THE IMPACTS OF TRANSPORTATION CORRIDORS ON GRIZZLY AND BLACK

BEAR HABITAT USE PATTERNS NEAR GOLDEN, B.C.

by

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ABSTRACT

The focus of the study was on the influence of transportation corridors (T-corridors), which included the Trans-Canada Highway (TCH), Canadian Pacific Railway, and Highway 95, on the distribution and habitat use patterns of black and grizzly bears near Golden, B.C. The relationship among bears, habitat, and T-corridors was examined using compositional analysis and univariate comparisons in conjunction with a Geographic Information System. During 1994-1997, 40 radio collared grizzly and 24 radio collared black bears were located 1061 and 505 times, respectively. Because the T-corridors followed major valleys and crossed a mountain pass where slide chutes and riparian areas predominated, I expected bears to be displaced from these habitat types during spring. During spring, 85% of all collared grizzly bears used areas adjacent to T-corridors less than expected by random use. The habitat analysis further revealed that although slide chutes were selected the majority of bears selected chutes adjacent to corridors less than expected, however, 15% of the radio collared individuals used slide chutes adjacent to T-corridors more than expected. These bears were all among those trapped within a home range radius of the T-corridors and only one of these 6 bears was an adult female. Eighty-eight percent of collared black bears used areas within 500 m of the corridors during the spring. At this time both male and female black bears selected right-of ways and timbered areas more than expected. Use of the rights-of-way increased the black bears' risk of mortality. To reduce mortality of black bear and return bears to a more natural diet, vegetation along the rights-of-way should be replaced with less palatable plant species. Because of the potential for habitat and population fragmentation among the grizzly bears, areas where bears cross the corridors should be identified before

the TCH is twinned. If possible, portions of the highway that contain such crossing areas should be protected from further development. If development must proceed, areas along the TCH which have the potential to act as crossing-underpasses for bears should be enhanced to encourage bear use and improve conductivity.

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Ring the bells that still can ring
Forget your perfect offerings
There is a crack in everything
That's how the light gets in
                    Leonard Cohen, 1991

INTRODUCTION

Rapid human population growth and resulting habitat changes have had dramatic impacts on wildlife. This trend is particularly true for large mammals that require vast land areas to maintain viable populations (Noss et al. 1996). Bears, in particular, face an uncertain future in a rapidly changing world. Throughout the world, the elimination of bears from 50-75% of their historic range has already occurred, and the status of six of the eight species of bears was worse in 1990 than in 1970 (Servheen 1990). Only the American black bear (*Ursus americanus*) and the polar bear (*Ursus maritimus*) are considered stable (Servheen 1990).

The brown or grizzly bear (*Ursus arctos*) used to occupy a wide range of habitats and had one of the largest distributions of any large terrestrial mammal (Nowak and Paradiso 1983). Once found across most of Asia, Europe, and the Atlas Mountains of northwestern Africa, the brown bear has largely been extirpated in the southern and western regions of its former range in Eurasia. The remaining European populations are now small and restricted to remote isolated islands of forested habitat (Servheen 1990).

In North America, the historic range of the grizzly bear encompassed most of western Canada and the United States. The grizzly bear population in the conterminous U.S. is still estimated to be < 1000 and remains a high management priority (Servheen 1990). Even in British Columbia, where the grizzly bear still occurs in relative abundance, its distribution is largely restricted to remote and mountainous locations (Banci 1991).

The geographic range of the American black bear has also receded, although the decline has been less dramatic than that of the grizzly bear. Originally widespread

throughout the forested regions of the continent, black bear populations today are more scattered and isolated. The most dramatic reduction in black bear distribution occurred in the eastern U.S. where bears must contend with high human densities (Schoen 1990). This species has been extirpated from most of Alabama, Kentucky, Ohio, and Illinois (Pelton 1982). It has been suggested that in some areas the black bear has benefited, at least over the short term, from the density of people through the creation of bears foods primarily as a result of timber harvesting practices (Manville 1983, Lindzey et al. 1986, Young and Beecham 1986, Garner and Vaughan 1987).

The reduction and fragmentation in bear distribution has been primarily attributed to unsustainable mortality rates combined with incremental habitat loss and habitat alienation (Servheen 1990). As human populations expand, associated impacts will increase and result in further fragmentation of bear populations. Fragmentation results from a culmination of individual factors that affect bear movement and habitat use patterns. Factors influencing fragmentation of bear populations remain poorly understood. The significance of roads toward fragmenting bear populations has been discussed in the literature but little empirical evidence has been presented. Numerous studies show that both grizzly and black bears are displaced from habitats adjacent to roads, although the degree of displacement varies among areas. McLellan and Shackleton (1988), demonstrated spring habitats within 100 m of the road were used significantly less than expected, by random, by grizzly bears in the north fork of the Flathead River drainage, representing a loss of 8.7% of the area available to bears. These finding are supported by Mace and Manley (1992) in the south fork of the Flathead river. In the East Front Grizzly Bear study, Aune and Kasworm (1989) found that grizzly bears avoided

areas up to 300 m from roads while black bears avoided areas within 100 m. It has also been demonstrated in Montana that grizzly bears prefer areas with lower road densities (Mace et al. 1996). Similarly, black bears in the North Carolina's Pisgah National forest strongly avoided high traffic volume roads as the density of these roads in their home range increased (Brody and Pelton 1989). Other studies found the extent to which bears avoided roads was a function of traffic volume (Carr and Pelton 1984, Brody and Pelton 1989, Beringer et al. 1990, Clark 1991, Lombardo 1993), roadside cover (Hugie 1982, Seibert 1989, Lombardo 1993), sex of the bear (Brown 1980, Young and Beecham 1986), season (Hellgren 1988, Kasworm and Manley 1990, Clark 1991), food abundance along the road (Hardy 1974, Garner 1986, Hellgren 1988, Clark 1991), time of day (McLellan and Shackleton 1988), and human activity along roads (Hamilton 1978, Garner 1986, Seibert 1989, Regan 1991).

