a USFS map, within a two-mile-squared block of land surrounding each structure. The resulting percentages were transformed into proportions using the formula: [(% Private*4)+(% Pl.Cr.*3)+(% State*2)+(% USFS*1)]/100, with the assumption that a higher value (Private=4, Pl.Cr.=3, State=2, USFS=1) corresponds to lower wildlife value.

Table 2.
Variables and crossing rates associated with each structure

STUCTURE ID	**Ungulate Use Rating**	**Sm. Carn. Use Rating**	**Med. Carn. Use Rating**	**Lge. Carn. Use Rating**	**Total Wildlife Use**	**Human Associated Use Rating**	**Structural Openness Rating**	**In Linkage Zone?**	**Avg. LZP Score (500m)**	**Std.Dev. of Elev. (500m)**	**Distance to Cover (m)**
Underpass											
81.5	0.4729	0.003	0.0025	0	0.48306	0.020232676	811.6308	NO	4.4667	21.16	8.15
69	0.2003	0.011	0	0	0.21088	0.003514691	27.7500	NO	3.8053	10.21	22.65
66.3	0.1118	0.012	0.0029	0.0029	0.13535	0.294230147	1058.77	NO	3.6644	28.77	13.25
58.5	0.8934	0	0	0	0.89344	0.004702342	659.4167	YES	4.5236	57.88	19.35
57.5	0.4574	0.01	0	0	0.48013	0.00648824	169.5417	YES	3.1310	15.6	6.00
53.7	0.431	0.017	0	0	0.45758	0.020885547	642.6615	YES	3.4740	15.04	3.00
39.8	0.6136	0.004	0.0143	0	0.61932	0.020885547	457.2733	NO	3.8262	33.89	18.10
Culvert											
57.5 C	0	0	0	0	0.0872	0.0116	0.2638	YES	3.2943	20.07	9.50
55.6 C	0	0.041	0	0	0.0407	0	0.1255	NO	4.3954	21.55	0.25
42.4 C	0	0.226	0.0982	0	0.2259	0.0393	0.7576	NO	4.3714	41.55	7.40

U=Underpass
C= Culvert
Ungulates = White-tailed deer, mule deer, and elk
Sm. Carn. = small carnivores (skunks, raccoons, house cats)
Med. Carn. = medium carnivores (coyotes and foxes)
Lge. Carn. = large carnivores (black bear)
Total Wildlife includes birds, squirrels, rabbits, etc.
Human associated = humans and domestic dogs
Use Rating determined with the formula: Use Rating = (∑#of photographs)/(∑#of functional camera days)
Structural Openness (SO) rating determined with the formula: SO = (OW*OH)/LOC, where OW = opening width, OH = opening height, LOC = length of crossing
LZP Score 1=most suitable for wildlife; 5=less suitable for wildlife
Std. Dev. Of Elev. = standard deviation of elevation within a 500 meter radius of structure
Cover = Adequate Hiding Cover (50% at a height of 1 meter)

The four potential linkage zones within the study area were identified using the Linkage Zone Prediction (LZP) model (Servheen et al. 2001a,b). The LZP model incorporates road density, human-developed sites, and the corresponding influence zone, riparian areas, and vegetative hiding cover to create a weighted score between 1 and 5 that predicts the ease with which wildlife may move through and live within an area. GIS layers from the LZP model were used to calculate an average score within 500 meters of each structure. We expected structures with a lower LZP score, corresponding to minimal impacts by humans, would have higher use, and structures with a higher LZP score would have less use by wildlife.

Wildlife mortality due to I-90 was also opportunistically documented during our 10-month study period and combined with data provided by the Montana Department of Transportation (MDOT) maintenance crews from 1998 to 2002. We collected additional information on road kills during the study period regarding milepost, species, sex, and the traffic direction (relative to I-90) where the animal was killed.

