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Grizzly bears, roads and human-bear conflicts in southwestern Alberta

by

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ABSTRACT

Because most grizzly bear mortalities occur near roads, the Province of Alberta plans to implement gated access management. Little is known about how grizzly bears will respond to road closures because the effects of roads are confounded by habitat and human use. I examined mechanisms underlying grizzly bear habitat selection near roads on private and public lands of southwestern Alberta. I incorporated habitat selection models into an analysis of conflict risk. Grizzly bears selected areas near roads with low traffic and were most active at night on private lands, where human use was low. However, habitat selection varied among individuals, and roads were not a consistent predictor of overall habitat selection across individual bears. Patterns of habitat selection led to the emergence of ecological traps on private land. Access and attractant management should be implemented to reduce bear-human conflicts, and decrease displacement of bears from high-quality habitats.

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CHAPTER 1

GENERAL INTRODUCTION

Roads are an ever-present part of our lives, forming the backbone of our economic and social networks. They also have altered the landscape in which we, and other organisms, exist, causing profound changes in local geology, hydrology, and biology (Spellerberg 2002). For wildlife, roads present a complex challenge and the ecological effects of roads are some of the most pressing issues facing wildlife managers. Roads increase mortality rates, modify behaviour, and allow non-native species to invade ecosystems (Trombulak and Frissell 2000, Spellerberg 2002). These effects extend beyond the roadbed itself and, as a result, areas close to roads can become ecological traps (Dwernychuk and Boag 1972, Forman and Alexander 1998, Nielsen et al. 2006).

Grizzly bears (*Ursus arctos* L.) are sensitive to human disturbance, particularly roads. However the relationship between bears and roads is complex. Roads decrease realized habitat due to avoidance by bears (Mattson et al. 1987, McLellan and Shackelton 1988, Kasworm and Manley 1990), segregate age and sex classes (Gibeau et al. 2002), alter movement patterns (Roever et al. 2010, Waller and Servheen 2005), and might act as genetic barriers (Proctor et al. 2002). However, in some areas bears appear to be attracted to roads due to the presence of food resources, or for use as movement conduits (Roever et al. 2008, Roever et al. 2010). The relationship between grizzly bears and roads is further complicated by the fact that bears respond differently to roads by season (Mattson et al. 1987, Mace et al. 1996), time of day (McLellan and Shackelton 1988), age class, and sex (McLellan and Shackelton 1988, Gibeau et al. 2002, Chruszcz et al. 2003). Furthermore, grizzly bears respond differently to roads of different traffic volume, though this idea has not been rigorously examined over an entire road network (Mace et al. 1996, Waller and Servheen 2005).

Despite the above confounding factors, grizzly bears are most likely to die near roads, and areas within 500 m of roads often are ecological traps (Dwernychuk and Boag 1972, Benn and Herrero 2002, Nielsen et al. 2004, Johnson et al. 2004, Nielsen et al. 2006). Access management, the limiting or elimination of human access, has been suggested as a means to reduce these mortalities (Servheen et al. 1999, Banci et al. 1994), and has been important in speeding recovery of grizzly bear populations in the United States (ICST 2007).

Despite the effectiveness of access management at reducing mortalities, there is little information on how it might affect grizzly bear habitat selection or human use of roads. Furthermore, many of the mechanisms underlying grizzly bear selection of areas near roads are poorly understood, despite the importance of this information to effective access management. This thesis examines some of the mechanisms for grizzly bear selection of roaded habitats, as well as spatial patterns of grizzly bear-human conflicts, in an attempt to more accurately inform access management decisions. This study took place in southwestern Alberta, near the town of Pincher Creek and Waterton Lakes National Park (Fig. 1-1).

In Chapter 2, I develop a temporally explicit model for human use of roads in southwestern Alberta using data from 73 traffic counters and trail cameras. This model represents the first fine-scale statistically rigorous model of motorized human use on an entire road network along the east slope of the Rocky Mountains. I use this model to examine the influence of traffic on grizzly bear habitat selection and road crossing behaviour. In Chapter 3, I examine several potential mechanisms underlying grizzly bear habitat selection in roaded areas in the context of overall habitat selection patterns. Using the traffic model developed in Chapter 2, as well as maps of the presence or absence of key grizzly bear foods (Appendix A), and large-scale terrain and landscape characteristics, I model and compare habitat selection near and far from roads separately to directly compare the patterns in these 2 areas. In Chapter 4, I examine grizzly bear-human conflict, and model and map the risk of conflict in relation to habitat. I overlay this map with a map of a resource selection function (RSF, Manly et al. 2002, Boyce et al. 2002) to identify areas that might be ecological traps: areas that grizzly bears are likely to select but where they are at high risk of coming into conflict with humans. In southwestern Alberta, grizzly bear mortalities are rare, compared to the rest of the province. Where mortalities do occur in Alberta, they occur close to roads and are mostly human-caused. Thus I sought to investigate if non-mortality conflicts had similar patterns to mortalities, and how access management might reduce or enhance these conflicts. While conflicts are not analogous to mortalities, many conflicts result in management trapping and translocations, which decreases survival and increases the probability of repeat conflict (Riley et al. 1994; Blanchard and Knight 1995; Linnell et al. 1997). In the final chapter I draw general conclusions and provide management recommendations according to my results.

Other than specific University of Alberta thesis guidelines this thesis was written with the 3 data chapters prepared as separate manuscripts, with the intention to submit each for publication separately. Formatting of the text and of specific sections is consistent throughout: however, in Chapter 2 references are formatted for the *Journal of Wildlife Management*, in Chapter 3, and Appendix A references are formatted for the *Journal of Applied Ecology*, and in Chapter 4 references are formatted for *Biological Conservation*. This introductory chapter and the concluding chapter are formatted according to the *Journal of Wildlife Management*.

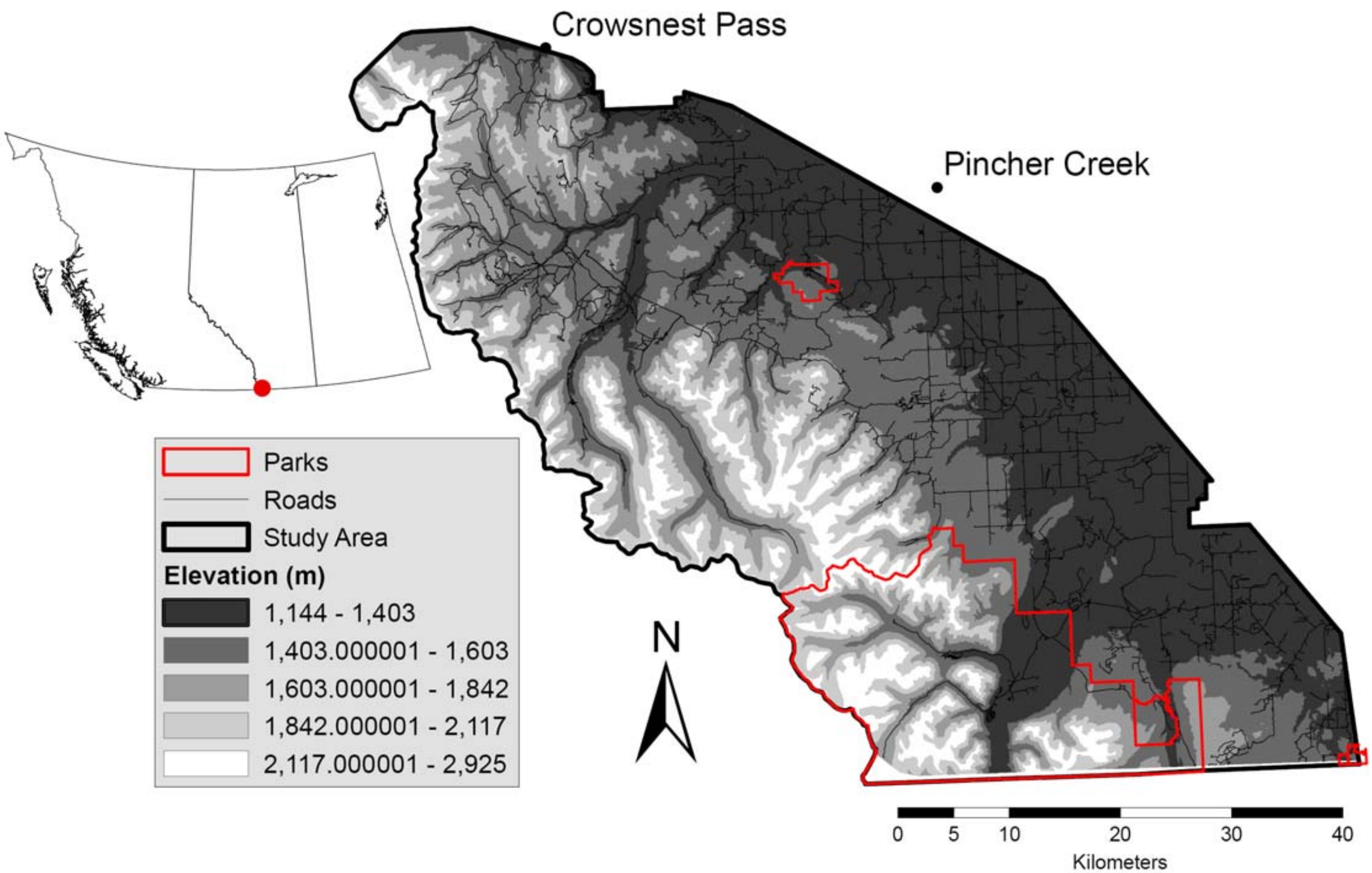

Figure 1-1. Map of the study area in southwestern Alberta, highlighting the road network, national and provincial parks and broad elevation classes.

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CHAPTER 2

GRIZZLY BEARS AND TRAFFIC: LINKING HUMAN USE TO WILDLIFE RESPONSE TO ROADS

1. INTRODUCTION

The ecological effects of roads are among the most pressing issues facing wildlife managers, particularly in areas with heavy industrial presence. Roads increase mortalities, modify behaviour, and facilitate the spread of exotic species (Trombulak and Frissell 2000). Often, road effects extend beyond the road bed itself and areas close to roads can become ecological traps (Dwernychuk and Boag, 1972, Forman and Alexander 1998, Nielsen et al. 2006). The effects of roads vary among species, sexes, and age classes (Spellerberg 2002), complicating the applicability of road studies to management strategies.

For large mammals, one of the most common effects of roads is that they alter habitat selection and movement patterns (Mace et al. 1996, Cole et al. 1997, Dyer et al. 2001, Whittington et al. 2004). Despite ample documentation of these effects we still have a poor understanding of how human use of roads affects these patterns. Road traffic influences amphibian and bird distribution and abundance, causes avoidance by small mammals (Fahrig et al. 1995, Forman and Alexander 1998, Carr and Fahrig 2001, Mazzerolle 2004), and is an important factor predicting the risk roads represent to animal populations (Jaeger et al. 2005). However, the above studies are theoretical modelling exercises or were undertaken at small geographic scales. Thus, their applicability to understanding fine-scale habitat selection by large mammals, and thus to management decisions, is limited.

Studies of road effects on large mammals often do not include, or oversimplify, measures of human use. Methods include counting traffic on a subset of roads and using these as indicators for overall traffic patterns (Mace et al. 1996, Cole et al. 1997, Dyer et al. 2001, Chruszcz et al. 2003), assuming levels of human use based on the accessibility of roads (i.e. restricted, opened etc., Wilegus et al. 2002), or using a relative index of traffic volume based on distance from towns, campgrounds, or oil and gas facilities (Apps et al. 2004, Roever et al. 2010). While some studies validate a portion of their classifications with actual traffic counts (see Rowland et al. 2000, Roever et al. 2010 supplementary material), often these are limited to a few roads and their classifications may still blur important fine-scale differences in traffic volume.

Grizzly bears (*Ursus arctos*) exemplify the complex relationship between roads and wildlife. Bears avoid roads in many areas and often will not inhabit areas with high road densities (Archibald et al. 1987, Mattson et al. 1987, McLellan and Shackelton 1988, Mace et al. 1996). However, in some instances bears are attracted to roads due to the presence of foods or for use as movement conduits (Roever et al. 2008, Roever et al. 2010). Grizzly bears also respond to roads differently by season (Mattson et al. 1987, Mace et al 1996), sex, and age classes (McLellan and Shackelton 1988, Gibeau et al. 2002, Chruszcz et al. 2003).

The complex nature of grizzly bear habitat selection near roads could be explained by differing levels of traffic volume. Bears avoid crossing roads with a high volume of traffic (Chruszcz et al. 2003), and a volume threshold might exist above which bears will not cross a road (Waller and Servheen 2005). Past studies have examined the influence of traffic on grizzly bear habitat selection, with findings ranging from no effect to selection of areas near roads with low traffic volume (Mace et al. 1996, Roever et al. 2010). However, as reviewed above, these studies used relative indices or broad scale extrapolations of traffic volumes.

Understanding the above relationships is important for effective management because grizzly bear avoidance of areas near roads can lead to the loss of large amounts of functional habitat (Hood and Parker 2001), whereas attraction can lead to mortalities and the emergence of ecological traps (Dwernychuk and Boag 1972, McLellan 1989, Benn and Herrero 2002, Johnson et al. 2004, Nielsen et al. 2006). In areas where there is concern over population numbers, access management (limiting motorized human access) has been outlined as the primary method to reduce the mortalities related to roads (Interagency Conservation Strategy Team 2007, Alberta Sustainable Resource Development 2008). Understanding the relationship between grizzly bear habitat selection and human use will help to identify road closures that are most likely to influence grizzly bear habitat selection patterns.

Our objectives were three-fold: 1) develop a statistical model of human use of roads for the east slopes of the Rocky Mountains in southwestern Alberta, 2) use this model to predict road traffic throughout the study area, and 3) examine the relationships between traffic, selection of areas near roads, and road crossings by grizzly bears.

2. STUDY AREA

The study was located in southwestern Alberta, Canada near the town of Pincher Creek and was composed of private agricultural land, multi-use public land, provincial parks and recreation areas, and Waterton Lakes National Park. The study area was bounded by Highway 3 to the north, the British Columbia-Alberta border to the west, the United States-Canada border to the south and the extent of grizzly bear range to the east. The landscape is characterized by a dramatic rise from prairies to mountaintops over a relatively short distance in the south, while there is a narrow strip of rolling foothills separating the mountains and prairies in the north. The eastern portion is a mosaic of grazing pastures, croplands, willow (*Salix* spp.), and aspen (*Populus tremuloides*) stands in upland areas, and balsam poplar (*Populus balsamifera*) along streams and rivers. The western portion is mostly forested, dominated by Engelmann spruce (*Picea engelmannii*), lodgepole pine (*Pinus contorta*) and Douglas fir (*Pseudotsuga menziesii*), with alpine habitat and barren rock at higher elevation. A moratorium was placed on grizzly bear hunting in Alberta in 2006 (Alberta Sustainable Resource Development 2008), but before that time grizzly bears were hunted throughout the public and private land. Conflicts between people and grizzly bears were common in the agricultural lands during the course of this study with approximately 5 grizzly bears trapped and relocated each year (Chapter 4).

Human use varied throughout the study area. The private land along the eastern half of the study area was dominated by small- to medium-sized cattle ranches where recreational access was tightly controlled by landowners. The western area saw extensive recreational use including off highway vehicle (OHV) use, hunting, fishing, and hiking, as well as industrial traffic related to natural gas extraction. The majority of the public land lay in the Castle Special Management Area (CSMA), a controlled access Forest Land Use Zone with a network of designated OHV trails, non-designated trails, open, decommissioned, and gated gravel roads. The majority of gated roads were accessed regularly by natural gas company employees. The road network of Waterton Lakes National Park consisted of a paved entrance road leading to a town site, 2 additional paved roads that led deeper into the Park, and a small network of gated maintenance roads. OHV use was not permitted inside the park.

3. METHODS

3.1 Traffic modelling

Traffic count data. – From spring 2008 through fall 2009, we deployed 46 traffic counters (Diamond Traffic Products, Oakridge, OR) on both roads and trails. The traffic counters work through air pressure from hoses placed across roads and thus we checked them regularly and replaced tubes if necessary. We downloaded data approximately once every 2 weeks. We obtained traffic data from 3 Alberta Transportation traffic counters (http://www2.infratrans.gov.ab.ca/mapping/), and 3 counters deployed in Waterton Lakes National Park.

From April to November of 2008, we randomly deployed 21 remotely activated trail cameras (RECONYX, Creekside, WI) on roads and trails. Trail cameras provided time-stamped photographs of motorized and non-motorized use (vehicles, hikers etc.) that passed the camera's infrared sensor. Cameras were checked and data were downloaded approximately once per month. Pictures of motorized vehicles were used to quantify traffic.