In addition to displacement, mortality associated with road and railway corridors is probably the most important factor that contributes to population fragmentation. Mortality acts as a filter to animal movement. Bears face a high risk of mortality from humans or vehicles when traveling through roaded landscapes. McLellan and Shackleton (1988) found that roads increased the bears' vulnerability to both legal and illegal hunters by providing ready access and most bears were shot from roads. Gilbert and Wooding (1996) found the major cause of death of tagged black bears in north central Florida was collisions with motor vehicles. In Banff National Park, Alberta, much of the bear mortality on the highway and railway is indirectly attributed to attractants, such as grasses, berries, and forbs, which grow along rights-of-way (Gibeau and Huer 1996). Bears seeking these food sources are more susceptible to vehicle collisions (Gibeau and

Huer 1996). Accidental grain spills and inadequate containment of grain cars on railways

attract bears, as do the carcasses of ungulates killed by trains (Gibeau and Huer 1996).

Although not clearly demonstrated, it has been suggested that roads, and major

highways in particular, may impede bear movement, as has been shown for wolves

(Paquet and Callaghan 1996). Beringer et al. (1990) found that high traffic volume roads

impede black bear movements but do not totally restrict them. They found that bears

crossed such roads significantly less than roads with lower traffic volumes. Two years of

radio-telemetry data indicated that none of the radio-collared sample of female grizzly

bear crossed the Trans-Canada Highway in the Bow Valley (Gibeau and Huer 1996).

It is believed that both black and grizzly bears may be susceptible to habitat

fragmentation, however, research findings suggest that black bears are more resilient than

grizzly bears. Black bears not only have larger litters, shorter interbirth intervals, and

mature at a younger age, but they also show more tolerance to human-associated

disturbances, such as roads and settlements than do grizzly bears (Tietje and Ruff 1983,

Kasworm and Manley 1990). In Montana, black bear use of habitats near roads suggests

that they can tolerate habitat disturbance to a greater extent than grizzly bears (Aune and

Kasworm 1989). Nagy and Russell (1978) suggested that as human encroachment and

habitat disturbances increased in the Swan Hills region of Alberta, black bear densities

increased and grizzly bear densities declined.

For an individual bear, fragmentation can inhibit efficient movements among

important habitats. Regionally, fragmentation can lead to small, isolated populations

surrounded by unsuitable habitat. Not only are island populations more vulnerable to the

negative consequences of demographic, genetic, and environmental stochasticity that can

lead to extirpation (Gilpin and Soulé 1986), but also small islands have an increased edge that often is a population sink (McLellan 1991). Due to their attraction to human foods and garbage, bears are particularly vulnerable to additional fractures where their distribution is already impacted by human presence. Along the southern fringe of bear distribution, human settlement and transportation corridors in valleys and low plateaus are gradually isolating several grizzly bear populations in the US and Canada (McLellan 1991).

Within southeastern B.C., the Trans-Canada Highway (TCH), Highway 95, the Canadian Pacific Railway (CPR), and associated human communities create the potential for large scale and permanent population fragmentation and habitat loss for both bear species. Development associated with these transportation corridors may constitute an irreversible fracture, separating bear populations in the north from those in the south, as well as bear populations in the Columbia Mountains from those in the Rocky Mountains.

In 1994, a research project was initiated to address the effects of transportation corridors (T-corridors) on bear habitat use patterns. I used both univariate and multivariate analysis to explore the habitat selection by both species of bears in a complex area that includes national highways, railways, and communities in both protected and multiple use lands. I tested the null hypothesis that both grizzly and black bears use habitats adjacent to T-corridors as often as they use habitats away from them. I also explored the effect of sex class and season on this pattern of use.

STUDY AREA

The study area is in southeastern British Columbia (51° 18'N, 117° 00'W; Fig. 1).

It is bounded on the west by the Columbia Mountains and by the Rocky Mountains on the

east. Both of these mountain ranges are rugged with peaks reaching 3400 m. The

Columbia River flows north at 760 - 710 m above sea level through the central portion of

the study area in the Rocky Mountain Trench.

The study area is located at a climatic divide; the western part is influenced

mostly by pacific weather systems, whereas the eastern part is influenced more by

continental weather systems (Parish et al. 1996). As a result, the Columbia Mountains

receive greater precipitation and have milder temperatures than the Rockies. The climatic

differences are reflected in two vegetation zones with distinguishing features most

prominent at low to mid-elevations. The interior wet belt covers the Columbia Mountains

and most of the Rocky Mountains north of Golden, B.C. (Parish et al. 1996). In the

interior wet belt, the Interior Cedar-Hemlock (ICH) biogeoclimatic zone is found at lower

elevations where mild temperatures and abundant moisture support western red cedar

(*Thuja plicata*) and western hemlock (*Tsuga heterophylla*). The drier, eastern slopes of

the Columbia Mountains, the Rocky Mountain Trench, and the western slopes of the

southern Rockies are in the East Kootenay vegetation zone (Parish et al. 1996). Here, the

lower elevations are dominated by the Interior Douglas Fir (IDF) that covers a small

proportion of the study area at low elevations south of Golden. Above the IDF is the

Montane Spruce (MS) biogeoclimatic zone that is dominated by logepole pine (*Pinus*

Figure 1. Westslopes study area in south-eastern British Columbia

contorta), hybrid spruce (*Picea glauca* x *engelmannii*) and sub-alpine fir (*Abies lasiocarpa*).