Results

We monitored seven underpasses and three culverts for ten months, from October 2002 through July 2003. Each structure was monitored with infrared cameras and snow tracking through March 31, 2003. We collected a total of 1493 photographs during our study period of 3,213 functional camera days (tables 3 and 4). Wildlife species observed were placed into faunal groups. White-tailed deer, mule deer and elk were placed into the ungulate group; skunks, raccoons, and house cats were considered small carnivores; foxes and coyotes comprised the medium carnivores; and large carnivores consisted of black bears. Human-associated species included humans and domestic dogs (table 3). The number of photos for each species was as follows: white-tailed deer (791), mule deer (379), elk (100); skunks (9), raccoons (3), house cats (41); foxes (1), coyotes (3); black bear (1); humans (113) and domestic dogs (7) (table 4; figure 2). Twenty-eight photographs of other species of small mammals and birds were collected during the course of our study. We used SPSS (SPSS Chicago, IL) 11.5 to explore correlations between our variables and use ratings, but found no significant relationships.

Table 3.
Total number of days that each location was monitored and photos recorded.

Structure ID	# of Cams[a]	# of Rolls[b]	Fxn'al Days[c]	# Ung's[d]	# Sm. Carn.'s	# Med. Carn.'s	# Lge. Carn.'s	# Other[g]	Total # Wildlife[h]	# Human Associated[i]
81.5	2	15	395.40	187	1	1	0	2	191	8
69	1	6	284.52	57	3	0	0	0	60	1
66.3	2	14	339.87	38	4	1	1	2	46	100
58.5	2	10	212.66	190	0	0	0	0	190	1
57.5	2	9	308.25	141	3	0	0	4	148	2
53.7	2	15	526.68	227	9	0	0	5	241	11
39.8	4	34	700.77	430	3	1	0	0	434	9
57.5 C	1	4	172.00	0	0	0	0	15	15	2
55.6 C	1	2	171.87	0	7	0	0	0	7	0
42.4 C	1	3	101.81	0	23	1	0	0	24	3

[a] total number of cameras used at this structure
[b] total number of rolls of film taken at this structure
[c] sum of functional days of all cameras at the structure
[d] number of photos of ungulates
[e] number of photos of mesopredators
[f] number of photos of carnivores or omnivores
[g] number of photos of other wildlife
[h] number of photos of ALL wildlife (ungulates + mesopredators + other wildlife)
[i] number of photos of humans and/or domestic dogs

Table 4.
Number of photos taken at each location by species.

Structure	UNGULATES			SMALL CARNIVORES			MEDIUM CARNIVORES		LARGE CARNIVORES	Other	Human Associated		
ID	WD	EK	MD	HC	SK	RC	FOX	CO	BB	Wildlife	HU	DD	TOTALS
81.5	181	0	6	0	0	1	0	1	0	2[a]	8	0	199
69	57	0	0	3	0	0	0	0	0	0	0	1	61
66.3	24	0	14	4	0	0	0	1	1	2[a,b]	98	2	146
58.5	67	0	123	0	0	0	0	0	0	0	1	0	191
57.5	121	0	20	2	0	1	0	0	0	4[a,c,d]	2	0	150
53.7	143	0	84	6	3	0	0	0	0	5[a,d]	11	0	252
39.8	198	100	132	3	0	0	0	1	0	0	9	0	443
57.5 C	0	0	0	0	0	0	0	0	0	15[e]	2	0	17
55.6 C	0	0	0	6	1	0	0	0	0	0	0	0	7
42.4 C	0	0	0	17	5	1	1	0	0	0	0	3	27
TOTALS	791	100	379	41	9	3	1	3	1	28	131	6	1493

WD = white tailed deer (*Odocoileus virginianus*)
EK = elk (*Cervus elaphus*)
MD = mule deer (*Odocoileus hemionus*)
HC = housecat (*Felis domesticus*)
SK = striped skunk (*Mephitis mephitis*)
RC = raccoon (*Procyon lotor*)
FOX = red fox (*Vulpes vulpes*)
HU = human (*Homosapien*)
DD = domestic dog (*Canis familiaris*)
CO = coyote (*Canis latrans*)
BB = black bear (*Ursus americanus*)