We compared traffic volumes on gated roads versus un-gated roads of similar type (unpaved, and not designated as trails) using a *t*-test.

Road data. – We obtained road and trail Geographic Information System (GIS) layers from the Government of Alberta current to 2007. We combined these layers in ArcMap 9.2 (Environmental Systems Research Institute Inc, Redlands, CA), and verified them using aerial photos and knowledge of the study area to obtain an access layer. Though there were changes to the road network throughout the time for which grizzly bears were collared, these changes were minor and as they represented only a fraction of the roads present in any one bears range, likely did not influence our results.

Models. – Because traffic varied by time of day and day of the week we modelled traffic in 3 separate periods; weekend day (WE), weekday (WD), and night. We defined night as the average sunrise and sunset times for Lethbridge, AB during each month the counters were deployed (http://www.nrc-cnrc.gc.ca/eng/services/hia/sunrise-sunset.html). Thus, the number of hours of night changed for each month of the study. Lethbridge was the closest city with available sunrise / sunset data from the government of Canada, and was located approximately 100 km east of the study area.

We estimated separate models for night, WD, WE, using linear regression. Data were right-skewed, thus we natural log transformed these data to normalize distributions. We excluded 3 counters (2 on Highway 3, and 1 on a dead-end designated trail) as probable outliers. We estimated models from a suite of candidate variables hypothesized *a priori* to influence traffic volume (Table 2-1). Many of these candidate variables measured the same characteristic of roads but in different ways and thus were highly correlated ($|r| > 0.7$). Therefore we conducted univariate analysis on correlated variables to determine which best fit the data (highest r^2 value). Using these results we fit a global model of only the best variables from each group of correlated variables, plus all remaining variables that were not highly correlated, and interaction terms we believed to be relevant (Hosmer and Lemeshow 2000). To obtain our final model we removed variables from the model for which the 90% confidence intervals of coefficients overlapped 0 to obtain our final model.

Model adequacy was determined by r^2 values. We examined model residuals and tested for normality, and the existence of skew, kurtosis and heteroskedasticity in residuals for all final models. We conducted all statistical analysis in STATA 10 (StataCorp LP, College Station, TX).

Final spatial road layer. – We used the above models to predict WD, WE and night-time traffic counts for all roads in the study area. For our final GIS layer we used empirical counts (from traffic counters and trail cameras) on all road segments on which we had deployed traffic counters and extrapolated these counts to adjacent road segments that fell between intersections with roads that did not dead end at houses or facilities. For roads, we extrapolated empirical counts beyond intersections with trails. Additionally, we extrapolated counts beyond intersections with roads of known traffic volume when these counts were lower than the road of interest (less than one half that of the intersecting road). For Highway 3, a high-volume Trans-Canadian highway, we averaged empirical counts from 2 counters and extrapolated along the entire length of the highway.

We split this road layer into 11 traffic categories (0-5, 5-10, 10-20, 20-30, 30-40, 40-60, 60-80, 80-100, 100-150, 150-1,000, and > 1,000 vehicles per day. Bins were non-overlapping, exclusive of the lower end but inclusive of the upper end: for example the second bin was any road traveled by > 5 but ≤ 10 vehicles per hour).

3.2 Grizzly bear selection of roaded areas

Bear data. – Between 2003 and 2008 we captured and immobilized 14 grizzly bears (6 adult males, 2 sub-adult males, 3 females with cubs, 2 adult females, and 1 sub-adult female) using helicopter, culvert traps and foot snares, following Cattet et al. (2003, University of Alberta Animal Care Protocol nos. 332205, and 552812, University of Saskatchewan Animal Care Protocol no. 20010016). Bears were collared with Televilt Tellus II and Simplex collars (Televilt Ltd., Lindesberg, Sweden) as well as ATS (Advanced Telemetry Systems, Isanti, MN) global positioning system (GPS) radiocollars. GPS acquisition schedules ranged from once every hour to once every 5 hours. Data from 2 additional bears (1 adult female and 1 sub-adult female), collared in Montana, USA and British Columbia, Canada, that inhabited our study area for some time were used in our analyses. We listed bear locations as weekend or weekday and as day or night based on the criteria described above for traffic counts.

Selection ratios. – We generated 5,000 random points within each grizzly bear home range (100% Alberta minimum convex polygon). We calculated the distance to the nearest road in each of the 11 traffic volume classes from every used and random location. We compared the mean distances to any road among day-time categories and the mean distance to roads of different traffic volume classes for all used points using *t*-tests.

We split the area within 500 m of roads into 50 m buffers and the area between 500 and 1000 m from roads into 100 m buffers. We calculated selection ratios, a measure of selection of habitat calculated as the frequency of used locations divided by the frequency of random locations within each buffer (Manly et al. 2002), for all bears pooled and the average selection ratio across individuals. We plotted traffic volume against selection ratios for each buffer and distance against selection ratio for each traffic volume class to visually examine potential thresholds in selection at certain traffic volume classes or distance buffers. We further split roads into 3 coarser traffic volume classes (low: ≤ 20 vehicles per day, medium: > 20 and ≤ 150 vehicles per day, and high: >150 vehicles per day) based on the results of the above visual examinations. We examined the effect of distance from roads of different traffic volumes among time periods by these coarser classes.

Crossing patterns. – To examine the influence of traffic volume on road crossings by grizzly bears we calculated the percent of steps (straight line between subsequent

GPS relocations, Turchin 1998) that crossed roads and the mean traffic volume of roads crossed by grizzly bears during the day, night, and across periods. We excluded steps that occurred over missed fixes.

We calculated mean step length and turn angles (Turchin 1998), and plotted step length against traffic volume for crossing steps. We compared step lengths of crossing movements over roads of different traffic volumes as well as to those steps that did not cross roads using *t*-tests. We calculated mean step length and turn angle by traffic volume class (low, medium, high) of the road crossed. For step length we calculated these separately for bears with collars set to obtain fixes once per hour and those with collars set to obtain locations at longer intervals. We calculated turn angles only for bears with collars set to obtain fixes once per hour, because exact turn-angles will become more obscured at longer time periods between fixes. We calculated mean turn angle for non-crossing and crossing movements using the circular package for Stata 10 and tested for differences in means using Watson's non-parametric 2-sample U^2 statistic.

For 7 bears with radiocollars set to obtain fixes once per hour we calculated mean hourly movement rates. Different movement lengths are indicative of different behavioural states (Morales et al. 2004), thus this analysis was intended to provide information on activity patterns of grizzly bears. As movements over longer time periods likely will measure different behavioural states, we examined those bears equipped with GPS collars set to obtain hourly fixes only.

4. RESULTS

4.1 Traffic data and modelling

There was significantly less traffic on gated roads than ungated roads of similar type ($p<0.05$) and of the 15 cameras or counters on gated roads 15, 13, and 12 fell into the low-volume category at night, weekend and weekday daytimes respectively. The final traffic-volume models are shown in Table 2-2. Both day-time models had an $r^2 > 0.77$, and the r^2 for the night model was 0.61. Standardized residuals were higher for most counters in the night-time model than in either daytime model, indicating lower predictive power. However the majority of night-time counts were low (<1 vehicle per hour), thus even though standardized residuals were higher than for daytime models, the absolute difference in predicted versus observed traffic counts were lower.

Traffic volume was similar between WE and WD with 36% of all roads classified as low-volume, 52% classified as medium-volume, and 12% classified as high-volume during both times. During the night 88% of roads were classified as low-volume, 10% as medium-volume and 1.5% as high-volume. Thus we pooled results for WD and WE into one day category.

4.2 Bear analysis

Grizzly bear selection of areas near roads differed by traffic volume, with a greater magnitude of selection for areas nears roads of lower traffic volume (Fig. 2-1). These patterns were consistent across bears and persisted between day and night, though with significantly smaller selection ratios during the day relative to night in most distance buffers near medium- and low-volume roads (Fig. 2-2).

Of consecutive successful fixes only, 13% of grizzly bear steps crossed roads (n = 2,146 of 16,601 steps), though crossings were more frequent at night, when most crossings were over low volume roads (Table 2-3, Fig. 2-3). The relationship between traffic volume and step length was weak for both groups of bears (1 hour fixes $r = 0.2$, > 1 hour fixes $r = 0.3$ respectively). Step length for non-crossing movements was significantly shorter than for all crossing movements combined ($P<0.0001$) and step lengths for crossing movements over low-volume roads were significantly shorter than movements over medium- ($P<0.0001$) or high-volume ($P<0.0001$) roads. Turn angles of crossing steps ($\bar{x}$ = 359º) were significantly straighter than those of non-crossing steps ($\bar{x}$ = 168.2º) during all times and over all roads ($p<0.001$), indicating more directed movements when crossing roads. Again these patterns depended on the traffic volume of roads crossed (Table 2-4)

For the 7 bears for which we calculated mean hourly movement rates there was a clear daily activity pattern (Fig. 2-4).

5. DISCUSSION

5.1 Traffic model

We developed models predicting the volume of motorized human use on roads and trails in southwestern Alberta, which explained spatial and temporal variation in human use of roads. These models were congruent with expected patterns of human use such as greater traffic on weekends and near rivers in the public land as a result of recreational use and random camping (camping at non-designated campsites). The high magnitude of the coefficient *castle* in the night model was unexpected and may be due to increased traffic in the predawn and twilight hours during hunting season.

Past human-use models with access to limited fine-scale data have relied on using distance from towns, oil and gas wells, and/or facilities for creating relative indices of human use of roads (Apps et al. 2004, Roever et al. 2010). Such models are useful when other data are not available, or where traffic is primarily industrial and likely to follow set travel routes (see Roever et al. 2010). However our results indicate that care must be taken when interpreting results of such models. None of the variables quantifying distance from towns, wells, or facilities were reliable predictors of traffic volume in any of our models, potentially related to the type of traffic in our study area (mostly recreational or agricultural).

5.2 Grizzly bear selection of roaded areas

Our results suggest a traffic volume threshold near 20 vehicles per day, below which grizzly bears selected areas near roads, and crossed roads more frequently. The majority of road crossings, and much of the selection of areas near roads occurred at night when most roads were travelled by fewer than 20 vehicles per day, and bears were most active. Grizzly bears use roads disproportionately during the night elsewhere and this has been attributed to differences in human use (McLellan and Shackelton 1988, Mueller et al. 2004, Waller and Servheen 2005). Grizzly bears in areas less populated than southwestern Alberta are most active during the day (Munro et al. 2006) and there is no daily pattern to their use of roads (Roever et al. 2010). Thus our finding that bears appeared most active at night, and are closer to roads at night indicate that the high levels of human use in our study area might have caused a switch in bear activity to night when there are fewer people, and the landscape as a whole is more permeable for bears.

In addition to selecting roadsides more frequently at night, grizzly bears might have used roads as travel conduits during this time. Of night-time steps 15% crossed low-volume roads and these movements were significantly longer and straighter, relative to previous steps, than non-crossing movements. Roever et al. (2010) hypothesized that a greater frequency of road crossings and the greater length of these movements, indicated use of roads for travel as bears would be most likely to frequently cross roads if they were moving along them. While an analysis of sequential steps would be necessary to clarify this pattern, the disproportionate use of areas within 50 m of roads, coupled with the frequent crossings and longer, almost straight movements when crossing roads could be explained by use of roads for movement.

Though bears crossed medium- and high-volume roads, it is unlikely that they used these roads for travel. Grizzly bears strongly avoided these roads but crossed them more often during the day than night. This pattern might indicate a greater perceived risk from higher-volume roads by bears during the night. Traffic at night likely is less predictable than during the day on high-volume roads, and distances of vehicles might be difficult for the bears to judge. Therefore bears might avoid crossing these roads during the night. Turn angles again were straighter for steps that crossed these roads, but because bears strongly avoided areas near these roads it is likely that they were moving more quickly, and from greater distances when seeking to cross, resulting in more directed movements.

The movement and habitat selection patterns that we documented around low- and medium-traffic volume roads are a management concern. Grizzly bear mortalities in Alberta occur disproportionately near roads, and the areas within 500 m of roads often are ecological traps (Dwernychuk and Boag 1972, Benn and Herrero 2002, Nielsen et al. 2006). Animal populations are sensitive to losses of specific age classes (Crouse et al. 1987), and long-lived animals are most sensitive to losses of adults (Meyers and Boyce 1994). Furthermore if sensitive vital rates associated with these age classes, such as survival, vary greatly, the result can be population decline (Brault and Caswell 1993). Demographic sensitivity in grizzly bear populations is highest for adult females (Knight and Eberhardt 1985, Boyce et al. 2001), thus loss of adult females will have the greatest consequence to population decline. This sex and age class often disproportionately selects areas near roads (McLellan and Shackelton 1988), and are more likely to cross lower-volume roads (Chrusczs et al. 2003). These behaviours might put them at increased risk of negative interactions with humans in some areas, and thus potentially putting the population at risk of decline. We did not have sufficient data to test for age and sex-specific differences in use of roads, though the disproportionate use of areas near roads is a management concern.

Access management has been recommended in Alberta to reduce the mortalities related to roads (Alberta Sustainable Resource Development 2010). Traffic behind gates was lower than for non-gated roads and this traffic was at levels below which grizzly bears will select roads. Wielgus et al. (2002) found that grizzly bears were more likely to make use of restricted roads then opened, or entirely closed roads; thus gated access management has promise as a recovery strategy in Alberta, provided these traffic patterns are generalizable to other areas.

6. MANAGEMENT IMPLICATIONS

Traffic models such as the one developed here can provide managers and land-use planners with information on patterns of human use and the subsequent impacts on wildlife. These models might be extrapolated, with minor modifications, to other areas to predict road and trail traffic volumes and aid in access management.

If the public complies with road closures, gating roads will act to reduce the potential conflict between the public and bears. However monitoring is necessary to ensure that traffic remains low if access management is to be effective. Furthermore roads must remain gated in perpetuity or be reclaimed. If bears become habituated to the low level of traffic on gated industrial roads, the opening of these roads to public use could lead to grizzly-bear human conflicts and subsequent mortalities. To better understand the risk associated with these roads, information is needed on both the food resources around roads and the relationship between traffic volume and mortality risk, as well as seasonal variations in foods and human use. Some roadsides might be selected more readily if they have a greater supply of foods, and both food availability and human use vary by season. Likewise, mortality risk might not be equal on all roads, and traffic volumes and types of traffic surely have some influence on this pattern. Combining analyses of these factors with measures of human use will ensure the most effective access management.

Table 2-1. Candidate variables, descriptions and pixel sizes for models predicting motorized human use of roads and trails estimated from count data from traffic counters and remotely activated trail cameras deployed along roads and trails in southwestern Alberta, Canada. All variables calculated at a pixel size of 30 × 30 m unless otherwise noted.

Variable	Description
d_facil[a]	Average distance to natural gas facilities
cost_d_facil[a]	[b]Cost-based average distance to natural gas facilities
min_d_facil[a]	Distance to nearest natural gas facility
d_town[a]	Average distance to towns
cost_d_town[a]	[b]Cost-based average distance to towns
d_town_pop[a]	Distance to towns divided by the population of the town
cost_d_town_pop[a]	[b]Cost-based average distance to towns divided by the population of each town
min_d_town[a]	Distance to nearest town
d_well[a]	Average distance to natural gas wells
cost_d_well[a]	[b]Cost-based average distance to natural gas wells
min_d_well[a]	Distance to nearest natural gas well
d_house_lwm	Length-weighted mean distance to houses
trail	Dummy variable indicating if the road was designated as a trail
public	Dummy variable indicating if the road ran predominantly through public land
park	Dummy variable indicating if the road ran predominantly through national and provincial parks
gated	Dummy variable indicating if the road was gated
castle	Dummy variable indicating if the road ran predominantly through the CSMA
t_ route	Dummy variable indicating if the road was a major travel route[c]
ag	Dummy variable indicating if the road ran through any agricultural land. Collingwood et al. 2009
paved	Dummy variable indicating if the road was paved
TRI_lwm	Length-weighted mean terrain ruggedness index. Nielsen et al. 2004
TRI_50_lwm	Length-weighted mean terrain ruggedness index calculated at 50 × 50 m pixel size.
NDVI_lwm	Length-weighted mean normalized difference vegetation index. Townshend and Justice 1986
for_age_lwm	Length-weighted mean forest age calculated from forest inventory layers
d_stream_lwm	Length-weighted mean distance to streams

ln_d_stream_lwm	Length weighted mean natural log transformed distance to streams

[a]Variable calculated as distance along road network using Network Analyst extension in ArcMap 9.2. [b]Distance divided by inverse of estimated speeds on road types (1 for trails, 30 for unimproved roads, 50 for one-lane gravel roads, 80 for two-lane gravel roads and one lane paved roads, 100 for two-lane undivided paved roads, and 110 for divided paved roads). [c]Major travel route was defined as a paved road that did not dead-end into a gravel road.