Due to cooler temperatures and a greater snow pack, Engelmann spruce (*Picea engelmanii*) and sub-alpine fir are found at higher elevations (1500 – 2200 m) throughout the study area. Above 2200 m, the Alpine Tundra zone (AT) begins and is vegetated primarily with shrubs, herbs, bryophytes, and lichens, but much of the alpine is rock and ice and lacks vegetation.

Due to the high snowfall, steep terrain, and narrow valleys, slide chutes are common. Slide chutes produce a variety of important bear foods such as glacier lilies (*Erythronium grandiflorum*) and cow parsnip (*Heracleum lanatum;* Mace et al. 1996). There are also some extensive riparian areas, the largest is in the Columbia valley. Riparian areas are important for bears during spring because they often contain succulent forbs (McLellan 1989). As well, high-elevation burns occur in portions of the study area and some produce huckleberries (*Vaccinium* spp), an important summer bear food (McLellan 1989).

The study area is a complex of protected, multiple-use, and private lands (Fig. 2). It is bounded by Glacier National Park in the west and Yoho National Park in the east. Both parks were established in 1886, following the completion of the CPR. The CPR is a high volume (25-35 trains/day) heavy commodity rail link between the west coast and agricultural land on the prairies and eastern Canada. The TCH, completed in 1962, parallels the railway. The TCH is the main transcontinental ground transportation route in Canada, with an average daily traffic volume approaching 10,000 vehicles during

Figure 2. West slopes core study area.

summer. Highway 95 begins in Golden and runs southward down the Rocky Mountain trench.

Although it has much less traffic than the TCH, Highway 95 traffic levels can exceed several hundred vehicles per day. Outside of the National Parks, timber extraction is common and much of the area has an extensive network of forestry roads and young plantations that further fragment the landscape.

Most human settlement is in the Rocky Mountain Trench where the town of Golden (population 5000) and many rural communities are situated. Although development is considerably reduced inside the parks, tourist facilities are common. Park visitor centers, such as Rogers Pass in Glacier Park and Field in Yoho Park, can receive up to 3000 people per day during the summer. Hunting is not permitted in either National Park. However outside these protected areas, a limited number of grizzly bear hunting permits are issued annually and there is a general open season lasting 6 months each year for black bears.

METHODS

Capture and Radio-telemetry

Between 1994-1997, both adult (≥ 5 years) and sub-adult (2-4 years) grizzly and black bears were captured during the spring and fall seasons. Collaring effort was not equal for grizzlies and blacks. Due to their lower numbers, both high and low elevation snare lines were used in combination with darting from helicopter to achieve a consistent sampling throughout the study area for grizzly bears. Conversely, many collared black bears were trapped at lower elevations.

Radio-collared grizzlies were located once a week and radio-collared black bears once every two weeks from a fixed-wing aircraft during daylight. The average aerial telemetry error of 150 m was based on relocations of dropped collars, den sites, and test collars placed in typical bear habitat.

Study Design

The study focussed on the influence of the T-corridors on the distribution of both black and grizzly bears. Because habitat availability is known to affect bear distribution and T-corridors were not located randomly with respect to habitat (Fig. 3), I also investigated bear habitat use in an effort to disentangle its effect from that of the corridor. Relationships among bears, habitat, and T-corridors was examined using compositional analysis (Aebischer et al. 1993) and univariate comparisons (Neu et al. 1974) in conjunction with a Geographic Information System (GIS). All analyses were applied to both grizzly and black bears. The differences in trapping efforts between the two bear species, however, prevented a direct comparison. To balance comparisons, grizzly bears were also sub-sampled to include only those trapped within a home range radius from the highway; these bears were called Highway bears. Analyses were applied to this sub-sample as well as to all grizzly bears.

Relationships were evaluated at Johnson's (1980) third order of resource selection. Bear use of habitat and T-corridors was compared to availability assumed to equal the proportion of area covered within the 97% multi-annual composite home range of radio-collared bears. Because grizzly bear home ranges were larger than black bear home ranges and the male ranges of both species were larger than female ranges, habitats available to each species and sex varied due to different composite home ranges. An

Figure 3.   The proportion of random points located in each habitat type for the 8 distance-to-transportation corridor classes, in the study area, between 1994 and 1997.

additional composite home range was built for the sub-sample of highway grizzly bears. The program CALHOME (1994) was used to construct the multi-annual composite home ranges and the 97% Minimum Covex Polygon isopleth was chosen to omit short-term forays. Seasons were based on a 5 year average of major changes in habitat use reflecting changes in the diet of bears (McLellan and Hovey 1995). These seasons included: (i) **spring**: den emergence to July 31, i.e. apprx. before berries were ripe, (ii) **summer:** August 1 to September 30, i.e. apprx. when fruits of *Vaccinium* spp. were ripe, and (iii) **fall:** October 1 to den entry, i.e. apprx. the post-berry season.

Habitat type and distance to T-corridors were variables included in the analysis and were selected because of their potential importance to bears. Except for habitat, all variables were available in digital format and could be used in the GIS. The study area had not been mapped for habitat type. Consequently, the availability of each habitat type was estimated using the random point method (Marcum and Loftsgaarden 1980). The study area was partitioned into different habitat types (Table 1) based on categories used in other studies (Servheen 1983, Zager et al. 1983, McLellan 1989). Composite home ranges of species and sex classes of bears were overlaid, and 1975 randomly located points were scattered over the area. Random points were added until there was less than a 3% change in variation for each habitat type. The habitat type at each location was determined using a combination of forest cover maps and ocular interpretation of the 1:50,000 and 1:20,000 scale air photos.

Table 1. Habitat type descriptions for the study area based on McLellan (1989), Servheen (1983), and Zager et al. (1983).