[a] bird
[b] squirrel
[c] turkey
[d] rabbit
[e] packrat

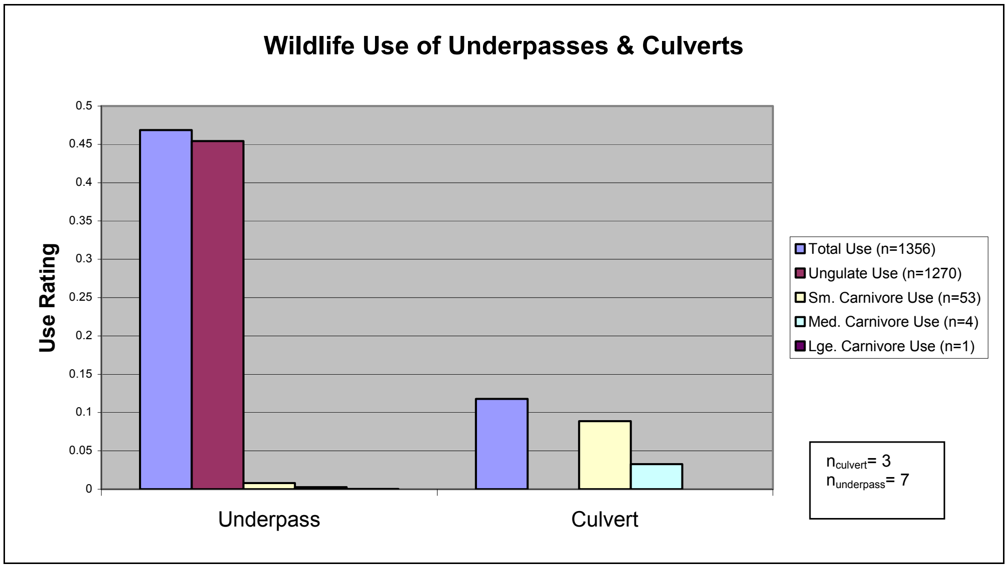

Fig. 2. The type and frequency of wildlife use compared between culverts and underpasses (Use Rating = (∑#of photographs)/(∑#of functional camera days)). Ungulates used underpasses exclusively while small carnivores were more frequent users of culverts. Medium carnivores were found at both underpasses and culverts and one black bear was recorded using an underpass.Total use ratings included other wildlife and humans.

Tracking was limited due to lack of precipitation. Some use of structures not captured by camera data were indicated by tracks. One bobcat was identified by tracks near a two-meter culvert, but did not use the culvert. Ungulate tracks comprised the majority of tracks recorded with a few other small predators, but no medium or large carnivore tracks were encountered. Additionally, no tracks were found in the track transects that were perpendicular to the road. Black bear hair and scat were found at an underpass (81.5), but not deposited during our study period.

We documented various road-kill including white-tailed deer, housecats, a coyote, and a black bear. Two wolves were killed in our study area prior to our study period (M. Jimenez. USFWS, pers. commun. 2003). Wildlife mortality distribution was independent of the crossing structures we monitored (figure 3).

Discussion

We monitored seven underpasses spanning the Clark Fork River, county roads, or railroads and three large culverts running underneath I-90 from October 2002 through July 2003. A total of 1,356 photos of animals were taken, with ungulates comprising the vast majority of these pictures (table 4). There were 1,270 photos of ungulates, 53 photos of small carnivores (with domestic and feral housecats being the most frequent users) 4 pictures of medium carnivores, and 28 photos of other wildlife, such as packrats and birds (tables 3 and 4). We recorded use by one black bear at an underpass, but no other larger omnivores and carnivores, such as wolves, lynx, or mountain lions, all of which are known to exist within our study area. We began monitoring in October assuming that animals would be more likely to move into valleys during winter. The winter of 2002-2003 was mild with average temperatures above normal and snowpack in our study area “below average” to “extremely below average” (USDA & NRCS MT 2003). Elk and mule deer did not make their normal fall migrations into the valley until late December and our first photos of these animals were on December 21, 2002.