Table 2-2. Variables, coefficients, and 90% confidence intervals for 3 models of traffic volume in southwestern Alberta, Canada, estimated using linear regression on natural log transformed data.

Model	Variable[a]	Coeff.	90% CI -	90% CI +
Weekend day				
	trail	-2.3432	-2.9473	-1.7392
	ln_d_stream	-0.3583	-0.5908	-0.1258
	gated	-2.3884	-2.9001	-1.8768
	paved	2.3772	1.7006	3.0537
	castle	1.0281	0.4935	1.5628
	t_route	1.0908	0.112	2.0691
	Intercept	5.6102	4.3114	6.9091
Weekday day				
	trail	-2.9661	-3.5533	-2.3788
	ln_d_stream	-0.3433	-0.5691	-0.1176
	gated	-1.5442	-2.0436	-1.0448
	paved	3.0425	2.4173	3.6678
	park	-1.1774	-1.9849	-0.37
	castle	0.5683	0.0476	1.0891
	Intercept	5.5569	4.2951	6.8186
Night				
	trail	-3.2468	-4.1517	-2.34182
	TRI_50_lwm	-0.0576	-0.11759	0.002472
	public	-1.137	-1.91716	-0.35676
	paved	2.9992	2.141304	3.857135
	castle	2.3552	1.481359	3.229094
	Intercept	1.6126	1.019696	2.205633

[a]See Table 2-1 for description of variables.

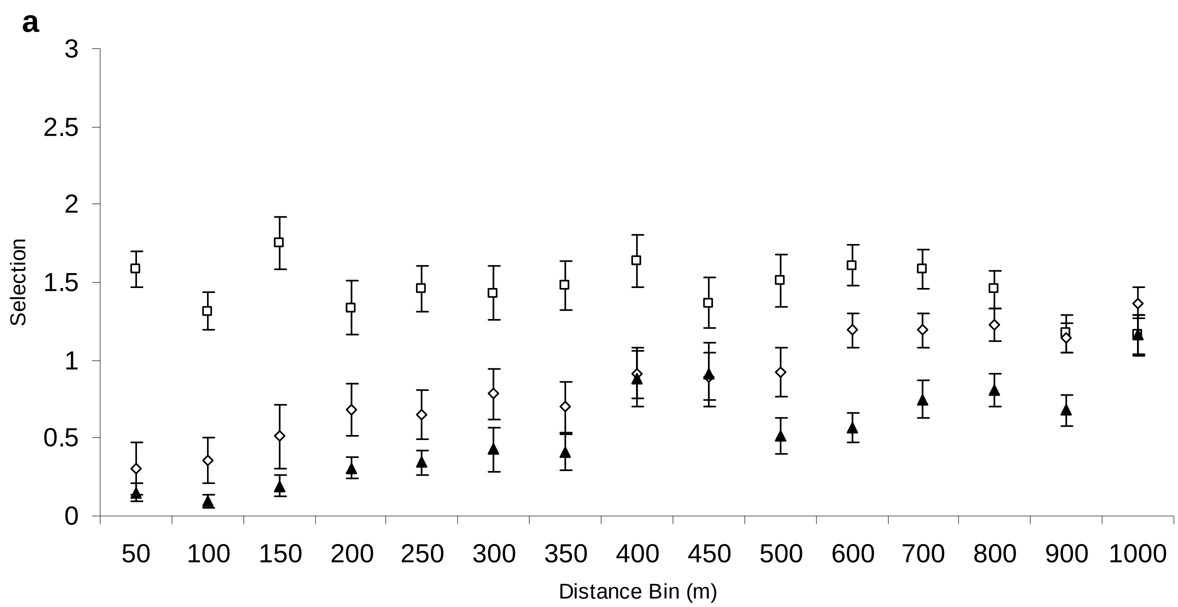
Table 2-3. Percent of steps crossing low- (<20 vehicles / day) medium- (between 20 and 150 vehicles / day) and high-traffic volume roads (>150 vehicles / day) for day, night, and all steps for 16 grizzly bears in southwestern Alberta, Canada. Movements across missed fixes were not included; n = 16,601 total steps and 2,146 crossing steps.

Time Period	Cross low	Cross med	Cross high
All	9.3	3.2	0.4
Day	1.5	3.7	0.8
Night	16	2.8	0.1

Table 2-4. Mean turn angle and 95% confidence limits (CL) by traffic volume class and time of day for crossing and non-crossing movements of 7 grizzly bears equipped with GPS collars set to obtain locations once per hour in Southwestern Alberta, Canada, calculated using the circular package in Stata 10. *n*=14,049 total movements and 1,472 crossing movements.

Cross	Traffic Volume	Time	$\bar{x}$ turn angle (degrees)	95% -	95% +
Yes	Low[a]	Night	0.0	354.6	5.5
		Day	354.7	338.3	11.1
	Medium / high[b]	Night	356.5	347.2	5.8
		Day	353.2	339.4	6.9
No	-	Night	165.2	132.1	198.4
	-	Day	180.2	170.3	190.0

[a]<20 vehicles per day. [b]>20 vehicles per day



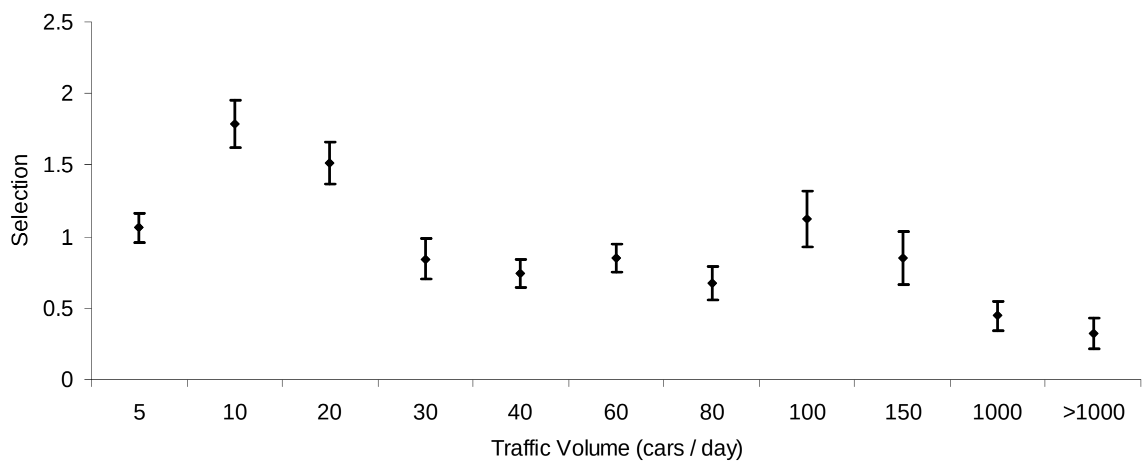


Figure 2-1. Mean and 95% confidence intervals for (a) selection ratios for 3 traffic volume bins; low (□, ≤ 20 vehicles per day), medium (◊, > 20 and ≤150 vehicles per day), and high (▲, > 150 vehicles per day), and (b) selection ratios by traffic volume for 11 traffic volume classes, for 16 grizzly bears in southwestern Alberta, Canada.

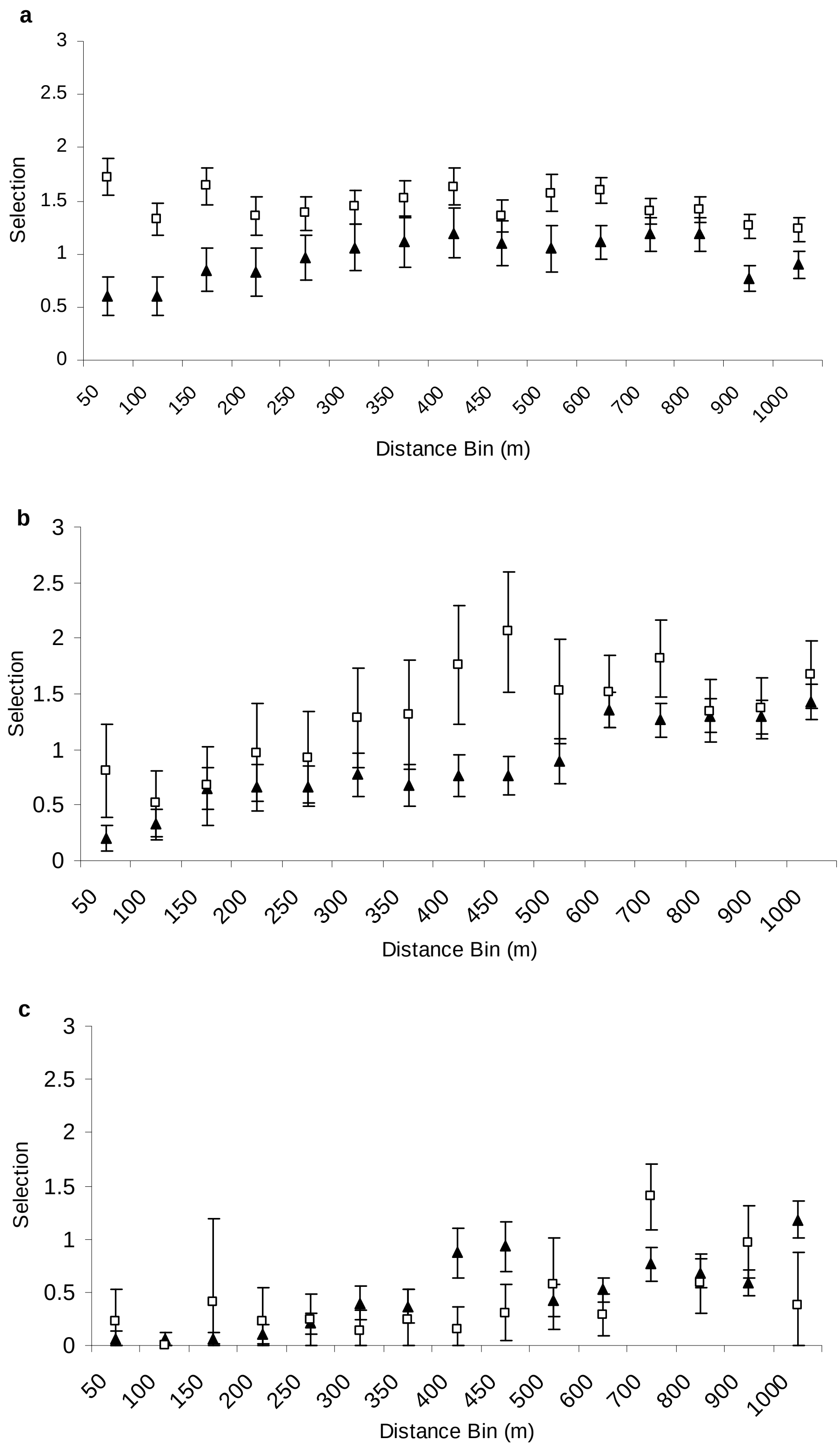


Figure 2-2. Mean and 95% confidence intervals for selection ratios for distance to road bins by day (▲) and night (□) for (a) low-volume roads (<20 vehicles / day), (b) medium-volume roads (20-150 vehicles / day) and (c) high-volume roads (>150 vehicles / day) for16 grizzly bears in southwestern Alberta.

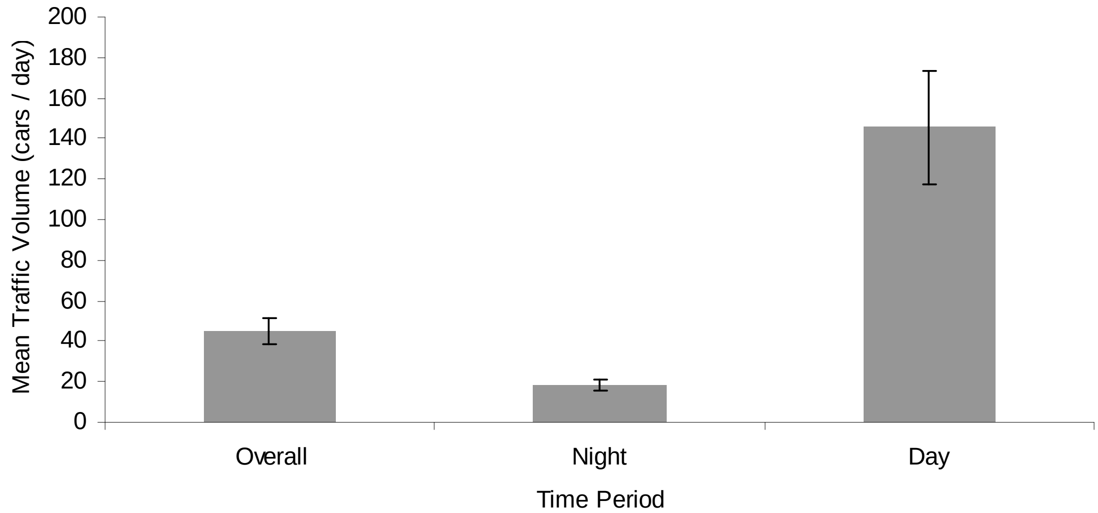


Figure 2-3. Mean and 95% confidence intervals of traffic volume for movements crossing roads for overall, night and day-time periods for 16 grizzly bears in southwestern Alberta, Canada. Movements over missed fixes were not included.

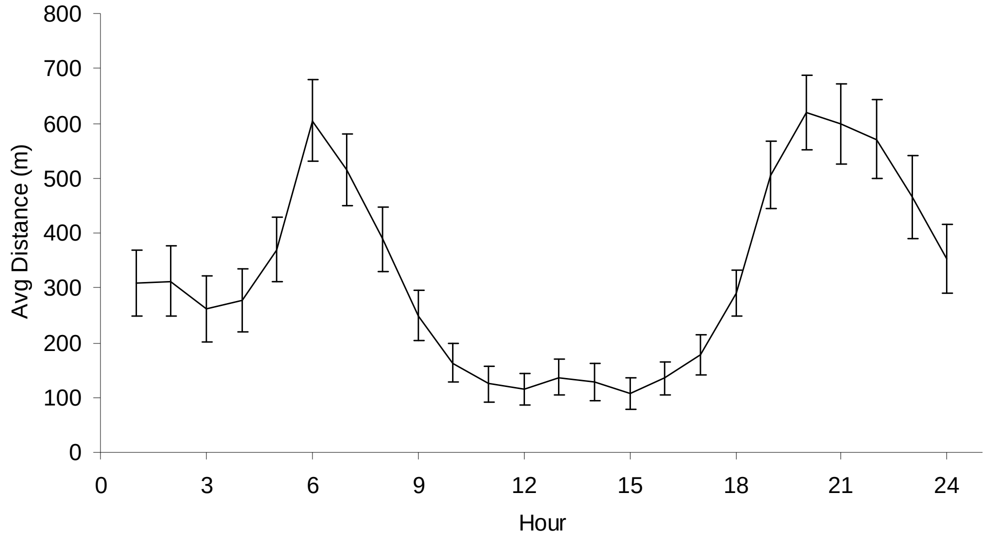


Figure 2-4. Mean and 95% confidence intervals for straight-line distance between consecutive GPS relocations by hour for 7 grizzly bears equipped with GPS collars set to obtain locations once per hour in southwestern Alberta, Canada.

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CHAPTER 3

MANAGING WILDLIFE IN THE FACE OF INDIVIDUAL VARIATION: MECHANISMS INFLUENCING THE EFFICACY OF ACCESS MANAGEMENT FOR GRIZZLY BEARS

1. INTRODUCTION

The effects of roads on wildlife are some of the most complicated issues facing managers today. Roads fragment habitats (Oxley, Fenton & Carmody 1974; Vos and Chardon 1998) and influence community structure (Adams & Geis 1983), while road construction, use and pollution can increase mortality (Oxley, Fenton & Carmody 1974; Trombulak & Frissell 2000), and alter habitats well beyond the road itself (Forman & Alexander 1998; Spellerberg 2002). These negative impacts often are specific to an area, species, age group, or sex (Spellerberg 2002; McLellan & Shackelton 1988), and vary by time of day as well as by season (Mattson, Knight & Blanchard 1987; Chapter 2), complicating effective implementation of conservation and management strategies.