Component Name	Description
slide chute	Steep open areas where periodic avalanches limit vegetation to forbs, graminoids, shrubs and stunted trees.
riparian	Hydrologically active with moving water that may be ephemeral. Generally flat (<5% slope) and timbered with dense understory.
burns	Areas with conifers <10 m in height due to early succession after a wildfire. These sites were often dominated by shrubs.
cutting unit	Open or partially timbered site where timber harvest has disturbed natural vegetation and the trees are ≤20 years old.
timbered	Treed areas where growth is > 3 m or areas where the trees are ≥20 years old.
sub-alpine	Areas that generally occur at elevations >2000 m where clumps of trees are mixed with sedges and forbs.
non-habitat	Non-vegetated areas including rock, ice and lakes.
developed	Areas altered by humans including residential areas, dumps, industrial areas and cleared areas adjacent to roads, railways and highways.

GIS Layers

The GIS software, PAMAP (PCI Pacific 1996), was used to build map layers. The linear disturbance features, (the TCH, Highway 95 and the CPR lines) were derived from 1:20,000 Terrain Resource Information Management (TRIM) data (Surveys and Resource Mapping Branch; MOELP 1992). Maps were in raster format with a 50 m pixel resolution. An unweighted distance-to- transportation corridor layer was created by combining the planimetric features of the TCH, Highway 95 and the CPR lines.

Compositional Analysis

Many methods have been proposed to determine whether a sample of animals use available habitats in a random fashion or if some are preferred over others, and to compare preference among different groups of animals (e.g. males and females). However, all techniques contain shortcomings that may affect the validity of the analysis, often at the statistical level (Alldredge and Ratti 1986, 1992 and Aebischer et al. 1993). For compositional analysis, the animal, rather than the radio-location, is the sampling unit. With other methods, radio-locations are often pooled over several individuals which inflates the degrees of freedom, rendering statistical tests over-sensitive and increasing the chance of a Type I error (Kenward 1992, Aebischer et al. 1993).

Other methods suffer from the problem of non-independence of proportions or the unit-sum constraint. A consequence of this constraint is that an animal's avoidance of one habitat type will almost invariably lead to an apparent preference for other types. In compositional analysis, Aitchison (1986) showed that the log-ratio transformation $y_i =$

$\ln(x_i/x_j)$ (where $x_i =$ is the proportion of the individual's trajectory in habitat i and $x_j =$ is the proportion of the individual's trajectory in habitat j) renders the y_i linearly independent. Another advantage of compositional analysis is that many statistical models such as MANOVA may be fitted to the transformed compositions to test for various effects such as sex, age, or season.

This study compared habitats used to those available at Johnson's third order of selection, i.e. the use of each habitat by both species of bear compared to the proportion of the 97% composite home range that was covered by each habitat. The available and used habitat compositions were transformed to log-ratios with the proportion of timber as the denominator. Because the number of locations varied among animals, the log-ratios were weighted by the square root of the number of locations. A 0.01% value replaced 0% values of unused, but available habitats. SAS (1998) was used for both conventional parametric and randomization tests. The level of rejection of a null hypothesis was $\alpha = 0.05$.

Both Wilks lambda and the randomization test were used to examine the effects of sex and season on habitat use. If results were significant, habitat types were then ranked in order of use based on a matrix of the mean and standard error of the elements calculated over all individuals. The significance of the log-ratio was assessed using t- and randomization tests. The final product is a matrix that ranks bear habitat in order of relative importance.

Univariate Analysis

To compare the use to availability of habitat variables, the method of Neu et al. (1974), as modified by Marcum and Loftsgaarden (1980) was used, with 90% simultaneous confidence intervals using Bonferroni adjustments. Limitations of this method have been discussed extensively in the literature (Alldrege and Ratti 1986, White and Garrot 1990, Aebischer et al. 1993, Garshelis 1997). The variable considered for this analysis, included distance to T-corridor and habitat. Because grizzly bear home ranges were larger than black bear home ranges the landscape was divided into different distance to T-corridor classes for each species. For grizzly bears the following 8 distance-to-transportation corridor classes were chosen: 0.0-0.5 km, 0.5-1.0 km, 1.0-5.0 km, 5.0-10.0 km, 10.0-15.0 km, 15.0-20.0 km, 20.0-25.0 km, and > 25.0 km. For black bears only the following 6 classes were designated: 0.0-0.5 km, 5.0-1.0 km, 1.0-2.0 km, 2.0-5.0 km, 5.0-10.0 km, and >10.0 km.

Mortality

Highway mortality data was obtained from the Parks Canada database for wildlife killed inside of Mt. Revelstoke and Glacier National Park between 1964 and 1997. Bear mortalities were tabulated based on species, sex and month of the year. Railway mortality data was obtained from Pat Wells, an engineman for CPR, who began in 1994 to collect data on animals killed on the railway between Field, B.C. and Revelstoke, B.C. Railway mortalities were tabulated based on species, and month of the year. Other sources for bear mortalities exist but were not used because of incomplete and inconsistent record keeping.

RESULTS

Grizzly Bears

Between 1994 and 1997, 26 male grizzly bears, including 19 adults and 7 subadults, were located 589 times. In addition, 15 females grizzlies, including 12 adults and 3 subadults were located 472 times. When the grizzlies were sub-sampled to include only bears trapped within one home range radius of the highway, only 10 males and 2 females remained and these were located 389 times. Because only 2 females had their trap site near a highway, they were combined with the males for this analysis.

Use of transportation corridors

Female grizzly bears used the distance to T-corridor classes that were <10 km less than expected during all three seasons (Figs. 4-6). However, males and highway grizzlies used areas < 500 m from the T-corridors more often that expected during spring, but similar to expected during summer and fall (Figs. 4-6).