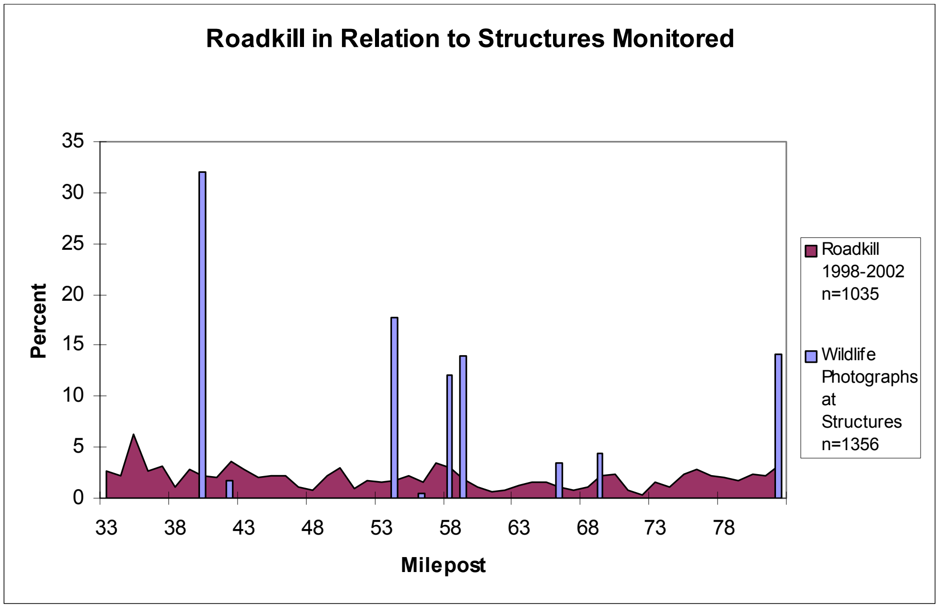

Fig. 3. Percentage of wildlife mortality along I-90 between mileposts 33 and 82, 1998-2002, combined with mortality recorded during this study from October 2002-March 2003 compared to percentage of wildlife photos at structures.

Crossing rates could have been affected by multiple factors that were uncontrolled for in our observational study. For instance, rates recorded by photos of unmarked animals could be high due to some individuals using the same structure repeatedly. We know this happened with housecats at several sites because we were able to identify individuals by their coloration patterns. Also, crossing rates at individual structures are at least somewhat reflective of densities of animals in the area and not necessarily related to the characteristics of the structure (Foster and Humphrey 1995, Rodriguez et al 1997). We suspect high population densities of ungulates due to abundant, available habitat to be at least partially responsible for the high numbers of photos at structure 39.8.

Wildlife use of structures was most frequent at underpasses and limited in culverts. Relative deer use was highest at underpasses; whereas, small carnivores were the most frequent users of culverts. We observed varying trends in the type and frequency of use between culverts and underpasses (fig. 2). Most culvert use consisted of skunks, raccoons, and house cats with a small portion of use attributed to rodents and humans. Although culverts were physically large enough to accommodate large mammal use, ranging in diameter from 2-4.6m, there were no ungulates or large carnivores recorded. We believe this is primarily a function of a lack of suitable substrate in the culverts and low structural openness ratios. This is partially in accordance with past studies which found that ungulates and most large mammals favor large, open structures with high structural openness ratings (Bruinderink and Hazebroek 1996, Foster and Humphrey 1995, Land and Lotz 1996, Reed et al. 1975, Ruediger 2001). Underpasses generally offer more natural lighting, vegetation, substrate, and moisture conditions; whereas, the cool, wet conditions found in culverts seems to favor use by small and medium carnivores, such as red foxes (*Vulpes vulpes*), wildcats (*Felis silvestris*), striped skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*) (Foster and Humphrey 1995, Land and Lotz 1996, Rodriguez et al. 1997). Mammal use of underpasses has consisted of ungulates, small, medium, and large carnivores, domestic animals, and humans.

Although we only recorded use by one black bear and three coyotes at our underpasses, we also encountered a coyote and black bear roadkill. The occurrence of these species in our opportunistic and limited collection of roadkills could suggest these animals cross the highway directly over the road surface often and show no preference for using crossing structures. Henke showed that deer, elk, coyotes, and foxes all demonstrated preference for crossing across the road surface (at grade) rather than using a crossing structure (below grade) but, when traffic volumes are extremely high, 24,000-37,000 vehicles per day (CDOT 2002), these animals used structures below grade more often than expected, as did a mountain lion and bobcats (2001). This could be a response to severe selection pressure against those animals that did not use crossing structures. The average traffic volume for our study area was comparatively low, 6480 vehicles/day, and may not be intense enough to disrupt carnivore and omnivore tendencies to cross at grade.