Alteration of habitat selection patterns by animals due to roads is well documented (Mace *et al*. 1996; Cole, Pope & Anthony 1997; Dyer *et al*. 2001; Whittington, St. Clair & Mercer 2004). However, this and other effects are confounded by habitats near the roads, and patterns of human use. The probability of a collision between animals and vehicles can be influenced by habitat characteristics, as well as traffic volumes (Malo, Suárez & Díez 2004; Seiler 2005). Elk *Cervus elaphus* L. avoid roads during seasons of higher than average use (Rowland *et al*. 2000), but at high road densities are less sensitive to road effects if road networks are designed to leave areas of unroaded habitat (Frair *et al*. 2008). In areas of highly productive habitat the negative impacts of roads on grizzly bears *Ursus arctos* L.

might be reduced (McLellan & Shackelton 1988), although certain foods are more likely to occur near roads (Roever, Boyce & Stenhouse 2008) which can lead to the emergence of ecological traps (Dwernychuk & Boag, 1972; Nielsen, Stenhouse & Boyce 2006).

Densities of amphibians and some breeding birds are lower near roads with higher traffic (Fahrig *et al*. 1995; Reijnen 1995). However traffic has no effect on small mammal avoidance of roads (McGregor, Bender & Fahrig 2008), or grizzly bear movements near roads (Roever, Boyce & Stenhouse 2010), and higher traffic levels increase the tendency of some medium-sized mammals to use culverts for crossing roads (Clevenger, Chruszcz & Gunson 2001). Furthermore patterns of human use of roads often are unknown, obscuring the above relationships (Chapter 2).

Grizzly bears exemplify the complex relationship between habitat selection and roads. Roads can cause effective habitat loss due to avoidance by bears (Mattson, Knight & Blanchard 1987), can alter movement patterns (Waller & Servheen 2005), and might act as genetic barriers (Proctor, McLellan & Strobeck 2002). However, in some areas grizzly bears appear to be attracted to roadsides that contain food resources (Roever, Boyce & Stenhouse 2008), and roads might serve as conduits for travel (Roever, Boyce & Stenhouse 2010). Traffic volume influences grizzly bear selection of roaded areas as well as the tendency of bears to cross roads (Chruszcz *et al*. 2003; Waller & Servheen 2005; Chapter 2). However, the interaction between traffic and habitat, and the ability for habitat to mitigate negative road effects have not been examined.

Further complicating the above patterns is variation in diets and habitat selection. Grizzly and black bears are omnivorous generalists with diets that vary by study area, season and year, and among age classes, sexes and individuals (Mattson, Blanchard & Knight 1991; McLellan and Hovey 1995; Jacoby *et al.* 1999; Hobson, McLellan and Woods 2000; Robichaud & Boyce 2010). The seasonal and annual variation likely is due to availability of foods, while age and sex class differences likely are a result of different nutritional requirements (Rode, Robbins, & Shipley 2001). Individual variation in diet and habitat selection indicate specialization, which allows individuals to have greater fitness when populations are near carrying capacity, and can enhance population persistence (Boyce 1984; Łomnicki 1988; White 2000; Bolnick *et al*. 2003). As generalists, under the niche variation hypothesis (van Valen 1965), bear populations should be comprised of individual habitat specialists (Bolnick *et al.* 2007; Araujo *et al.* 2010; Robichaud & Boyce 2010). This possibility, along with seasonal, annual, and age and sex-specific differences in habitat selection and diet might blur population-level patterns of habitat selection near roads.

An understanding of the above patterns is crucial for managing grizzly bears, because mortalities occur disproportionately near roads as a result of conflict between bears and humans (Benn & Herrero, 2002). Decreasing the potential for bear-human conflict through restricting, or eliminating, motorized access (access management) is the primary means to reduce these mortalities (Interagency Conservation Strategy Team, 2007). Our objective was to examine the influence of a suite of road, food, and landscape variables on individual grizzly bear habitat selection in roaded areas and to assess the importance of this information to access management decisions.

2. METHODS

2.1 Study area

The study area was located in southwestern Alberta, Canada near the town of Pincher Creek. This area was composed of private agricultural land, multi-use public land, provincial parks and recreation areas, and Waterton Lakes National Park. The study area was bounded by Highway 3 to the north, the British Columbia-Alberta border to the west, the United States-Canada border to the south and by the eastern extent of grizzly bears to the east. The landscape is characterized by a dramatic rise from prairies to mountains over a relatively short distance in the south, while there is a thin area of rolling foothills separating the mountains and prairies in the north. This area is dominated by a mosaic of broadleaf forest, shrub, and open grassland in the east and conifer forests and alpine habitat at higher elevations in the west. There is a diversity of bear foods in this area (Hamer, Herrero, & Brady 1991). Human use of roads and trails varies substantially across the study area (Chapter 2).

Bear data

Between 2004 and 2008 12 grizzly bears (5 adult males, 2 sub-adult males, 2 females with cubs, 2 lone adult females, and 1 sub-adult female) were captured using helicopter, culvert traps and foot snares, and immobilized following Cattet *et al.* (2003). Bears were collared with Televilt Tellus and Simplex (Televilt Ltd., Lindesberg, Sweden) and ATS (Advanced Telemetry Systems, Isanti, Minnesota, USA) geographic positioning system (GPS) radiocollars with remote upload capabilities. Fix schedules ranged from once every hour to once every 5 hours. All capture methods were approved by the University of Alberta and University of Saskatchewan Animal Care Committees.

Traffic and food models

We used the time-specific motorized human-use models from Chapter 2, developed for this study area, to classify roads into high- (>150 vehicles per day), medium- (>20, <150 vehicles per day), and low- (<20 vehicles per day) traffic-volume roads. We estimated models predicting the presence or absence of 6 food items selected by grizzly bears: (buffalo berry *Shepherdia canadensis* (L.) Nutt., Saskatoon berry *Amelanchier alnifolia* Nutt., cow parsnip *Heracleum maximum* Bartram, horsetail *Equisetum* spp. L., dandelion *Taraxacum* spp. F.H. Wigg., and huckleberry *Vaccinium* spp. L.; see Appendix A).

Modelling of habitat selection in roaded areas

We used 3 separate analyses to examine the mechanisms influencing individual grizzly bear habitat selection. For all analyses we generated 5000 random (available) points per grizzly bear home range (100% Alberta minimum convex polygon (MCP); grizzly bears move between Alberta, British Columbia and Montana in this study area). For resource selection functions (RSFs; Manly *et al.* 2002; Johnson *et al*. 2006) below, we assumed the selection function to be exponential and estimated model coefficients using logistic regression. Because fix success was below 90% for all collars, we weighted all used location by the inverse of the probability of a successful fix (Frair *et al.* 2004; Hebblewhite, Percy & Merrill 2007). For bears with a home range that fell mostly in the mountains we used the fix success probability model of Hebblewhite, Percy & Merrill (2007) and in the prairies and foothills we used the model of Frair *et al*. (2004).

To examine the general pattern of selection or avoidance of areas near roads we calculated selection ratios, the frequency of used locations divided by the frequency of available locations (Manly *et al.* 2002), for areas within 500 m of any road for each bear. This distance has been shown repeatedly to be the distance within which bears are most affected by roads (Mattson, Knight & Blanchard 1987; Mace *et al.* 1996; Benn & Herrero 2002; Nielsen, Stenhouse & Boyce 2006). Because traffic differs significantly between day and night (Chapter 2), and grizzly bear diets vary between seasons, we calculated selection ratios for day, night, fall (August 1st to den entrance) and spring (den exit to July 31st) separately as well as for all locations combined. Night was defined to be the time between the average sunset and sunrise in Lethbridge, Alberta (the nearest city with available sunrise / sunset data from the government of Canada, located approximately 100 km east of the study area), and was calculated separately for each month (http://www.nrc-cnrc.gc.ca/eng/services/hia/sunrise-sunset.html).

To examine the relationship between grizzly bear selection of roaded areas and available foods, traffic, and landscape characteristics, we fit two RSFs for each bear and averaged coefficients across individuals (Marzluff *et al.* 2004; Fieberg *et al.* 2010). The first was for locations within 500 m of a road and the second for locations beyond 500 m of roads. We were interested in comparing habitat selection by grizzly bears near and far from roads so we fit a single global model of uncorrelated variables to each individual grizzly bear (Table 3-1). Variables in the global model were selected *a priori* and all influenced grizzly bear habitat selection in other studies in Alberta (Nielsen *et al.* 2002; Nielsen *et al.* 2004; 2010; Roever, Boyce, and Stenhouse 2008; Chapter 4). Data were not split by time or season in this analysis, because we were interested in examining overall relationships between selection of roads, food, landscape and traffic. For some bears such splits would have reduced the amount of data and thus the power of analysis. To account for seasonal availability of foods we considered foods to be absent if the location fell outside the time during which that food was found in diets of bears in west-central Alberta (Munro *et al.* 2006). For available locations, we randomly assigned each location to a month based on the probability of a location falling in that month and used the same criteria as above to account for seasonal availabilities of foods.

We fit individual RSFs for night, day, fall and spring seasons separately. We examined a suite of candidate models hypothesized *a priori* to influence overall grizzly bear habitat selection patterns (Table 3-2), and identified the best models using Akaike's Information Criteria (AIC; Burnham and Anderson 2002). In this analysis we wanted to understand what affects grizzly bear habitat selection during the day, night, fall and spring. Thus our candidate models represented potential factors influencing habitat selection, as well as combinations of these factors.

3. RESULTS

3.1 Grizzly bear selection of roaded areas

Grizzly bear selection of areas within 500 m of roads was greater at night than during the day (95% confidence intervals did not overlap); however, the magnitude of selection varied substantially among bears, and by season (Table 3-3).

For global habitat selection models near and far from roads, coefficients varied among individuals and between models for the same individuals (Table 3-1, Fig. 3-1). However, bears consistently selected to be near low-volume roads. In both areas bears selected coarse landscape characteristics, such as streams and land-cover, but the signs and magnitudes of coefficients differed by bear. Selection of food variables varied substantially among bears (Table 3-1).

In overall RSFs, combined models had lower AIC values for most bears during all times and seasons, though no model was consistently best. Model coefficients varied among individuals, though some variables were selected more consistently than others. These patterns were mostly for coarse landscape variables such as distance to streams and edges, or land-cover variables, as opposed to the finer-scale food and traffic variables (Table 3-4, Fig. 3-2).

4. DISCUSSION

Grizzly bear habitat selection was characterized by individual variation across all analyses. However, there were some consistent patterns. When bears were within 500 m of roads, the roads consistently were low-traffic volume roads. Thus even when habitat and foods have been accounted for, traffic volume is still an important predictor of bear selection of roadsides. However, there was little evidence that roads and traffic-volume variables were important for daily and seasonal habitat selection overall. Rather bears selected habitats based on coarse landscape characteristics and availability of individually preferred foods. This pattern of more consistent selection of coarse landscape characteristics held true in all models, with distance to edges and streams consistently selected by bears, particularly when near roads.

Compared to individual bear foods, these large-scale characteristics provide a coarser view of the landscape, and the consistent selection of these variables likely is due to the fact that foods, distributed at a fine scale, are nested within. Areas where timber has been harvested contain preferred grizzly bear foods (Nielsen *et al*. 2002), as do cut lines and areas near streams. Being close to edges provides grizzly bears with easy access to cover and some preferred bear foods are more common near edges (Roever, Boyce & Stenhouse 2008). These patterns of selection are similar to those that have been documented in other studies and may lead to generalizations about habitat selection patterns of grizzly bears when implementing access management. However, at the finer scale of particular foods, individual variation dominated. When close to roads no more than 7 of the 12 grizzly bears selected a particular food item. During the day, bears consistently selected cow parsnip, and far from roads bears avoided buffalo berry and Saskatoon berry.

The above variation among individuals is a fundamental aspect of animal ecology (Łomnicki 1988), and is consistent with density-dependent natural selection allowing for greater fitness of specialized individuals at high densities and a higher carrying capacity (Boyce 1984). However, this variation might arise as a result of different mechanisms. The niche variation hypothesis (van Valen 1965), suggests that variation is plastic and that a population of generalists should be composed of specialized individuals partitioning available resources (Bolnick *et al*. 2003; 2007; Araujo *et al.* 2010). For bears to specialize in this manner would require learning to exploit resources more efficiently than other individuals. Evidence for the influence of learning on habitat selection patterns has been shown for a broad range of taxa (Davis and Stamps 2004). Furthermore, female grizzly bears produce offspring that select habitat more similarly to them than other bears, even their male relatives, indicating learning does occur (Nielsen 2005). The bear-human conflict literature contains examples of bears becoming habituated to the presence of people or conditioned to non-natural food resources (Craighead & Craighead 1971; Mattson, Blanchard, & Knight 1992; Herrero *et al.* 2005), indicating the ability for bears to learn from past experience.

While bears might learn to specialize on resources in their lifetime, the personality of an animal is fixed, and has been shown to vary among individuals across diverse taxa (Biro & Stamps 2008). Bolder and more explorative individuals may be more likely to use high-quality resources in risky areas (Wolf *et al*. 2007), such as those near roads, which might manifest itself as differences in habitat selection patterns.

While individual variation might explain the above patterns, grizzly bear diets vary between seasons and years, as well as among age classes and sexes (Mattson, Blanchard & Knight 1991; McLellan and Hovey 1995; Jacoby *et al.* 1999; Hobson, McLellan and Woods 2000), potentially influencing our results. We did not have sufficient data to test for these differences, though if they are driving our results the above ideas still are applicable. Females with young might be more security conscious, thus crossing roads less (Waller & Servheen 2005), while sub-adult males might make use of riskier areas as they are found closer to high traffic roads (Gibeau *et al.* 2002) and cross them more often (Waller & Servheen 2005). Sub-adults also are more often the focus of management efforts (McLellan *et al.* 1999; Blanchard & Knight 1995). Bears of different sizes, ages, or reproductive status, require or seek out different types and quantities of prey (Sterling and Derocher 1990) and herbaceous material (Rode, Robbins, & Shipley 2001). Thus, the specialization of individuals might still occur, but due more to differences in nutritional or other needs between sexes and age classes, than to individual learning or personalities.

The above variation will complicate access management decisions. Access management is a fine scale management option that will affect a subset of roads only and is likely to be unpopular with some stakeholders. Thus, fine-scale information needs to be used to verify that road closures are effective. While low-volume roads near streams and edges likely will see the most selection by grizzly bears, even within these broad classifications we observed substantial individual variation. Furthermore areas near low-volume roads and streams will vary in the types and abundances of food resources, and as such certain areas will be used more frequently than others. The substantial variation among sexes and age classes, by season and year, as well as among individuals means that access management will affect bears in different ways depending on their individual habitat selection patterns and personalities, or what foods are available during any particular year or season. For all bears, during times when there are food shortages, and for bold individuals and those specializing on foods found near roads, access management will provide increased security. However, individuals, or age and sex classes that avoid roads, especially busier roads, might see increased perceived habitat quality due to the decrease in traffic that is likely to accompany the installment of a gate (Chapter 2). Regardless of the specific response by bears, gated access management will be effective, as long as there is proper enforcement and compliance.

In our study area the majority of bears avoided roads during the day but selected roads during the night when human use, and presumably mortality risk, was low. Thus, access management in SW Alberta might act more to enhance habitat suitability than to protect bears from interactions with humans, and access management should focus on roads surrounded by the best habitat. In areas that see moderate levels of human use, where bears use roadsides during times when people are more active, access management could greatly reduce the risk of mortality and enhance public safety near roadsides, and might restore areas that are ecological traps (Dwernychuk & Boag 1972; Nielsen et al. 2006).

5. MANAGEMENT IMPLICATIONS

In the face of large individual variation, conservation and management strategies often only affect subsets of populations (Devictor *et al*. 2010). The confounded nature of habitat selection patterns near roads further complicates this issue. For grizzly bears, variation at the age, sex, or individual level means that access management likely will affect different bears in different ways. The most effective means of management will be to keep open road densities low, and gate any new industrial roads. In areas where road densities are high, access management could be used to improve both security and perceived habitat quality, though traffic volumes should remain below 20 vehicles per day (Chapter 2) and gates must remain in perpetuity or roads should be reclaimed.

Managers should ensure that they understand the habitat selection and mortality patterns for grizzly bears in their particular area, to make the most effective access management decisions. If bears are dying near roads, then access management should focus on areas that might be ecological traps (Nielsen *et al.* 2006), whereas if roads are mainly acting to displace bears, access management should focus on those areas with the greatest abundance of diverse food resources. To ensure the efficacy of access management, food availability as well as habitat selection and mortality patterns should continue to be monitored. This monitoring will inform managers if access management has been successful, or if there is need for additional closures. During times of low food availability, such as berry-crop failures, bears likely will be nutritionally stressed, and might make use of roadsides more often, increasing the risk of negative interactions with humans. By monitoring food availability, managers might be able to pre-empt such situations with temporary road closures. While access management will be a contentious issue, such monitoring will allow the best possible information to be used in an adaptive management framework.