Use of habitat types

Grizzly bear habitat use varied by sex (Wilks lambda = 0 .782, $F_{7,106}$ = 4.22, $p<$ 0.05) and season (Wilks lambda = 0.658, $F_{14,212}$ = 0.352, $p < 0.05$). Consequently, to reduce variance, habitat use by sex and season were considered separately. Habitat selection by grizzly bears trapped near highways did not differ from habitat selection by male grizzly bears.Compositional analysis of spring habitat selection ranked slide chutes higher than all other habitat types for female, male, and highway grizzly bears (Fig. 7). There was no detectable difference in the selection of the remaining habitat components.

(a) Female

(b) Male

proportion of locations

use

availability

(c) Highway bears

distance to transportation corridor classes (km)

Figure 4. Grizzly bear **spring** use and availability of the 8 distance-to-transportation corridor classes, in the study area, between 1994 and 1997. Use differing significantly (p<0.05) from expected is indicated by + or -.

(a) Females

0.30
0.20
0.10
0.00

(b) Males

proportion of locations

0.40
0.30
0.20
0.10
0.00

use
availability

(c) Highway bears

0.50
0.40
0.30
0.20
0.10
0.00

0.0-0.5 0.5-1.0 1.0-5.0 5.0-10.0 10.0-15.0 15.0-20.0 20.0-25.0 >25.0

distance to transportation corridor classes (km)

Figure 5. Grizzly bear **summer** use and availability of the 8 distance-to-transportation corridor classes, in the study area, between 1994 and 1997. Use differing significantly (p<0.05) from expected is indicated by + or -.

(a) Females

(b) Males

(c) Highway bears

distance to transportation corridor classes (km)

Figure 6. Grizzly bear **fall** use and availability of the 8 distance-to-transportation corridor classes, in the study area, between 1994 and 1997. Use differing significantly ($p < 0.05$) from expected is indicated by + or -.

(a) Females

(b) Males

(c) Highway bears

SC   RP   BU   CU   SA   NH   DV   TB

habitat type

Figure 7. **Spring** habitat use by grizzly bears based on compositional analysis. Also shown is the proportion of random points located in each habitat component. Habitat types labelled **a** ranked significantly (p<0.05) higher than those labelled **b**, which in turn, ranked higher than those labelled **c**. Habitat types with the same letter did not differ significantly from each other. SC=slide chutes, RP=riparian, BU=burn, CU=clear cuts, SA=sub-alpine, NH=non-habitat, DV=developed, TB=timber.

In summer, female grizzly bears selected slide chutes, sub-alpine, burns, and timber (Fig. 8a). Although burned areas comprise only 5.8% of the female composite home range, 12 females were located in it between 10-90% of the time. Only 3 females were not located in burns. Similarly, sub-alpine covered only 4.7% of the composite home range and 6 individuals were not located in it, but 9 others used it 10-50% of the time. Males and highway grizzly bears selected slide chutes and burns during summer and the remaining habitats equally (Fig. 8 b, c). Burns covered only 5.4% of the male composite home range yet 18 of 25 individuals monitored were located there between 10-80% of the time, with an average use of 32.4%.

During fall, for female grizzlies sub-alpine ranked above the other habitat types (Fig. 9a). Fourteen individuals spent 30-90% of their time in this habitat type. Fall habitat selection among male grizzlies was less apparent than it was for the females. Males ranked slide chute, burn, timber, and sub-alpine, developed and riparian equally (Fig. 9b) but more than cuts and non-habitat. Like males, highway grizzlies showed little selection during fall (Fig. 9c).

Influence of habitat types on use of transportation corridors

Determining the influence of the T-corridors on the distribution of grizzly bears is complicated by the unequal distribution of habitats in relation to the corridors. Habitats were not randomly distributed relative to the T-corridors (p<0.05). For example, developed habitat comprised 64% of the habitats in the 0.0-0.5 km class but was absent from classes beyond 5.0 km. Conversely, slide chutes made up 2% of habitat within 500 m of the corridor but 23% in the 5-10 km category. To overcome the correlation between

Figure 8. **Summer** habitat use by grizzly bears based on compositional analysis. Also shown is the proportion of random points located in each habitat component. Habitat types labelled **a** ranked significantly (p<0.05) higher than those labelled **b** which, in turn, ranked higher than those labelled **c**. Habitat types with the same letter did not differ significantly from each other. SC=slide chutes, RP=riparian, BU=burn, CU=clear cuts, SA=sub-alpine, NH=non-habitat, DV=developed, TB=timber.

(a) Female

(b) Males

(c) Highway bears

Figure 9. **Fall** habitat use by grizzly bears based on compositional analysis. Also shown is the proportion of random points located in each habitat component. Habitat types labelled **a** ranked significantly (p<0.05) higher than those labelled **b** which, in turn, ranked higher than those labelled **c**. Habitat types with the same letter did not differ significantly from each other. SC=slide chutes, RP=riparian, BU=burn, CU=clear cuts, SA=sub-alpine, NH=non-habitat, DV=developed, TB=timber.

habitat and the corridors, a comparison was made between the use of the slide chutes, a habitat type that was clearly selected for by all groups of bears, and the use expected within each distance to T-corridor class. If T-corridors caused bears to reduce their use of nearby slide chutes, selection of these habitats should decrease with decreasing distance to the corridors. If bears responded primarily to habitats rather than to the T-corridors, selection of a given habitat would be independent of T-corridor class. Spring and summer locations were pooled because there were insufficient data for separate seasonal analyses.

Use of slide chutes was not proportional to availability in the distance-to-transportation corridor classes. Female grizzlies used slide chutes in the closest corridor class less than expected and used the 20-25 km, and >25 km classes more than expected (Fig. 10a). Conversely, both male and highway grizzly bears used slide chutes in the 0.0-0.5 km class more than expected (Fig. 10 b, c).