Furthermore, large, scavenging and predatory mammals could be displaying active avoidance of structures due to higher road densities and human presence associated with structures (tables 1 and 2) (Haas 2001, Rodriguez et al. 1997, Ruediger 2001). All underpasses that we monitored had either a railroad or county road running underneath the interstate were within 200m of the entrance to the structure. In addition to the road or railroad use, structures also usually possessed increased human activities, such as permanent residences associated with roads and exit ramps.

Most human-associated photographs were recreationists (hunters, fisherman, and kayakers). Seventy-five percent of all human associated photographs occurred at one location and were kayakers. Wildlife use was low at this structure, but included a black bear and coyote. Rugged topography may have limited the movement of ungulates while also limiting the degree of human development possible near the structure. It is interesting to note however, the deer and black bear that used this structure did so during the day, and the kayakers used the structure during dusk and at night.

One underpass is being monitored in the Ninemile area where a pack of wolves reside. One of the two wolf mortalities occurred at this location, and black bear hair and scat were also collected at this structure, but the use at this structure consisted almost entirely of ungulates, with one coyote recorded. High human activity underneath the bridge consisting of heavy equipment including chainsaws may account for this low use by medium and large carnivores.

The majority of crossing structures in our study area coincide with riparian areas. At three locations, we have located wildlife trails parallel to I-90, which then continue underneath the highway structures. These trails seem to indicate active avoidance of crossing I-90 at these sites and preference for crossing the interstate via the underpasses. The absence of tracks in transects that were located perpendicular to the highway between I-90 and standard MDOT right-of-way fencing suggests that wildlife may be using underpasses exclusively if within 50m of a structure. This is important and needs further monitoring to determine if this is true.

Underpasses were constructed in the mid-1960's, and most were upgraded in the 1980's; therefore, the surrounding wildlife knows of the existence of crossing structures. Some tree harvesting occurred below the underpasses during our study period. Few trees were cleared, but some that were blocked existing wildlife trails, thus disrupting animal movement. The culverts were originally installed below I-90 to facilitate movement of intermittent streams.

Wildlife that uses these structures may possibly be habituated to the associated surrounding interferences (noise, average traffic volume, seasonal and daily human activity, etc.) and make behavioral adaptations to minimize chances of mortality. For example, ungulate use of underpasses peaked around dawn and dusk as expected, but there was consistently high use throughout the night, corresponding to low traffic volumes (figure 4). The ability of grizzly bears to predict human activities has also been proposed as a possible explanatory variable in understanding grizzly bear movements (Chruszcz et al. 2003). Various seasonably predictable recreational activities occur within 500 meters of I-90 including USFS roadside campgrounds, kayaking and rafting, fishing, hunting, and rest areas. Timber harvests by Plum Creek Timber Company and the State of Montana are spread out on a larger temporal scale and may impact wildlife movement due to this unpredictability. A significant portion of the surrounding landscape was being logged during the latter part of our study period.