Table 3-1. Global model variables, averaged coefficients and standard errors (Marzluff *et al.* 2004, Fieberg *et al.* 2010) and number of individual bear models in which the variables were positive or negative for use versus available models separated by locations within 500 m of roads and those beyond 500 m of roads, for 12 grizzly bears in southwestern Alberta, Canada. Because not all variables were represented in used distributions of all bears, some variables were not included in all models.

Variable	Within 500 m of roads				Beyond 500 m of roads			
	avg. coeff.	SE	+	-	avg. coeff.	SE	+	-
d_stream[a]	-0. 91[m,n]	0.491	2	10	-0.59[m,n]	0.198	2	10
d_edg_int[b]	-0. 42[n]	0.506	4	8	-0.97[m,n]	0.434	3	9
d_edg_ext[b]	-3.46[m,n]	1.462	4	8	-3.67[m,n]	0.901	1	11
shrub[c]	-0.507[m]	0.1955	1	10	0.0404	0.1834	7	3
herb[b]	-0.0858	0.2079	5	7	-0.2212[m]	0.1855	4	8
cutblock[d]	0.1403	0.2544	7	5	0.1814	0.2413	7	5
elev[b]	-9.864[o]	9.860	5	7	-0.085[m,o]	0.0545	3	9
vacc[e]	-0.2443	0.2431	4	7	0.0101	0.2387	6	6
amel[f]	0.1459	0.1879	6	3	-0.3010[m]	0.2951	4	8
shep[g]	0.0220	0.1752	4	7	-0.3727[m]	0.1612	4	8
equis[h]	0.1473	0.2236	6	4	0.2271	0.4502	7	3
tarax[i]	-0.3259	0.2743	4	6	-0.0997	0.2712	4	8
herac[j]	-0.2510	0.1563	7	3	-0.2781	0.1825	8	3
nearest_low[k]	0.9573[m]	0.1218	12	0	0.0304	0.11687	8	4
nearest_high[l]	-0.4192	0.3641	2	8	-0.2834[m]	0.2143	3	7

[a]Distance to streams. [b]See Appendix A for description of variable. [c]Shrub land-cover (Franklin *et al.* 2001). [d]Forest cut within the last 100 years. [e]*Vaccinium* spp. (see Appendix A). [f]*Amelanchier alnifolia* (see Appendix A). [g]*Shepherdia canadensis* (see Appendix A). [h]*Equisetum* spp. (see Appendix A). [i]*Taraxacum* spp. (see Appendix A). [j]*Heracleum maximum* (see Appendix A). [k]Dummy variable indicating if the nearest road was a low volume road as described in Chapter 2. [l]Dummy variable indicating if the nearest road was a high volume road as described in Chapter 2. [m]Indicates 90% confidence intervals that do not overlap 0. [n]Coefficients multiplied by 1000. [o]Coefficients multiplied by 100.

Table 3-2. Candidate models used to examine selection of habitat by grizzly bears, for night, day, fall and spring season in southwestern Alberta.

Name	Model[a]
Landscape	*d_stream d_edg_int d_edg_ext age shrub herb elev elev × herb*
Anthropogenic	*d_house*[b] *d_cut prop_ag*[c]
Rd distance	*d_rds*[d]
Rd density	*rd_dens*[e]
Traffic distance	*log_dhigh*[f] *log_dmed*[f] *log_dlow*[f]
Food	*vacc tarax shep equis herac amel*
Land management	*ag*[g] *prop_private*[h] *well_dens*[i]
Combo traffic	*d_stream d_edg_int d_edg_ext age shrub herb elev elev × herb log_dhigh log_dmed log_dlow vacc tarax shep equis herac amel*
Combo rd distance	*d_stream d_edg_int d_edg_ext age shrub herb elev elev × herb d_rds*[d] *vacc tarax sheph equis herac amel*
Combo rd density	*d_stream d_edg_int d_edg_ext age shrub herb elev elev × herb rd_dens*[e] *vacc tarax shep equis herac amel*
Combo house	*d_stream d_edg_int d_edg_ext age shrub herb elev elev × herb d_house*[b] *vacc tarax shep equis herac amel*

[a]See Tables 3-1 and Appendix A for descriptions of variables unless otherwise noted. [b]Distance to houses. Locations of houses were obtained from municipal district offices. [c]Proportion of agriculture (Collingwood *et al.* 2009) within a 6km radius. Six km is the average maximum daily distance moved by grizzly bears in this area. [d]Distance to roads of any type. [e]Density of roads within a 6 km radius. [f]Natural log transformed distance to high, medium, and low traffic-volume roads as classified in Chapter 2. [g]Dummy variable for if the location fell in agricultural lands (Collingwood *et al.* 2009). [h]Proportion of private land within a 6 km radius. [i]Density of natural gas wells within a 6 km radius.

Table 3-3. Selection ratios and 95% confidence intervals for areas within 500 m of roads during day, night, fall (August 1st – den entrance), spring (den exit – July 31st) and overall for 12 grizzly bears, by sex and overall, in southwestern Alberta, Canada.

Bears		Overall	Day	Night	Fall	Spring
All						
	Selection ratio	1	0.75	1.18	1.06	1.11
	95% CI	0.8 - 1.2	0.6 - 0.9	0.91 - 1.45	0.87 - 1.25	0.85 - 1.37
Female						
	Selection ratio	0.91	0.69	1.06	1.03	1.04
	95% CI	0.63 - 1.19	0.45 - 0.93	0.74 - 1.38	0.66 - 1.4	0.8 - 1.28
Male						
	Selection ratio	1.06	0.76	1.27	1.07	1.16
	95% CI	0.77 - 1.35	0.54 - 0.98	0.85 - 1.69	0.85 - 1.29	0.72 - 1.6

Table 3-4. Number of positive and negative coefficients from best individual day, night, fall, and spring season RSFs for 12 grizzly bears in southwestern Alberta, Canada. Because these results are taken across models with different variables some variables did not appear in all models.

Variable[a]	Night		Day		Fall		Spring	
	-	+	-	+	-	+	-	+
d_stream	10	1	9	2	9	1	6	3
d_edg_int	9	2	9	2	9	1	7	2
d_edg_ext	7	4	4	7	4	6	6	3
age	5	6	3	8	5	5	3	6
shrub	6	4	5	4	4	6	5	4
herb	7	4	10	1	5	5	6	3
elev	6	5	5	6	3	7	4	5
herb × *elev*	4	7	1	10	4	6	3	6
shep	8	3	9	1	9	1	-	-
vacc	7	4	5	6	5	5	-	-
tarax	6	5	8	3	7	3	6	3
equis	6	5	8	3	5	3	6	3
amel	4	7	7	4	4	6	-	-
herac	2	9	1	10	3	7	1	7
d_house	3	2	5	2	2	2	2	0
log_dhigh	0	2	0	3	-	-	0	1
log_dmed	0	2	0	3	-	-	0	1
log_dlow	1	1	0	3	-	-	1	0
rd_dens	0	3	0	2	1	4	2	2
d_cutline	1	0	1	0	6	3	6	1
prop_ag	0	1	1	0	0	8	3	4
d_rds	1	2	0	0	2	2	1	3
ag	-	-	-	-	-	-	2	0
prop_private	-	-	-	-	-	-	2	0
well_dens	-	-	-	-	-	-	1	1

[a]See Tables 3-1, 3-2, and Appendix A for description of variables

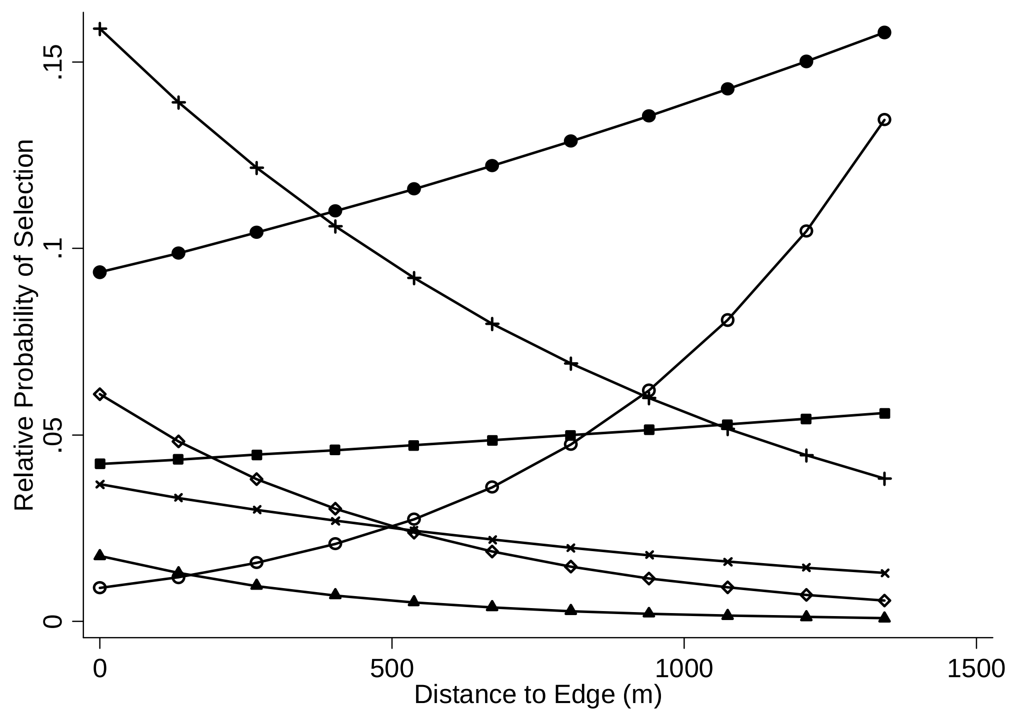

Figure 3-1. Relative probability of selection by distance to edges from the interior of the forest within 500 m of roads for 7 grizzly bears, G064 (▲), G081 (■), G076(X), G087 (●), G124 (|), G123 (O), and G125 (◊)

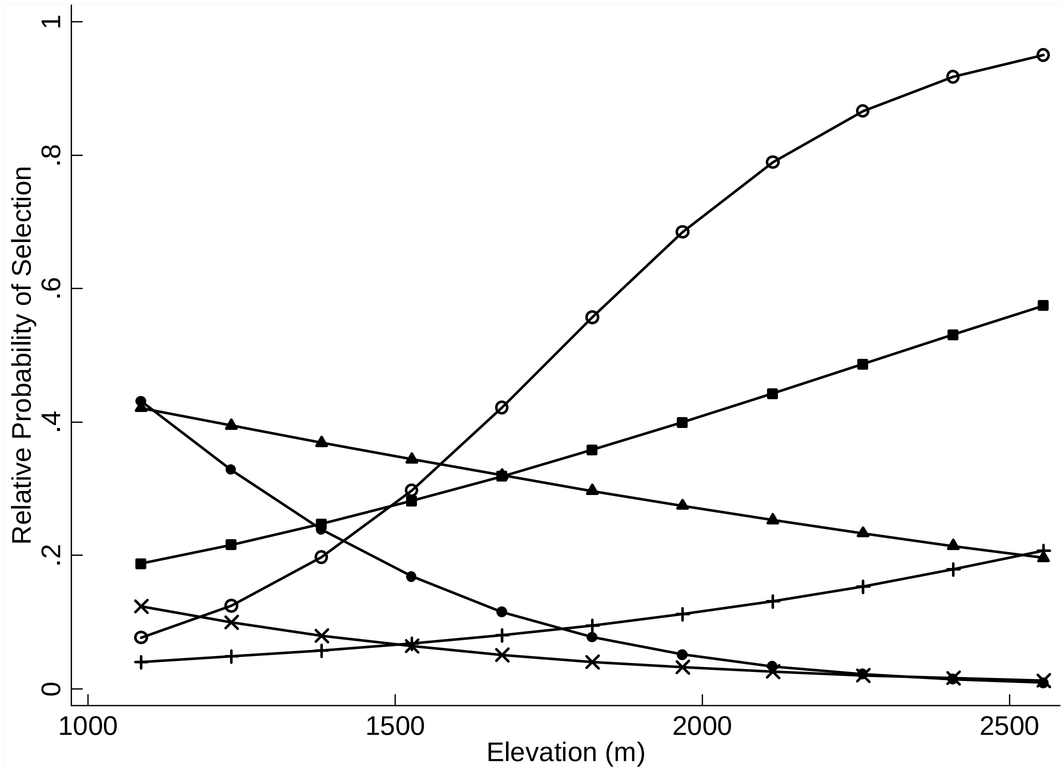

Figure 3-2. Relative probability of selection by elevation during night for overall RSFs for 6 grizzly bears, G084 (●), G077 (O), G085 (■), G090 (▲), G087 (|), and G124 (X).

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CHAPTER 4

AGRICULTURAL LANDS AS ECOLOGICAL TRAPS FOR GRIZZLY BEARS IN SOUTHWESTERN ALBERTA

1. INTRODUCTION

Conflict with humans has contributed to historic carnivore declines and threatens the current viability of many populations (Woodroffe and Ginsberg, 1998; Woodroffe, 2000; Treves and Karanth, 2003). As human populations continue to grow, reducing these conflicts will be of critical importance for carnivore conservation as well as human safety and livelihoods.

Grizzly bears (*Ursus arctos*) in western North America have a long history of conflict with humans. Persecution, along with over-hunting and habitat loss contributed to dramatic declines and large-scale extirpations during the 20^{th} century (Brown, 1985; Mattson and Merrill, 2002). Currently, grizzly bears occupy less than 10% of their former range in the United States and some populations in Canada have declined (Banci et al., 1994; Mattson and Merrill, 2002). Much of current grizzly bear range in North America is either protected land, or has relatively low human use. Those areas that have greater overlap of humans with bears often must be carefully managed to reduce conflict. As a result, bear-human conflicts are a rarity in national parks and some public lands (Mattson et al., 1996; Mattson and Merrill, 2002; Gunther et al., 2004). However, grizzly bear-human conflict on private agricultural lands still persist (Gunther et al., 2004; Wilson et al., 2005; 2006; Madel, 2008), and may be set to increase as bears recolonize historically occupied lands.

Spatial analysis has been used to identify areas of greater grizzly bear-human conflict (Wilson et al., 2005; Wilson et al., 2006), higher relative probability of human-caused bear mortality (Johnson et al., 2004; Nielsen et al., 2004), and population sinks (Knight et al., 1988; Mace and Waller, 1998; Gunther et al., 2004). Studies of other carnivores also have taken a spatial approach to better understand where conflicts occur, providing valuable information on potential areas to focus management (Rondinini and Boitani, 2007), the probability of present and future conflict (Mech et al., 2000; Treves et al., 2004; Michalski et al., 2005), and areas and times that should be avoided by humans or livestock to reduce conflict (Rajpurohit and Krausman, 2000; Polisar et al., 2003; Kolowski and Holekamp, 2006; Sangay and Vernes, 2008).

Fundamental to anticipating where grizzly bear-human conflicts will occur is an understanding of both the spatial patterns of conflicts, and habitat selection by bears. However data required to examine conflict in conjunction with habitat selection often are not available. Using a two-stage modelling approach incorporating habitat selection and mortality risk, Nielsen et al. (2006) documented the presence of ecological traps (Dwernychuk and Boag, 1972), or "attractive sinks", i.e., areas of high apparent habitat quality where there is high mortality risk as well. However these authors were interested in mortality alone, and worked in an area dominated by timber harvest, natural gas extraction and mining, where other conflicts were rare. Non-mortality conflicts are more common in agricultural landscapes, and conflict patterns are influenced by different factors (Wilson et al., 2005; 2006; Madel 2008). Johnson et al. (2004), working in the Greater Yellowstone Ecosystem, documented high mortality and conflict risk related to agriculture; however, they did not overlay this with information on grizzly bear habitat selection. Wilson et al. (2005; 2006) identified grizzly bear-human conflict hotspots in agricultural lands, and related these to broad-scale habitat features. However this was an analysis based on the spatial locations of known attractants, and data that could be used to model grizzly bear habitat selection were unavailable. Linking habitat selection to these areas of conflict risk will be crucial for conflict reduction and conservation, as well as for identifying where and how to focus management actions to prevent future conflicts.

We examined the spatial patterns of grizzly bear-human conflict in an agricultural landscape in southwestern Alberta, where grizzly bears recently have been listed as threatened. We overlaid maps of grizzly bear-human conflict risk with maps predicting grizzly bear habitat selection. The resulting maps were used to delineate areas that might be ecological traps, non-critical habitat and secure habitats and to suggest potential mediation strategies.