Individual variation in use of transportation corridors

To further elucidate the influence of the T-corridors, it was important to consider individual variation because effects can be masked by the pooling locations from all bears. There were insufficient data on each bear to examine statistical variation among individuals. However, Fig. 11 suggests some individual variation among bears in their use of habitats adjacent to T-corridors in the spring.

There was little variation among females of their use of the closest three T-corridor classes. Fourteen of 15 bears did not use areas within 2 km of the corridor and the individual that did use areas within 2 km spent only 10-20% of its time there (Fig.

(a) Females

(b) Males

(c) Highway

distance to transportation corridor classes (km)

Figure 10. Grizzly bear use and availability of slide chutes in each of the 8 distance-to-transportation corridor classes in the study area.   Data represent spring and summer seasons between 1994 and 1997. Use differing significantly (p<0.05) from expected is indicated by + or -.

(b) Females

(a) Males

proportion of locations

•   availability

○   1 bear

○   2 bears

○   3 bears

○   4 bears

○   5 bears

○   10 bears

○   15 bears

○   25 bears

(c) Highway bears

0.0-0.5
0.5-1.0
1.0-5.0
5.0-10.0
10.0-15.0
15.0-20.0
20.0-25.0
>25.0

distance to transportation corridor classes (km)

Figure 11. Individual variation in grizzly bear use of the 8 distance-to-transportation corridor classes, in the study area, between 1994 and 1997.

11a). The majority of males and highway bears did not use the 0-0.5 km from corridor class but a some bears spent considerable amount of time there (Fig. 11b, c). Among the 25 males, 5 used the 0-0.5 km class between 10-50% and among the highway bears, 6 of 12 individuals used it between 10-50% of the time, even though the availability of this category is <5.0%.

Mortality

No radio-collared grizzly bears were killed on the highways or railways during the study, although one male grizzly was suspected of being hit by a vehicle on the highway but not killed. This bear was feeding on a grain spill on the railway tracks adjacent to the TCH. The only known death of a grizzly bear caused by a vehicle or train during the study was of a non-collared adult grizzly bear that was hit by a train (Pat Wells pers. comm.).

Mount Revelstoke and Glacier National Park historical records for TCH bear mortalities reveals a total of 5 grizzly bears killed between 1964 and 1978. The last known grizzly mortality was in 1978. These mortalities included 3 cubs, 1 male and 1 of unknown age and sex (Fig. 12) and 3 were killed in May, 1 in June and 1 in September (Fig. 13).

<u>Black Bears</u>

Between 1994 and 1997, 15 male black bears, including 9 adults and 6 subadults, were located 241 times. In addition, 9 adult female black bears were located 264 times

Figure 12. Observed number of bear TCH mortalities by sex class. Data recorded by Mount Revelstoke and Glacier National Park between 1964 and 1997.

Figure 13. Observed number of bear TCH mortalities by month. Data recorded by Mount Revelstoke and Glacier National Park between 1964 and 1997.

Use of transportation corridors

Both female and male black bears used distance-to-transportation corridor classes differently from what was available to them during spring and summer but not during fall. In spring, both sexes used the 0.0-0.5 km category more than expected (Fig. 14). In summer, females continued to use the 0.0-0.5 km from corridor class significantly more than expected, while using the three most distance categories less (Fig. 15a). Conversely, males used the farthest distance from corridor class (>10 km) more than expected (Fig. 15b).

Use of habitat types

Black bear habitat use varied by sex (Wilks lambda = .740, $F_{7,55}$= 2.75, $p < 0.05$) and season (Wilks lambda = 0.412, $F_{14,110}$= 4.38, $p < 0.05$).

Overall, selection of specific habitat types was less apparent among black bears than it was among grizzly bears. During spring, there was little distinct selection of habitats by females. They selected timber and developed areas more than other habitats and were never located in non-habitat or sub-alpine (Fig. 16a). All radio-collared female black bears were often located in timbered areas with the average amount of time being 45%. Although the majority of females did not use developed areas, 4 spent 10-20% of their time in this habitat. Although not significant, riparian was used by 6 of the 9 bears at an average of 16.7%, even though it comprised only 9% of their composite home range. Male black bears showed similar habitat preferences during spring. Males also selected timber and developed areas more than other habitats (Fig.16b). All 15 males

(a) Females

(b) Males

distance to transportation corridor classes (km)

Figure 14. Black bear **spring** use and availability of the 6 distance-to-transportation corridor classes in the study area, between 1994 and 1997. Use differing significantly (p<0.05) from expected is indicated by + or -.

Figure 15. Black bear **summer** use and availability of the 6 distance-to-transportation corridor classes in the study area, between 1994 and 1997. Use differing significantly (p<0.05) from expected is indicated by + or -.

(a) Females

(b) Males

Figure 16. **Spring** habitat use by black bears based on compositional analysis. Also shown is the proportion of random points located in each habitat component. Habitat types labelled **a** ranked significantly (p<0.05) higher than those labelled **b**, which in turn, ranked higher than those labelled **c**. Habitat types with the same letter did not differ significantly from each other. SC=slide chutes, RP=riparian, BU=burn, CU=clear cuts, SA=sub-alpine, NH=non-habitat, DV=developed, TB=timber.

used timber 20-90% of the time. Seven bears used developed areas 10-50% of the time, even though it comprised <2.0% of the composite home range.

During summer, non-habitat ranked lower than all other habitat types for male and female black bears (Fig. 17). Although females showed considerable variation in habitat selection, timber continued to be used an average of 35% of the time by all bears. Although not significant, both female and male black bears increased their use of burns from 3% to 16% and 44%, respectively.

During fall, sample sizes were too small to obtain statistical confidence in habitat selection patterns (Fig. 18). Trends indicate that timber remained selected for by both males and females and males continued their use of burns.