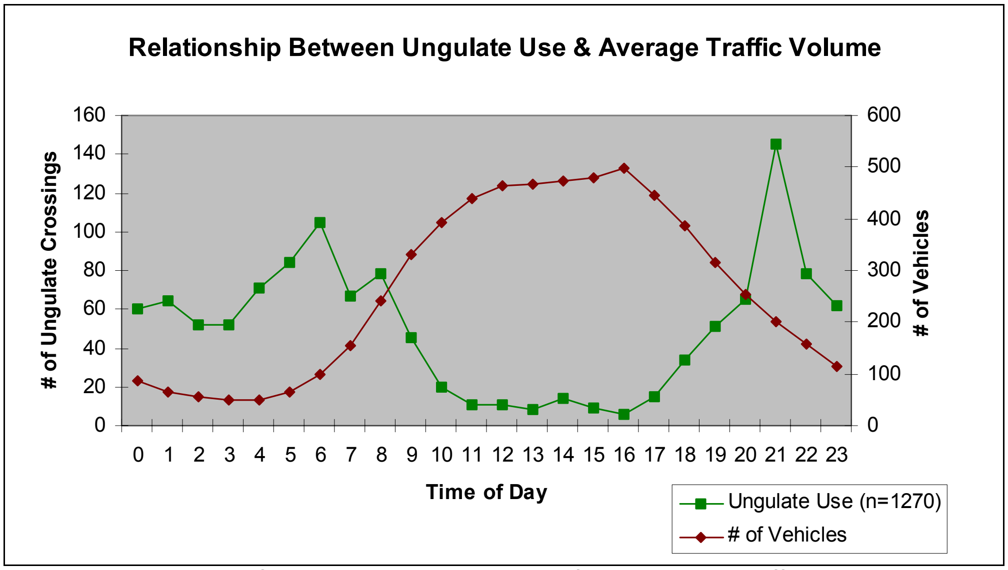

Fig. 4. Ungulate use of underpasses related to time of day and hourly traffic volume. The increased ungulate use throughout the night corresponds to low traffic volumes and could represent animals that are particularly sensitive to traffic and have made corresponding behavioral adaptations. N = 1270 ungulate crossing photos.

Future Studies and Management Implications

More rigorous studies and repeatable methods must be used to gain a better understanding of wildlife movements under differing conditions. Sample sizes must be adequately large enough to draw conclusions and significant relationships. Our failure to find any significant relationships was due in part to these discrepancies but also could be a result of animals using structures opportunistically. For example, many studies have found that crossing structures are more likely to be used when placed in areas already known as travel routes by wildlife (Bruinderink and Hazebroek 1996, Foster and Humphrey 1995, Land and Lotz 1996, Ruediger 2001).

Right-of-way fencing exists along both sides of the entire length of I-90, but was put in place to prevent cattle from wandering into the road, not to encourage wildlife use of crossing structures. As such, it is poorly maintained, if at all, and is not high enough to keep deer and elk from jumping over it and onto the road surface. It was interesting to find that ungulates did follow the fencing for at least 50m on either side of an underpass even though they were fully capable of jumping it. This suggests that properly maintained highway fencing that is of adequate height (>1.5m) could be an effective tool for funneling animals into underpasses. Care must be taken though to ensure that crossing structures are placed closely enough to each other so that the fencing does not simply make the highway a more effective barrier to movement between wildlife populations on both sides of the valley.

Key Conclusions

Our findings indicate that even large culverts may not be effective structures for movement of large- and medium-size mammals, probably due to a combination of unnatural surface substrate and the small openness ratios of these culverts. Continuity of the natural habitat on either side of the structure, and under bridges, when possible, is important and increases the probability of wildlife use of underpasses. The highest use occurred at sites that we subjectively judged to be the most remote from human use and where less disturbed habitat occurred right up to the structure. Structural openness was high at underpasses we monitored and may be the contributing factor to wildlife use. Levels of deer use may be a function of seasonal movements (fall migration, hunting pressures, and breeding), which may inflate assumed yearly use. Highway mortality of wolves, coyotes, and black bears was documented in our study area.

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References

Bashore, T. L., W. M. Tzilkowski, and E. D. Bellis. 1985. Analysis of deer-vehicle collision sites in Pennsylvania (USA). *Journal of Wildlife Management* 49:770-428.

Belden, R. and B. Hagedorn. 1993. Feasibility of translocating panthers into northern Florida. *J. Wildl. Manage*. 59:388-397.

Bookhout, T. A. (ed.) 1996. *Research and management techniques for wildlife and habitats*. The Wildlife Society, Bethesda, Maryland.

Bruinderink, G. and E. Hazebroek. 1996. Ungulate traffic collisions in Europe. *Conservation Biology* 10: 1059 - 1067.

Chruszcz, B., T. Clevenger, K. Gunson, and M. Gibeau. 2003. Relationships among grizzly bears, highways and habitat in the Banff-Bow Valley, Alberta, Canada. Can. J/. Zool. In press.

Clevenger, A.P., J. Wierzchowski, B. Chruszcz, and K. Gunson. 2002. GIS-Generated, expert-based models for identifying wildlife habitat linkages and planning mitigation passages. Conservation Biology 16: 503-514.