2. MATERIAL AND METHODS

2.1 Study area

The study took place in southwestern Alberta, Canada near the town of Pincher Creek, along the east front of the Rocky Mountains. The study area was bounded to the north by Highway 3, to the west and south by political boundaries with British Columbia and the United States respectively, and to the east by the eastern edge of grizzly bear range. The land in this area falls under several management jurisdictions and is composed of private agricultural land, multi-use public land, provincial parks and recreation areas, and Waterton Lakes National Park. The landscape is characterized by a sharp transition from prairies to mountains in the south with a gradually widening area of rolling foothills beginning in the north-central portion of the study area. The western portion of the study area was public land where human activities included natural gas extraction, logging, recreation in the form of hunting, fishing and off-highway vehicle use, and seasonal cattle grazing.

The majority of the private land in the eastern portion of the study area was agricultural, mainly used for cattle ranching.

Grizzly bear habitats in this area are productive, with many food sources, both natural and manmade. Bears use private agricultural lands extensively, with several home ranges almost entirely in this area (J.M. Northrup, unpublished data). The eastern range of grizzlies was limited in the north but extended into the prairies in the south, with bears documented as far east as 45 km from the mountains of Waterton Lakes National Park. This area is part of the Northern Continental Divide Ecosystem which includes grizzly bears in the Flathead Valley of British Columbia and Montana, and those in Glacier National Park, two areas with some of the highest recorded densities of grizzly bears in interior North America (McLellan, 1989; Kendall et al., 2008).

2.2 Methods

We reviewed all Alberta Sustainable Resource Development Fish and Wildlife occurrence reports involving grizzly bears between April 1999 and August 2009 in the study area. Occurrence reports are filed whenever grizzly bear sightings or incidences are reported to enforcement personnel. These reports may be as innocuous as a bear being seen by hikers, or as serious as a mauling. Not all occurrence reports involve an investigation by enforcement personnel, and as such many reports are unsubstantiated. However, some reports are investigated by teams of officers and lead to the capture or destruction of grizzly bears.

Our goal was to obtain a set of grizzly bear-human conflicts that could be summarized and used in spatial analysis. Thus, we reviewed all occurrence reports and evaluated if they could be considered a bear-human conflict. We defined “conflict” as an activity that could lead to damage or harm to people, pets, or property, or that involved unnatural attractants or food sources. This included instances in which a bear was travelling close to dwellings, as this ultimately could lead to a bear-human conflict (Wilson et al., 2005). Because some reported grizzly bear-human conflicts actually involved black bears (*Ursus americanus*), we assigned a confidence level to all reports indicating how confident we were that the animal involved was a grizzly bear (Table 4-1). Conflicts were reviewed for repetition and were mapped using ArcMap 9.2 (Environmental Systems Research Institute Inc (ESRI), Redlands, CA), to further review spatially overlapping conflicts and determine if there were repeated reports. Unrepeated conflicts were summarized by year, conflict and outcome.

Conflict risk model

For every occurrence report, a location with resolution at least to the 65 ha parcel of land (quarter section) on which the conflict occurred was provided. We used logistic regression to estimate the probability of grizzly bear-human conflict for each quarter section. We viewed the data as a landscape of 65 ha cells in which a conflict had occurred or not. Quarter sections in which conflicts occurred were assigned a 1 and those in which conflicts had not occurred were assigned a 0. Cattle depredation or other instances that might be considered a conflict likely occurred in cells that we assigned 0s. However, for the purposes of statistical analysis, we defined our set of conflicts as all activities by grizzly bears that were witnessed or discovered and reported to SRD within the time-frame of the study. These occurrences are the ones that will lead to management actions against bears.

We selected a suite of predictor variables that we hypothesized would influence bear-human conflict (Table 4-2). Because many of these variables were highly correlated ($|r| > 0.7$) we used univariate logistic regression to determine which variable from a set of correlated variables best fit the data (greatest log-likelihood). Using the results of this analysis we fit a global model of all the best-fitting variables from a set of correlated variables plus all variables that were not highly correlated, along with interaction terms we believed to be biologically relevant (Hosmer and Lemeshow, 2000). We removed non-significant variables ($p > 0.1$) until only significant variables remained. We monitored the coefficients and significances, as well as the log-likelihood of models for large changes with removals of non-significant variables. In the case of such changes, we examined the data for further interactions and kept non-significant variables in models if interactions with other variables were significant and biologically feasible. Using the methods described above we estimated two best models; one using all conflicts potentially involving a grizzly bear (very low to certain confidence; Table 4-1) and one with those conflicts that were given moderate or better confidence only according to our classifications (Table 4-1). Model adequacy was determined using area under the receiver operating characteristics curve (Swets 1988; Manel et al. 2001)

Using the final models from the above analysis, we generated maps in ArcMap 9.2 (ESRI) depicting the probability of bear-human conflict. Maps were reclassified from 1-10 using a quantile method with 1 representing the lowest probability of conflict and 10 the highest.

Models of grizzly bear habitat selection

Between 2004 and 2008 12 grizzly bears (5 adult males, 2 sub-adult males, 2 females with cubs, 2 lone adult females, and 1 sub-adult female) were captured following the methods of Cattet et al. (2003) and fit with Televilt Tellus II and Simplex (Televilt Ltd., Lindesberg, Sweden), and ATS (Advanced Telemetry

Systems, Isanti, MN) GPS radiocollars. Collars were set to obtain fixes once every hour or 5 times per day. We estimated a resource selection function (RSF; Manly et al., 2002) assuming the selection function took the exponential form, and estimated coefficients using logistic regression in a use-available design (Johnson et al., 2006). Because grizzly bears in this area show variation in their habitat selection patterns, and select different habitats by day and night (Chapter 3) we estimated individual models for each bear for day and night separately. We determined the start and end of night by the average sunset and sunrise times at Lethbridge, Alberta (the nearest city with sunrise / sunset data available from the Canadian government, located approximately 100 km east of the study area) for the month in which each location occurred (http://www.nrc-cnrc.gc.ca/eng/services/hia/sunrise-sunset.html). For each bear we drew 5,000 random locations from their 100% Alberta minimum convex polygon homerange (bears in this area moved between Alberta, British Columbia, and the United States). The same random locations were used for both night and day models. Because GPS fix success was less than 90% we weighted used locations by the inverse probability of a successful fix (Frair et al. 2004; Hebblewhite et al., 2007). For bears whose homeranges were predominantly in the mountains we used the model of Hebblewhite et al. (2007), and for those in the foothills and prairies we used the model of Frair et al. (2004)

We selected a set of variables that we hypothesized *a priori* to influence grizzly bear habitat selection based on previous studies (Nielsen et al., 2004; 2006; 2010; Roever et al., 2008; 2010; Table 4-3). Because several of these variables were highly correlated ($|r| > 0.07$) we used univariate logistic regression to examine which of a set of correlated variables explained the most variation for each individual. We then fit a global model of the uncorrelated variables that explained the most variation for each individual, along with biologically relevant interaction terms. We removed insignificant terms ($p > 0.1$) individually until only significant variables remained. We tested for further interactions between variables if the log-likelihood or regression coefficients changed appreciably after removal of insignificant variables, and if the terms were thought to be biologically relevant. Non-significant terms were retained in models if they interacted significantly with other variables.

We averaged regression coefficients across bears to obtain a population-level model. Some variables did not appear in all models so a coefficient of 0 was used for model averaging (Marzluff *et al.*, 2004; Fieberg *et al.,* 2010).

Maps of relative probability of selection

Using the above averaged RSF we generated maps indicating the relative probability of selection for each landscape pixel using the exponential function

$$w(\mathbf{x}) = \exp(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n)$$

Where β_i represents the coefficient for variable x_i in a vector, $\mathbf{x}$, of n covariates, and $w(\mathbf{x})$ is the RSF. Maps were reclassified into 10 bins (1-10) using a quantile method, with 1 representing the lowest relative probability of selection and 10 representing the highest. Maps were masked by non-vegetated areas (water, barren landscape, and roadways), which were assigned a value of 0. We used a 5-fold spatial cross validation to internally validate the averaged model (Boyce et al., 2002).

Habitat states

We overlaid the conflict risk map with the RSF maps for day and night and identified 5 habitat states: non-critical habitat, primary and secondary habitat, and primary and secondary traps (Dwernychuk and Boag, 1972; Nielsen et al., 2006;

Table 4-4). We calculated the proportion of the landscape in private land, public land, and Waterton Lakes National Park that was composed of each of the habitat classes for both day and night.

3. RESULTS

3.1 Summary of conflicts

There were 314 records of grizzly bear-human conflicts between 1999 and 2009. Grizzly bear-human conflicts ranged from a low of 14 in 2003 to a high of 49 in 2007, with conflicts increasing from 2004 onward ($r^2 = 0.78$; Table 4-5). The number of conflicts varied by year (Table 4-5) and there was low correlation between the number conflicts per year and the number of bears captured ($r = 0.53$) and relocated, translocated or removed ($r = 0.5$). Most conflicts (63%) were related to agriculture (Fig. 4-1), and occurred in all months when bears were active, though most often during the late summer and fall (73% from July – August; Fig. 4-2).

Grizzly bear conflict risk

Models of conflict risk estimated with all conflict sites and those estimated using only moderate-or-better confidence conflict sites only had similar coefficient values and significances. Thus for further analysis, only the model estimated using all conflicts (very low to certain; Table 4-1) was used.

Grizzly bear-human conflict risk was influenced by natural habitat characteristics as well as human-disturbance features (Table 4-6). The overall conflict risk model had good model accuracy (area under the receiver operating characteristics curve = 0.84). Spatial patterns of grizzly bear habitat selection and model coefficients differed between night and day. The signs of coefficients were the same for many variables for both time periods, but the magnitudes differed (Table 4-3). Five-fold cross validations indicated that our maps were accurate.

The proportion of land in each habitat state varied by management district with the majority of traps in private lands and the majority of primary and secondary habitat in public forests and parks (Table 4-6). There was a marked difference in the proportion and location of each of the habitat states between night and day (Fig. 4-3 & 4-4).

4. DISCUSSION

4.1 Patterns and causes of conflicts

Grizzly bear-human conflicts increased throughout the period analyzed, with a marked increase since 2003. Most conflicts occurred on private land and were related to agriculture. The greatest single source of conflict was from livestock that had died previously to being discovered by a bear, which has become a more substantial issue since the discovery of bovine spongiform encephalopathy (BSE) in Alberta cattle in 2003. This discovery led to the Canadian Food Inspection Agency (CFIA) enacting regulations that require a permit each time dead livestock are removed from the owners land. Furthermore, landfills were required to obtain permits to accept dead livestock (http://www.inspection.gc.ca/english/anima/heasan/disemala/bseesb/bseesbindexe.shtml), and the cost of rendering increased to prohibitive levels for some ranchers. Since this time ranchers have resorted to the creation of "boneyards;" areas on their land where dead cattle are put to be scavenged. Thus the increased complications in dealing with dead livestock arising from the manner in which the CFIA has managed BSE have created a greater source of attractants, leading to increased conflict between grizzly bears and people. Furthermore, as potentially infected cattle now are being left on the landscape, the chance of further infection likely has not been reduced in some areas.

While conflicts related to boneyards often were not the most severe, compared to livestock predation, bears approaching people, or damaging property, and did not always lead to management trapping, these boneyards are a major source of unnatural protein. The habituation of bears to unnatural food sources often leads to more serious conflicts (Herrero and Fleck, 1990), though this potential likely is dependent on the individual bear. Thus boneyards might be acting as an initial attractant eventually leading to more troublesome behaviour. While the locations of some boneyards were known, we did not know the locations of all boneyards and thus could not include their presence in our models of conflict risk, as it is likely that there were unknown boneyards in quarter sections for which there were no conflicts recorded. However boneyards are predictors of grizzly bear-human conflict hotspots along the east slope of the Rocky Mountains in Montana, a similar system to ours (Wilson et al., 2005; 2006; Madel, 2008), and appear to be playing a similar role here.

4.2 Grizzly bear habitat selection and conflict risk

Spatial patterns of grizzly bear habitat selection varied substantially between day and night. In both models, the signs of most coefficients were similar, however the magnitude varied markedly. During the day, when grizzly bears likely are bedding, they avoided open areas strongly. During the night, when bears were more active, they weakly avoided some variables related to open areas while selecting strongly for others. These patterns were reflected in the maps of habitat states where much of the private land, which has more open terrain, was selected during the night when bears select more open habitats, while most of the public forest was non-critical habitat at night.

Most bear-human conflicts were related to agricultural practices and this was reflected in the conflict-risk model. In addition, conflicts occurred in quarter sections that were closer to natural gas facilities, and had higher densities of cut lines and trails. These findings likely indicate the higher incidence of conflict in areas that have more people, and more access. Ranchers in this area access much of their land by off-highway vehicle (OHV) and truck trails, thus a higher density of cut lines and trails would indicate a greater potential for them to witness a conflict. However, road access was not an important predictor of grizzly bear-human conflict, which differs from the mortality risk models of Nielsen et al. (2004). While human-caused grizzly bear mortality is a type of bear-human conflict, apparently it is driven by different factors than the conflicts we documented, of which bear mortalities were few.

4.3 Ecological traps and secure habitat

The most striking result of our analysis of habitat states was the large amount of the landscape that was non-critical habitat, or ecological traps. While moderate proportions of the public forest and park land were primary and secondary habitat, almost all of the private land was ecological trap or non-critical habitat, with over 50% of the landscape composed of ecological traps at night when grizzly bears were most active in this area (Boyce et al., 2010; Chapter 2). Predictably, almost all successful management trapping efforts occurred at night during the time period examined.

The presence of ecological traps (Dwernychuk and Boag, 1972) is a conservation concern. The most-selected habitats also were the most dangerous, and there was little secure habitat. During the day bears are largely inactive (Chapter 2) and spend much of the time bedding. The public forests and more secluded and forested areas of the private land might offer some security for bears during the day. However, the majority of activity appears to be occurring at night on private land, which appears to be an ecological trap. While conflicts were rare, considering the amount of time bears spent on the private land, the risk of conflict is high, and throughout the lifetime of a bear, they likely are faced with a high potential of coming into conflict with humans.

The conflicts occurring in southwestern Alberta potentially affect a large proportion of grizzly bears in this area, where the population is estimated to be 51 bears (Alberta Grizzly Bear Inventory Team, 2007). On average 5.4 bears were captured and 4.9 bears were relocated, translocated, or removed each year. While not analogous to an actual mortality, capture can be stressful and potentially injurious for grizzly bears, and can decrease movements for several weeks (Cattet et al., 2008). Additionally, bears that have been relocated or have management actions taken against them are more likely to come into conflict again or to die (Riley et al., 1994; Blanchard and Knight, 1995; Linnell et al., 1997).

Nearly one third of the bears involved in captures were females. Animal populations often are more sensitive to fluctuations of certain vital rates, or losses of specific age classes (Crouse et al. 1987; Brault and Caswell 1993), and long-lived animals are most sensitive to losses of adults (Meyers and Boyce 1994). There is evidence that grizzly bear populations are most sensitive to losses of adult females (Knight and Eberhardt 1985, Boyce et al. 2001). Furthermore, the highest incidence of captures took place during September and October when nutritional needs were greatest as bears acquire resources for denning. These numbers indicate that potentially a large proportion of the population is coming into conflict with humans, and the fact that female bears are part of this conflict population is a management concern. Alberta recently ha listed grizzly bears as a threatened species, with a reduction of bear-human conflicts highlighted as an important step towards recovery (Alberta Sustainable Resource Development, 2008). These conflicts obviously have negative implications for bears, but raise concerns over human safety as well.

5. CONCLUSIONS AND IMPLICATIONS

The above issues highlight the need for management to reduce the potential for bear-human conflict in areas that are attractive to the bears. In other jurisdictions where similar problems have arisen, removal of attractants has reduced the number of conflicts substantially (Madel, 2008). Similar work is underway in our study area to remove dead livestock, install bear-proof garbage bins, and secure grain bins. In a study that complements our analysis, Wilson et al. (2005; 2006) generated maps of the probability of conflict related to known locations of specific attractants. Our analysis links these causes of conflicts with patterns of grizzly bear habitat selection to provide habitat-specific maps of conflict risk. Managers and conservationists should examine these two approaches collectively. By working with private landowners to map attractants such as boneyards, grain bins and bee hives, managers could use this dual approach to pinpoint critical areas for management action; those areas in the best habitat with the highest potential for conflict, and with known attractants. These methods can be used to reduce current conflicts, but also to reduce the risk of new conflict in areas where bear populations might be expanding.

Managing attractants is not a new idea, but is difficult on private lands where management agencies have less authority. In these cases, grassroots movements are the most likely to succeed, and these should be encouraged and supported by government agencies interested in managing and conserving grizzly bear populations. Such efforts could reduce the risk to grizzly bears, thus restoring some of the best perceived habitat from ecological traps.

Table 4-1. Criteria used to assign a confidence level to Fish and Wildlife occurrence reports involving grizzly bears. Confidence refers to the likelihood of the conflict involving a grizzly bear as opposed to a black bear.