Influence of habitat types on use of transportation corridors

As with the grizzly bears, habitat components were not randomly distributed relative to the T-corridors. Because both male and female black bears showed strong selection for timber, I examined their use of this habitat in relation to the T-corridors. Spring and summer timber locations were pooled for female black bears because there were insufficient locations to examine these seasons separately. Among the male black bears, only spring was selected because males shifted their use to habitats >10 km away from the T-corridors in the summer. This shift was probably as a result of bears using burns that are, on average, 10 km away from a corridor, rather than an avoidance of T-corridors. Both male and female black bears used timber within 0.5 km of the T-corridors greater than expected and 5-10 km less (Fig. 19a, b).

(a) Females

(b) Males

habitat type

Figure 17. **Summer** habitat use by black bears based on compositional analysis. Also shown is the proportion of random points located in each habitat component. Habitat types labelled **a** ranked significantly (p<0.05) higher than those labelled **b**, which in turn, ranked higher than those labelled **c**. Habitat types with the same letter did not differ significantly from each other. SC=slide chutes, RP=riparian, BU=burn, CU=clear cuts, SA=sub-alpine, NH=non-habitat, DV=developed, TB=timber.

Figure 18. **Fall** habitat use by black bears based on compositional analysis. Also shown is the proportion of random points located in each habitat component. SC=slide chutes, RP=riparian, BU=burn, CU=clear cuts, SA=sub-alpine, NH=non-habitat, DV=developed, TB=timber.

(a) Females

(b) Males

proportion of locations

distance to transportation corridor classes (km)

Figure 19. Black bear use and availability of timbered habitat in each of the 6 distance to-transportation corridor classes in the study area. Data represents spring and summer seasons between 1994 and 1997. Use differing significantly (p<0.05) from expected is indicated by + or -.
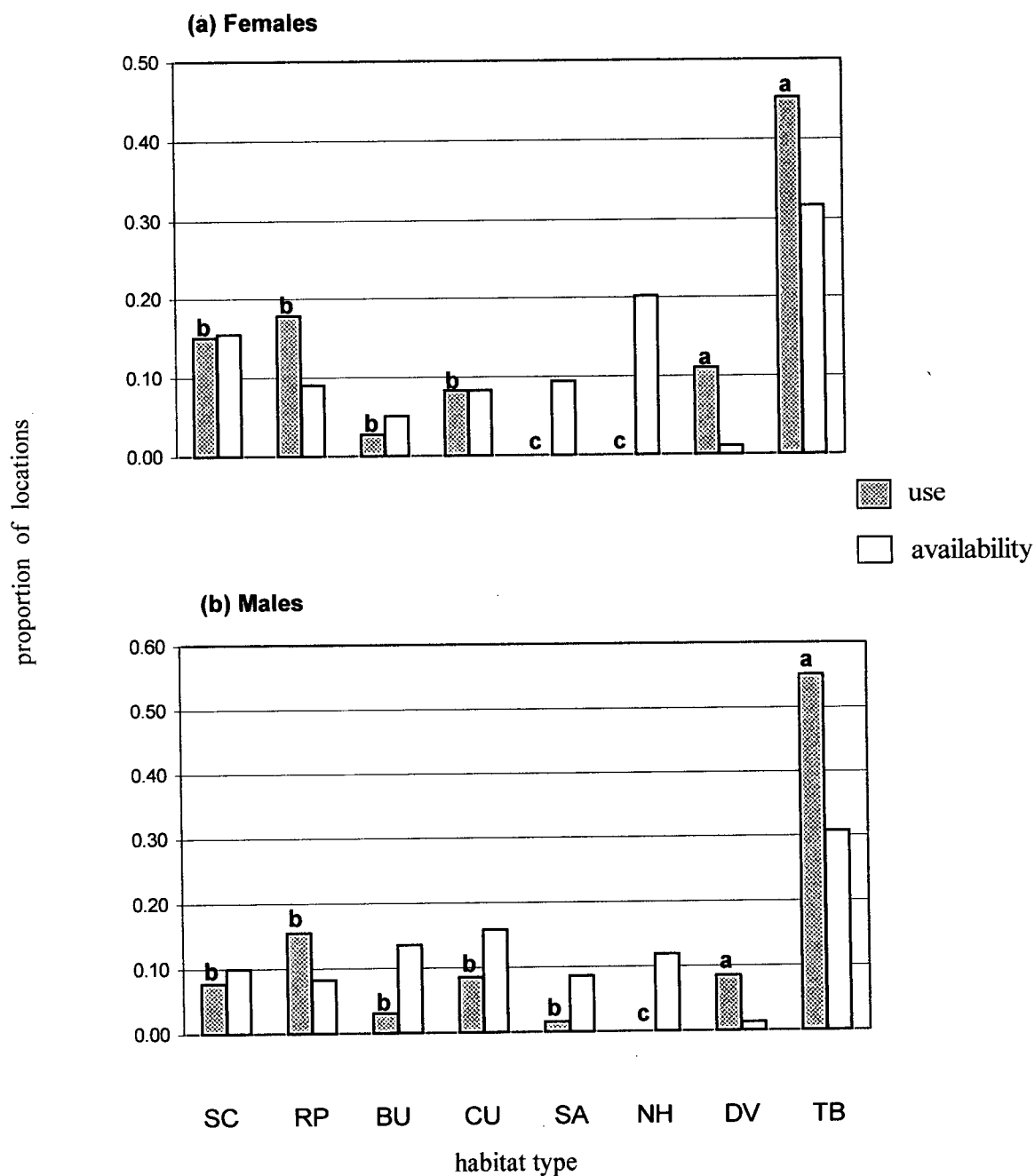
Individual variation in use of transportation corridors

Variation among females was greatest within the first four corridor categories. All females used areas >10 km less than expected while 8 of 9 bears used the 5-10 km class less than expected (Fig. 20a). Eight of 9 bears used the 0.0-0.5 km from T-corridors more than expected with use ranging from 20-100%. Thirteen of 15 males used areas within 0.5 km of the T-corridors 20-100% or the time (Fig. 20b).