Colorado Department of Transportation (CDOT). Annual average daily traffic counts for US 85 and I-25. Website: http://www.dot.state.co.us. Accessed November 25, 2002.

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

Garland, T., and V. G. Bradley. 1984. Effects of a highway on Mojave desert rodent populations. American Midland Naturalist 111(1):47-56.

Gibeau, M. and S. Herrero. 1998. Roads, rails, and grizzly bears in the Bow River Valley, Alberta. G. Evink et al., eds. *Proceedings International Conference on Ecology and Transportation.* FL-ER-69098, Florida Dept. of Transportation, Tallahassee, 263 pp.

Gilpin M. and M. E. Soule. 1986. Minimum viable populations: the processes of species extinctions. Pp13-34. M.E. Soule (ed.) *Conservation Biology: the Science of Scarcity and Diversity*. Sinauer associates, Sunderland, Mass.

Gleason, J. and J. Jenks. 1993. Factors influencing deer/vehicle mortality in east-central South Dakota. *Prairie Naturalist* 25: 281-287.

Haas, C.D. 2001. Responses of mammals to roadway underpasses across an urban wildlife corridor, the Puente-Chino Hills, California. *Proceedings of the international conference on wildlife ecology and transportation*. G. Evink and K.P. McDermott, Eds. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

Halfpenny, J. and E. Biesiot. 1986. *A field guide to mammal tracking in North America*. Johnson Books, Boulder.

Henke, R.J., P. Cawood-Hellmund, and T. Sprunk. 2001. Habitat connectivity study of the I-25 and US 85 corridors, Colorado. *ICOET 2001 Proceedings: A Time for Action*. 499-508.G. Evink and K.P. McDermott, Eds. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

Jimenez, M. 2003. Letter to the authors. 24 Apr. 2003.

Land, D. and M. Lotz. 1996. Wildlife crossings design and use by Florida panthers and other wildlife in southwest Florida. *Proceedings of the international conference on wildlife ecology and transportation*. Florida Department of Transportation, Tallahassee.

MacArthur, R.W. and E.O. Wilson. 1967. *The theory of island biogeography*. Princeton University Press. Princeton, NJ. 203 pp.

Montana Department of Transportation (MDOT). 2003. Average daily traffic volumes for 2002-2003.

Reed, D.F., T.N. Woodard, and T.M. Pojar. 1975. Behavioral response of mule deer to a highway underpass. *Journal of Wildlife Management* 39: 361-367.

Rodriguez, A., G. Crema, and M. Delibes. 1997. Factors affecting crossing of red foxes and wildcats through non-wildlife passages across a high-speed railway. *Ecography* 20: 287-294.

Romin L.A. and J.A. Bissonette. 1996. Deer-vehicle collisions: Status of state monitoring activities and mitigation efforts. *Wildlife Society Bulletin* 24: 276-283.

Ruediger, B. 2001. High, wide, and handsome: Designing more effective wildlife and fish crossings for roads and highways. *Proceedings of the international conference on wildlife ecology and transportation*. G. Evink and K.P. McDermott, Eds. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

Servheen, C. and P. Sandstrom. 1993. Ecosystem management and linkage zones for grizzly bear s and other large carnivores in the Northern Rocky Mountains in Montana and Idaho. *Endangered Species Technical Bulletin*. 18:10-13.

Servheen, C., J. Waller, and P. Sandstrom. 2001a. Identification and management of linkage zones for grizzly bears between the large blocks of public land in the northern Rocky Mountains. U.S. Fish and Wildlife Service, Missoula, Montana. 87 pp.

Servheen, C., J.S. Waller, and P. Sandstrom. 2001b. Identification and management of linkage zones for grizzly bears between the large blocks of public land in the Northern Rocky Mountains. *ICOET 2001 Proceedings: A Time for Action*. Pages 161-198. G. Evink and K.P. McDermott, Eds. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

United States Dept. of Agriculture (USDA) and Natural Resources Conservation Service Montana (NRCS). 2003. Montana snow and water information. http://nris.state.mt.us/Nrcs/Snowater.html. Accessed 4/28/2003.

Yanes, M., J.M. Velasco, and F. Suarez. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. *Biological Conservation* 71: 217-222.