Confidence	Criteria
Not grizzly	No mention of grizzly bear, OR, complainant believes was a black bear, OR, investigated by Fish and Wildlife personnel and deemed not to be a grizzly bear
Very low	No witness to conflict and complainant claims is a grizzly, OR, complainant or immediate family are only people to witness the conflict. Claim the animal involved is a grizzly but is not confident. Officer does not investigate or investigation reveals no new evidence
Low	Complainant or immediate family are only people to witness the conflict. Came into close proximity with bear or are adamant that animal involved is a grizzly. Officer does not investigate or investigation reveals no new evidence
Moderate	Several people report conflict, and state that animal involved is a grizzly, OR complainant reports as a grizzly and in officer's report it is confirmed as a bear, though the officer provides no information on the species, OR positive VHF telemetry of a grizzly bear in the area
Confident	Bear or tracks seen by officer and confirmed as a grizzly, OR predation on livestock by grizzly confirmed by officer, OR GPS telemetry data indicates grizzly bear in the area at the time of the conflict
Certain	Grizzly bear captured by SRD staff OR destroyed

Table 4-2. Covariates used in models of conflict risk and resource selection functions (RSF). All variables were calculated at a 30 × 30 m cell size. For conflict model these were averaged across the quarter section unless otherwise noted.

Variable	Description	Model
d_facil	Distance to nearest natural gas facility	Conflict
d_wells	Distance to nearest natural gas well	Conflict
facil	Dummy variable indicating if there was a natural gas facility in the quarter section	Conflict
wells	Dummy variable indicating if there was a natural gas well in the quarter section	Conflict
num_facil	Number of natural gas facilities in the quarter section	Conflict
num_well	Number of natural gas wells in the quarter section	Conflict
house	Dummy variable indicating if there was a house in the quarter section	Conflict
num_house	Number of houses in the quarter section	Conflict
d_house	Distance to nearest house	Conflict
d_prot	Distance to protected areas	Conflict
d_public	Distance to non-park public land	Conflict
Private	Distance to private land	Conflict
Park	Dummy variable indicating if the quarter section lay predominantly in National or Provincial Parks	Conflict
d_stream	Distance to streams	Conflict
perc_rip	Percent of quarter section within 100 m of streams	Conflict
d_rds	Distance to nearest road	Conflict
ln_d_rds	Natural log transformed distance to nearest road	Conflict
den_rds	Density or roads calculated with a 6 km radius moving window	Conflict
perc_rds	Percent of quarter section within 500 m of roads	Conflict
den_cut	Density of cutlines	Conflict
d_low[a]	Distance to nearest low-volume road (Chapter 2)	Conflict
d_med[a]	Distance to nearest medium-volume road (Chapter 2)	Conflict
d_high[a]	Distance to nearest high-volume road (Chapter 2)	Conflict
dens_traff[a]	Density of roads of different traffic volumes	
slope	Calculated from 30 m digital elevation model	Conflict
ag_type	Categorical variable indicating the type of agriculture in the quarter section (Collingwood et al. 2009)	Conflict

tree × *slope*	Interaction term between *slope* and *tree*	Conflict
herb × *slope*	Interaction term between *slope* and *herb*	Conflict
tree	Dummy variable indicating if the dominant land-cover type was treed (Franklin et al. 2001)	Conflict
herb	Dummy variable indicating if the dominant land-cover type was herbaceous (Franklin et al. 2001)	Both
shrub	Dummy variable indicating if the dominant land-cover type was shrub (Franklin et al. 2001)	Both
ln_d_stream	Natural log transformed distance to streams	Both
canopy	Canopy cover	Both
agric	Dummy variable indicating if there was agricultural land in the quarter section (Collingwood et al. 2009)	Both
CTI	Compound topographic index (Nielsen et al. 2004)	Both
TRI	Terrain ruggedness index (Nielsen et al. 2004)	Both
ln_d_house	Natural log distance to houses	RSF
d_ cut	Distance to cutlines or trails	RSF
NDVI	Normalized difference vegetation index (Townshend and Justice 1988)	RSF
d_edge_int	Distance to edges from within treed habitat	RSF
d_edge_ext	Distance to edges from within non-treed habitat	RSF
ln_d_low	Natural log distance to low volume roads (Chapter 2)	RSF
ln_d_med	Natural log distance to medium volume roads (Chapter 2)	RSF
ln_d_high	Natural log distance to high volume roads (Chapter 2)	RSF
cutblock	Dummy variable for if a location was in forest < 100 years old	RSF
elev	Elevation from Digital elevation model	RSF
amel	Dummy variable indicating presence or absence of *Amelanchier alnifolia* (Appendix A)	RSF
Vacc	Dummy variable indicating presence or absence of *Vaccinium* spp. (Appendix A)	RSF
shep	Dummy variable indicating presence or absence of *Shepherdia canadensis* (Appendix A)	RSF
herac	Dummy variable indicating presence or absence of *Heracleum maximum* (Appendix A)	RSF
equis	Dummy variable indicating presence or absence of *Equisetum* spp. (Appendix A)	RSF
tarax	Dummy variable indicating presence or absence of *Taraxacum* spp. (Appendix A)	RSF
d_cut × *private*	Interaction term between *d_cut* and *private*	RSF
herb × *elev*	Interaction term between *herb* and *elev*	RSF

[a]Separate variables used for three time periods defined in Chapter 2: weekend day, weekday day, and night

Table 4-3. Variables used in habitat-selection models for individual grizzly bears, and coefficients and standard errors (SE) of best averaged night and day RSFs for 12 grizzly bears in southwestern Alberta. Coefficients were averaged across individual models with a coefficient of 0 used for models not containing a specific variable (Fieberg *et al*. 2010).

Covariate[a]	Night Avg. Coeff.	SE	Day Avg. Coeff.	SE
ln_d_house	-0.2353	0.1083	-0.1922	0.2301
d_ cut	-0.19[b]	0.1715	0.041[p]	0.6204
ln_d_stream	-0.0611	0.0211	-0.0359	0.0229
canopy	8.64E-4	0.0027	0.01177	0.0043
agric	-0.0852	0.0354	-0.2489	0.0894
NDVI	-6.1E-05	4.35E-05	-8.7E-05	3.78E-5
d_edge_int	-1.0[b]	0.3544	-0.065[b]	0.3947
d_edge_ext	-2.9[b]	1.2284	-1.7[b]	1.5140
ln_d_low	0.0722	0.0441	0.1177	0.0524
ln_d_med	0.1874	0.1048	0.4025	0.1014
ln_d_high	0.2464	0.0985	0.1871	0.1157
cutblock	0.124	0.1800	0.4124	0.2160
elev	-4.2E-4	4.65E-4	-0.0015	0.0010
TRI	0.124	0.0045	-0.0051	0.0042
herb	-0.675	0.8726	-1.565	0.6843
shrub	-0.2433	0.1810	0.1508	0.1686
herb × *elev*	4.45E-4	6.07E-4	0.0011	0.0005
d_cut × *private*	-0.11[b]	4.25E-4	- 0.99[b]	0.0011
amel	0.0183	0.0931	-0.2167	0.1816
vacc	-0.1029	0.1448	0.0151	0.1985
shep	-0.0872	0.131	-0.0905	0.1647
herac	0.0046	0.0629	0.4367	0.1890
equis	0.0781	0.2031	0.0357	0.1924
tarax	0.0534	0.1151	-0.4881	0.2241
CTI	-0.0106	0.0319	-	0.2301

[a]Variables defined in Table 4-2. [b]Coefficients multiplied by 1000.

Table 4-4. Definitions of habitat states relative to RSF and conflict-risk maps, percent of landscape comprised of each habitat states by night and day, in public forests, private land, and parks, as derived from combinations of conflict-risk maps and habitat selection maps for grizzly bears in southwestern Alberta. Non-critical habitat does not imply that bears did not select these areas, but rather that they were selected rarely.

Habitat State	RSF	Risk	Night				Day			
			all	park	public	private	all	park	public	private
Non-critical	<5	-	60	82	81	36	54	52	49	59
2° trap	5-7	>5	15	2	2	31	12	2	4	20
2° habitat	5-7	≤5	10	27	14	6	18	12	29	5
1° trap	>7	>5	12	2	0.5	25	7	1	2	13
1° habitat	>7	≤5	3	16	2	3	10	2	15	3

Table 4-5. Number of conflicts, bears captured, recaptured, removed, females captured, and conflicts related to dead cattle (cattle) by year for 285 grizzly-bear human conflicts between 1999 and 2008.

Year	Conflicts	Capture	Recapture	Removed[a]	Females captured	Cattle
1999	15	5	2	5	3	4
2000	19	5	1	4	0	3
2001	21	2	1	2	0	6
2002	23	6	1	6	4	5
2003	14	3	0	2	0	2
2004	28	8	1	7	4	5
2005	38	3	1	3	2	11
2006	38	3	1	1	1	6
2007	49	11	1	11	0	10
2008	40	8	3	8	3	21
Total	285	54	12	49	17	73

[a]Represents number of bears translocated, relocated, or destroyed.

Table 4-6. Coefficients and standard errors (SE) of conflict risk model for grizzly bear-human conflicts between 1999 and 2009 in southwestern Alberta calculated at a cell size of 16 ha (quarter section). Covariates were calculated at a cell size of 30 × 30 m and averaged across the entire quarter section unless otherwise noted.

Covariate[a]	Coefficient	SE
slope	-0.032	0.022
d_facil	0.0425[d]	6.87E-3[d,e]
private	0.66	0.26[e]
house	1.18	0.18[e]
tree	0.97	0.25[e]
tree × *slope*	-0.13	0.04[e]
dens_cut	0.66	0.19[e]
dens_high_wed[b]	-2.31	0.86[e]
d_med_wdd[c]	0.385[d]	0.177[d,e]
intercept	-3.08	0.42[e]

[a]See Table 4-2 for definitions unless otherwise notes. [b]Density of roads classified as high-volume on weekends. [c]Distance to roads classified as medium-volume on weekdays (Chapter 2). [d]Coefficients and standard errors multiplied by 1000. [e]Indicates 90% confidence intervals that do not overlap 0.

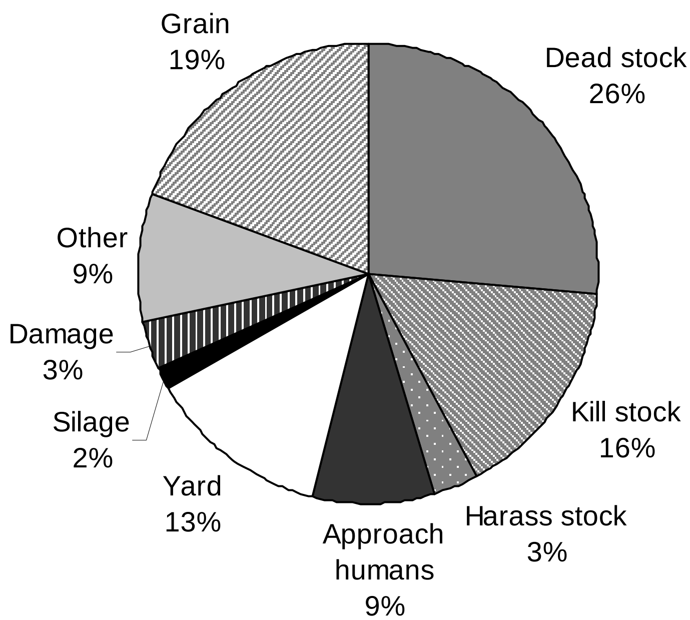

Figure 4-1. Percent of conflicts by cause of conflict for 314 incidents between 1999 and 2009. Other indicates other attractants, damage indicates damage to personal property and yard indicates a bear in the yard of a private residence.

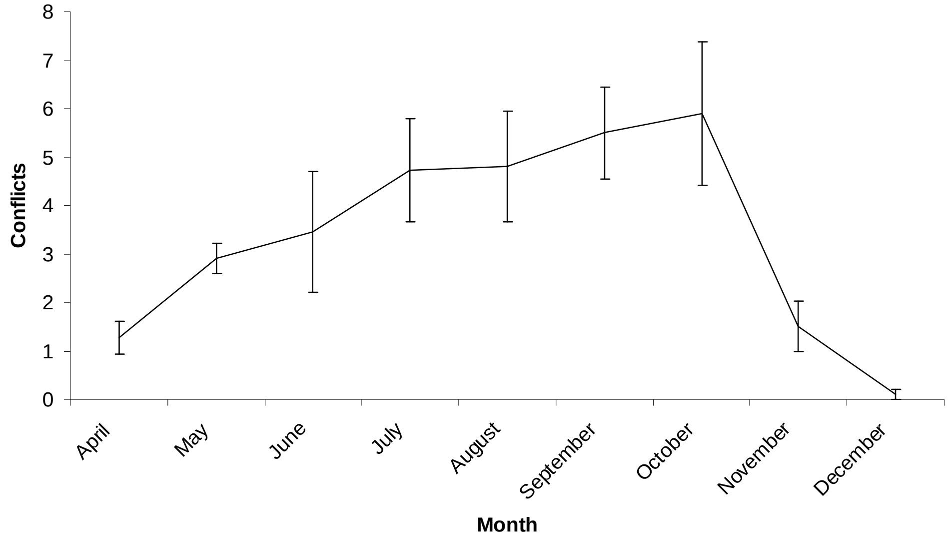

Figure 4-2. Mean and standard error of grizzly bear conflicts by month between April 1999 and August 2009 in southwestern Alberta. No conflicts have been reported for January, February or March when bears are denning.

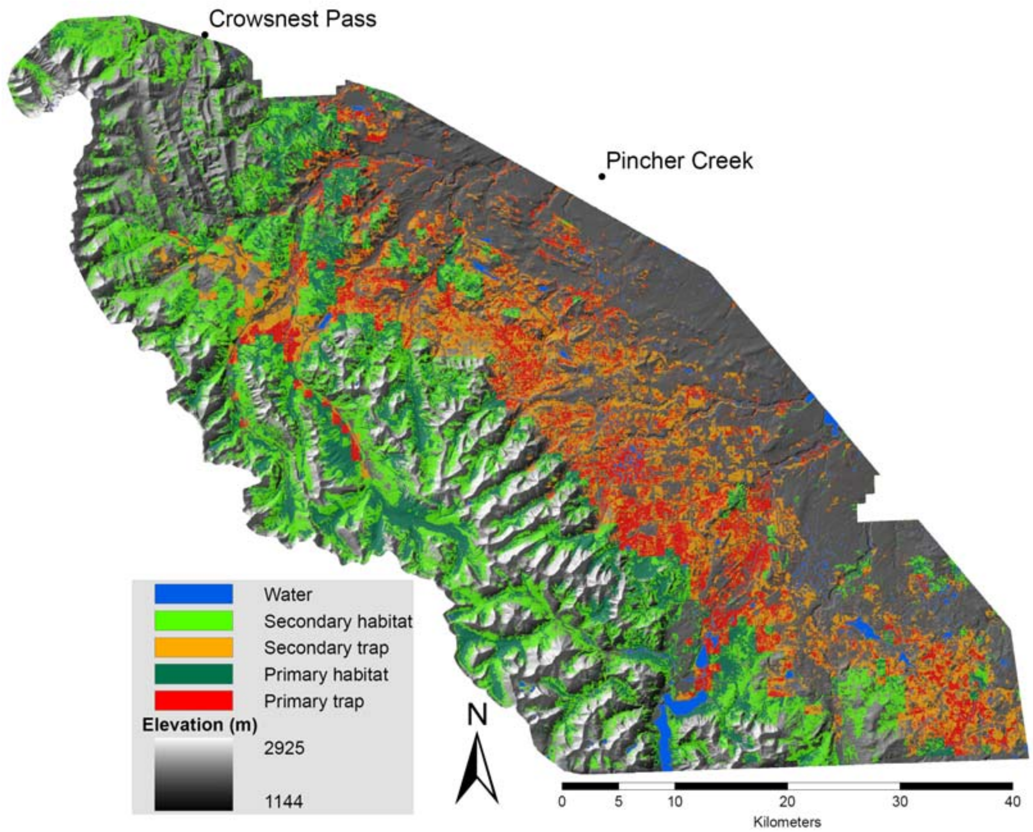

Figure 4-3. Day time habitat states for grizzly bears in southwestern Alberta, calculated from maps of conflict risk and habitat selection. Non-critical habitat is colourless to allow for elevation gradient to be displayed.

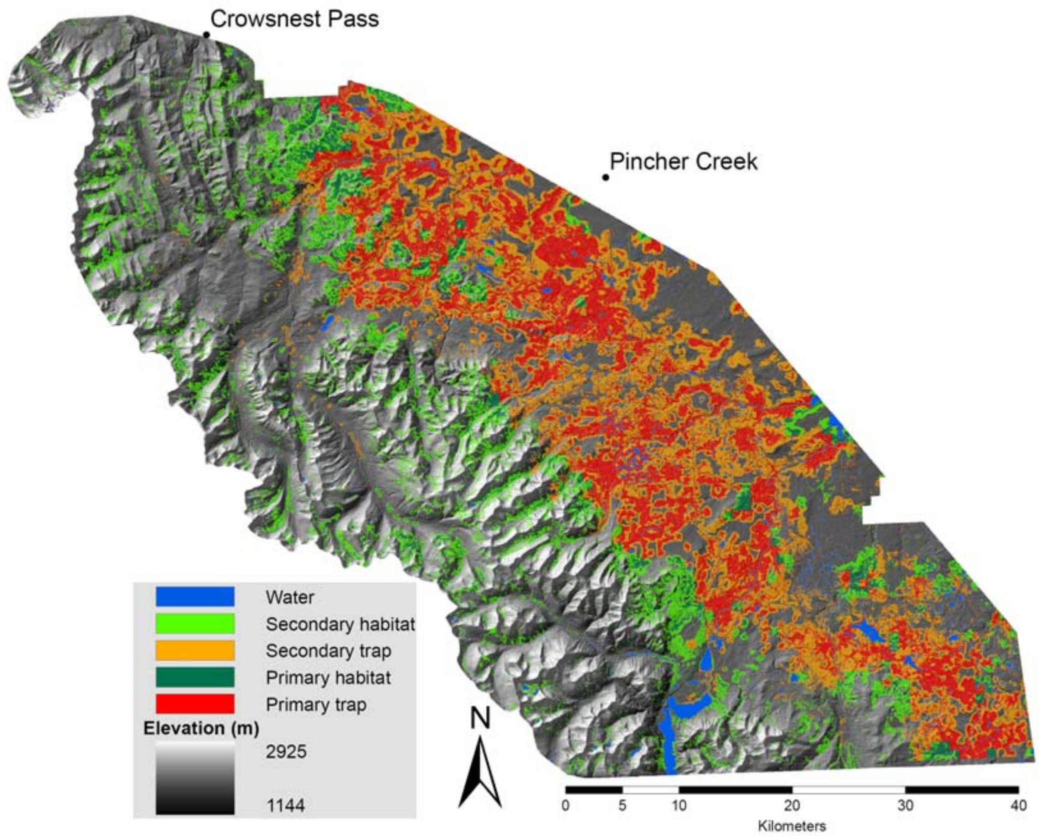

Figure 4-4. Night time habitat states for grizzly bears in southwestern Alberta, calculated from maps of conflict risk and habitat selection. Non-critical habitat is colourless to allow for elevation gradient to be displayed.

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CHAPTER 5

GENERAL CONCLUSION

Grizzly bear habitat selection near roads is confounded by human use and by the foods and habitats associated with the roads. Understanding these confounding factors is important if we are to conserve grizzly bears because most bear mortalities occur near roads and might constitute ecological traps (Benn and Herrero 2002, Nielsen et al. 2004, Nielsen et al. 2006). Access management has been used to reduce grizzly bear mortalities in the United States, with great success (Interagency Conservation Strategy Team 2007). However, this strategy is expected to be contentious in Alberta where a diverse set of stakeholders use roads and trails along the east slopes of the Rocky Mountains. Thus, access management gains will be hard fought and need to be implemented with the best available science.

In this thesis I attempt to clarify some of the confounding factors associated with bear use of areas near roads, in an attempt to better inform access management. I estimated models predicting motorized human use of roads and trails in southwestern Alberta and examined grizzly bear selection of areas near roads in relation to traffic (Chapter 2). This analysis established potential traffic volume thresholds below which grizzly bears would make use of roadsides.

Traffic volume clearly is an important factor influencing grizzly bear habitat selection near roads. This idea has been examined in past studies (Mace et al. 1996, Waller and Servheen 2005, Roever et al. 2010), though I am the first to develop a statistically rigorous fine-scale model of motorized human use in bear habitat. My results are congruent with these past studies that used less precise methods to group roads into traffic-volume classes. This finding indicates that managers and conservationists should take traffic volume into account when implementing access management strategies. If roads are closed, but traffic volumes remain high, grizzly bears likely will avoid the areas near these roads. While avoidance of these roads will not influence the risk of mortality, closed roads in essence should be considered secure habitat, as long as there is enforcement and compliance, and should be managed in a way that bears might make use of them. However, information on food availability should be taken into account when examining these factors. This idea was the focus of my third chapter.

In Chapter 3 I examined habitat selection in relation to the presence or absence of foods, obtained from maps predicting food occurrence developed in Appendix A, along with landscape characteristics and vehicular traffic. In this analysis, roads and road traffic were less important to overall habitat selection patterns of grizzly bears. However when near roads, all bears selected to be near roads classified as low-volume. Beyond this selection for low-volume roads variation in selection for foods among individuals dominated, with some consistent selection for coarse landscape characteristics such as the distance to streams and land-cover variables.

Even when accounting for the presence of foods and other habitat characteristics, traffic is important for grizzly bear habitat selection when near roads. Beyond this finding, I documented large variation in habitat selection patterns among bears. This variation might be due to differences in annual and seasonal food abundance, as well differences in age and sex classes of bears. Another explanation is variation in the innate habitat selection patterns of individual bears, from either differences in personalities (Wolf et al. 2007) or through specialization on food different food resources. Grizzly bear and black bear diets have been shown to vary widely among individuals (Robichaud and Boyce 2010). This information coupled with the fact that bears were selecting foods and habitat differently from one another regardless of availability in this study give support to the possibility that this variation in habitat selection patterns is at the individual level. Individual variation in habitat selection is consistent with density-dependent natural selection, allowing for individuals to produce more offspring in an environment that might be at carrying capacity (Boyce 1984, Bolnick et al. 2003).

Regardless of the source of the individual variation, whether it is from specialization (Bolnick et al. 2003), personality differences (Wolf et al. 2007) or from differences among age and sex classes, managers might need to account for variation when planning access management. Individual bears likely will be affected differently by road closures. Bears that are more willing to use roadsides will experience increased security, while bears that avoid roads, especially higher-traffic volume roads, will enjoy increased realized habitat size. Regardless, access management will at worst have a neutral effect on grizzly bears, and at best provide improved habitat security and a greater amount of realized habitat.

Despite the ample variation I documented, managers should take habitat characteristics and food resources into account when implementing access management. Understanding the distribution of important bear foods in relation to roads will allow for more informed access management. This information should be coupled with traffic volume patterns to make the most informed decision on access management. Roads with low traffic-volume and a high density of bear foods will be good candidates for access management because they will be areas that bears might already be using, thus eliminating any adjustment period. While mortality risk may be higher around roads with higher traffic-volumes, closures of these roads might be more difficult and compliance lower.

In chapter 4, I examined how roads and road traffic influenced the presence of ecological traps for grizzly bears. Although cut lines and trails were important predictors of conflict, roads themselves were not. Strikingly, more than half of the private land in this study area appeared to be an ecological trap, with little secure habitat. Though these patterns are not directly related to roads, one of the greatest discrepancies between the public and private land in this area was the amount of road access and the traffic on the roads. (Chapter 2). Private lands had the lowest traffic volumes, and bears selected these areas frequently at night, with little regard for roads. Thus access management in this area might have the potential to increase realized habitat size on public lands, potentially decreasing the time that bears spend in the apparent ecological trap of the private land. However, this strategy should be linked with attractant management, which will decrease bear-human conflicts as well as the perceived attractiveness of the private lands. Grizzly bears in this area will continue to come into conflict with people until the attractant situation is under control and bears are no longer able to find large sources of protein and other nutrients near human habitations.

Grizzly bear conservation is closely linked to roads and human use of roads. The most effective means to ensure persistence of grizzly bears is to reduce human-caused mortalities by keeping densities of open roads low. However the public lands of Alberta are multi-use lands and roads are often necessary to access timber, mineral, and energy resources. Provided road densities are not excessive (>0.6 km/km^2 in core grizzly bear habitat, Mace et al. 1996, Alberta Grizzly Bear Recovery Team, 2008) gated access management is a good option to limit the effects of roads on grizzly bears. For access management to be successful, my results indicate that industrial road traffic behind gates should be kept below 20 vehicles per day and gates must remain in perpetuity or, ideally, roads no longer in use by industry should be reclaimed. Bears might become habituated to low-traffic volumes, creating potentially hazardous situations when roads are reopened. This potential highlights the need for consistent enforcement to ensure that the public complies with road closures. A lack of compliance could lead to bear-human conflicts on roads that have been closed but where the public manages to find a way around gates. Future work on access management should focus on understanding the relationship between mortality and traffic volume. While I have shown a link between habitat selection and human use, this does not translate to a direct understanding of how differences in human use might influence grizzly bear mortalities. The traffic volume of 20 vehicles per day likely is directly applicable to this study area only and should not be broadly applied to other areas.

In the face of the large individual variation among bears, there must be increased monitoring to better understand the efficacy of management decisions. Ultimately, bears, industrial and recreational interests all can be accommodated along Alberta's east slopes as long as access management is used to reduce impacts and improve habitat for bears. Furthermore, in areas of high bear-human conflict, methods will be needed to reduce conflicts by eliminating attractants and enhancing education.

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APPENDIX A

MODELLING THE OCURRENCE OF GRIZZLY BEAR FOODS

1. PURPOSE

Grizzly bear selection of areas near roads is confounded by the foods near roads. Bears have high nutritional needs and food occurrence is an important predictor of habitat selection (Munro *et al.*, 2006; Nielsen *et al.*, 2010). Some preferred bear foods occur disproportionately near roads, and in clear cuts, which often are associated with roads (Nielsen *et al*, 2002; Roever, Boyce and Stenhouse, 2008). Thus the presence of foods near roads could influence the selection or avoidance of these areas by grizzly bears. We developed models predicting the presence or absence of known grizzly bear foods in our study area for use in modelling habitat selection in relation to roads.

2. METHODS

In 2008, 7 grizzly bears (4 adult males, 2 females with cubs and one sub-adult female) were captured using helicopter, culvert traps and foot snares, and immobilized following Cattet *et al*. (2003). Bears were collared with Televilt Tellus II (Televilt Ltd., Lindesberg, Sweden) geographic positioning system (GPS) radiocollars with remote upload capabilities set to obtain relocations once per hour. Between 2008 and 2009 we remotely uploaded global positioning system (GPS) radiotelemetry locations from a subset of 5 grizzly bears and visited more than 200 of these locations. For each, location, we visited a point located 300 m from the used point in a random cardinal direction. We thoroughly searched a 30 × 30-m area around each used and random point and documented the presence or absence of known grizzly bear foods at each location (Hamer & Herrero, 1987; Hamer, Herrero, & Brady, 1991; Munro *et al.* 2006; Roever, Boyce & Stenhouse, 2008; Nielsen *et al.*, 2010; Table A-1). We documented the presence or absence of animal carcasses at all locations, though found too few to estimate predictive models of occurrence. To determine the foods that grizzly bears were selecting we used conditional logistic regression to compare the occurrence of foods at used sites relative to random locations. Coefficients for food variables with 90% confidence intervals that did not overlap 0 were chosen for further use in our analysis (Table A-1). We added to these a set of food items known to be important predictors of grizzly bear habitat selection in West Central Alberta (Nielsen *et al.* 2002; Munro *et al.* 2006; Nielsen *et al.* 2010; Table A-2).

We used logistic regression in a presence-absence design to predict the probability of the presence of food items (Table A-2). Fifteen *a priori* variables were selected that we hypothesized would influence the occurrence of grizzly bear foods (Table A-3). We fit global models and removed variables for which the 90% confidence intervals overlapped 0 to obtain a final model (Hosmer and Lemeshow 2000). We determined model accuracy using receiver operating characteristics (ROC) area under the curve (AUC) with models only used for further analysis if they had good or better accuracy (AUC >0.7; Swets 1988; Manel, Williams & Ormerod, 2001). For models with AUC >0.7 we calculated the cut-off probability corresponding to the minimum absolute difference between sensitivity and specificity values to determine if a food was present or absent (Liu *et al*. 2005). We mapped the probability of occurrence for each food item, and reclassified these maps to binary presence-absence (1 or 0) maps using the determined cut-off values in ArcMap 9.2 (Environmental Systems Research Institute Inc (ESRI), Redlands, CA).

Six food items had an AUC greater than 0.7 indicating the models had good predictive ability (Table A-2). These food items were used for modelling habitat selection.

Table A-1. List of known grizzly bear foods found at sites with recorded bear presence and randomly selected sites in southwestern Alberta. Used sites were uploaded from GPS radiocollars on 5 grizzly bears. Random locations were located 300 m in a random cardinal direction from each used site.

Latin name	Common name
Amelanchier alnifolia Nutt.	Saskatoon berry
Apiaceae	Carrot family
Arctostaphylos uva-ursi (L.) Spreng.	Kinnikinnick; bearberry
Equisetum spp. L.	Horsetail
Erythronium grandiflorum Pursh.	Yellow avalanche-lily
Fragaria spp. L.	Strawberry
Hedysarum spp. L.	Sweet vetch
Heracleum maximum Bartram	Cow parsnip
Hymenoptera spp.	Ants, yellow jackets
Lathyrus spp. L.	Pea vine
Lonicera spp. L.	Honeysuckle
Medicago spp. L.	Alfalfa
Prunus spp. L.	Plum
Ribes spp. L.	Currant
Rosa acicularis Lindl.	Prickly rose
Rubus spp. L.	Blackberry
Sambucus racemosa L.	Elderberry
Shepherdia canadensis (L.) Nutt.	Buffalo berry
Sorbus spp. L.	Mountain ash
Taraxacum spp. F.H. Wigg.	Dandelion
Trifolium spp. L.	Clover
Vaccinium spp. L.	Huckleberry, blueberry, grouseberry
Valeriana spp. L.	Valerian
Xerophyllum tenax (Pursh) Nutt.	Common beargrass

Table A-2. Plants predicting habitat selection by bears in west central Alberta, or found in used sites more often relative to random sites in southwestern Alberta, seasons used, common name, and AUC of logistic regression models used to predict occurrence from presence-absence data collected at paired random and used grizzly bear locations from 5 grizzly bears equipped with GPS radiocollars in southwestern Alberta.

Latin name	Common name	Season	AUC
Shepherdia canadensis (L.) Nutt.	Buffalo berry	Fall	0.76
Amelanchier alnifolia Nutt.	Saskatoon berry	Fall	0.73
Hedysarum spp. L.	Sweet vetch	Fall/Spring	<0.7
Heracleum maximum Bartram	Cow parsnip	Summer	0.71
Equisetum spp. L.	Horsetail	Summer	0.79
Taraxacum spp. F.H. Wigg.	Dandelion	Summer	0.79
Vaccinium spp. L.	Huckleberry	Fall	0.84
Hymenoptera spp.	Ants	Fall/Spring	<0.7

Table A-3. Variables and signs of coefficients from best models predicting occurrence of 6 bear foods in southwestern Alberta. A 0 indicates a variable that did not appear in the model for the respective food. See Table A-2 for description of bear foods.

Variable	Grizzly bear food item					
	Vaccinium spp.	*Amelanchier alnifolia*	*Shepherdia canadensis*	*Heracleum maximum*	*Equisteum* spp.	*Taraxacum* spp.
age[a]	+	+	+	-	-	0
perc_con[b]	+	0	+	+	+	-
NDVI[c]	0	0	0	+	+	0
herb[d]	0	0	-	+	0	-
valley[e]	0	0	+	-	+	0
gentle_slope[e]	0	-	+	0	+	0
steep_slope[e]	0	0	0	0	-	0
SRI[f]	0	+	0	-		0
CTI[g]	0	-	-	0	+	0
elev[h]	+	0	0	0	-	-
d_edg_ext[i]	0	-	0	-	-	0
d_edg_int[j]	0	-	0	0	0	0
d_cut[k]	-	0	0	0	0	-
perc_con × *elev*	0	0	0	-	-	0
age × *elev*	-	-	0	+	+	0

[a]Forest age. [b]Percent conifer forest in cell. [c]Normalized difference vegetation index (Townshend and Justice 1986). [d]Herbaceous land-cover (Franklin et al. 2001). [e]Narrow valley, gentle slope and steep slope calculated from 30 m digital elevation model (DEM) using the topographic position index extension for ArcView 3.2 (Jenness Enterprises, Flagstaff, Arizona). [f]Solar radiation index (Nielsen et al. 2004). [g]Compound topographic index (Nielsen et al. 2004). [h]Elevation from a 30 m DEM. [i]Distance to forest edge from tree land-cover. [j]Distance to forest edge from non-treed land-cover. [k]Distance to cutlines and trails

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