Mortality

During the study, a radio-collared adult female and a male black bear were killed by a train. In addition, a 6 year-old male was suspected of being killed in a highway-related incident because his carcass was found < 100 m from the TCH and he had been frequently seen feeding on the TCH right-of-way. However, there were no obvious signs, such as broken bones, that a vehicle had hit him.

Although few collared black bears were killed on the T-corridors, at least 30 non-collared bears were killed by trains between Field and Revelstoke, from 1993 to 1997 (Pat Wells pers. comm.). The majority of these kills occurred on the railway tracks within the Beaver valley (Pat Wells pers. comm.) and nearly 63% occurred during May (Fig. 21). Park records indicated that the TCH accounted for a minimum of 102 black bear mortalities between 1964 and 1997. Furthermore, most of these mortalities were cubs, and nearly twice as many males were killed as females (Fig. 12). Black bear mortalities on the TCH were highest during June, July, and August (Fig. 13).

Figure 20. Individual variation in black bear use of the 6 distance-to-transportation corridor classes in the study area, between 1994 and 1997.

Figure 21. Observed number of black bear railway mortalities by month (n=30). Data recorded by Pat Wells from Field to Revelstoke, B.C. between 1993 and 1997.

DISCUSSION

Grizzly Bears

Slide chutes were clearly selected by both sexes of grizzly bears during the spring. Similar preference for this habitat was reported by Waller and Mace (1998) in Montana and for some bears in southeastern B.C. by McLellan (1989). Unlike grizzly bears in some study areas (Servheen 1983, McLellan 1989), riparian areas were not selected by grizzlies in this study, perhaps due to higher levels of human activities adjacent to riparian areas plus an abundance of slide chutes in which similar spring foods grew.

There was an inconsistent response by grizzly bears to the T-corridors. It appeared to depend on season and varied among individual bears. Because the T-corridors followed major valleys containing riparian areas and crossed a mountain pass where slide chutes predominate, I expected the effects of the corridor to be most clearly demonstrated during spring. During this season, 85% of all collared grizzly bears used areas adjacent to T-corridors less than expected. The habitat analysis further revealed that while slide chutes were selected as a habitat type, the majority of bears selected chutes adjacent to corridors less than expected. Other studies have reported displacement of 100 m to >900 m (McLellan and Shackleton 1988, Kasworm and Manly 1990, Mattson et al. 1987). My study suggests that, in general, there is even greater displacement from a major T-corridor. The apparent little use of riparian habitats, particularly in the upper Columbia valley, may be due to rural settlements, which form a network of development

throughout the valley bottom. It is difficult to determine if bears avoid such areas or whether those that had once used them were killed.

Although most bears appeared to avoid the T-corridors, 15% of the radio-collared individuals did use slide chutes adjacent to transportation more than expected. These bears were all among those trapped within a home range radius of T-corridors and ranged in age from 6-25 years old. Only one of these 6 bears was an adult female. Wittenberg (1998) found to that grizzly bears did not select glacier lily sites based on their distance from the TCH in Glacier National Park. Some dig sites were as close as 12 m from the road. She found these sites to be usually partially or fully concealed by vegetation and concluded that such cover may have reduced the amount of displacement (Wittenberg 1998). Furthermore, some individual bears have likely become habituated to the constant flow of traffic on the TCH. Vehicles are a relatively predictable stimulus and seldom stop on the highway, thus making the highway innocuous to these bears. Furthermore, it is possible that intraspecific competition in slide chutes away from the corridors may be high and that these bears may be compromising between the need to maximize energy intake and the need to minimize risks associated with feeding.

All radio-collared grizzly bears moved farther away from T-corridors during summer. This shift in distribution was likely due to a change in diet rather than an avoidance of T-corridors. During summer, many bears fed on huckleberries *(Vaccinium* spp.) in high elevation burns, which were located, on average, 10 km from the T-corridors. Huckleberries were found under a forest canopy and in cuts within 1 km of the T-corridors, but I suspect that the volume of berries in these areas was insufficient to support the larger bodied grizzlies. The T-corridors appeared to have little influence on

the distribution of radio-collared males and highway grizzlies during fall, but females continued to use more distant areas. During fall, berries diminished and females selected sub-alpine, likely in preparation for hibernation.

Black Bears

During spring, 88% of collared black bears used areas ≤ 500 m from the T-corridors more than expected, with approximately 40% of all spring locations occurred $\leq$ 300 m of the corridor. The majority of collared black bears that used areas adjacent to the corridors did so in the Beaver River valley. This valley is located partially inside of Glacier National Park and, at its widest portion (1 km wide), the TCH and CPR run parallel but on opposite sides of the river. There, the valley bottom contains several important spring bear foods, such as *Equisetum* spp., grasses, sedges (*Carex* spp.), clover (*Trifolium* spp.) and dandelion (*Taraxacum officinale*). Such herbaceous matter is at its highest nutrient quality in the spring (Hamer and Herrero 1983). The majority of collared black bears used portions of the Beaver valley at some point during the spring and it is not surprising that most locations were ≤ 500 m from a T-corridor because the valley is so narrow. Because most black bears studied were trapped within a home range radius of the TCH, it is likely that bears that avoid the T-corridors were under-represented in our sample. Perhaps the collared bears have been forced to use these areas as a result of intra-specific competition at high densities. Such competition may have caused some bears to take higher risks. It is also possible that some bears have adapted to deal with the T-corridors and those that did not either moved or were killed.

During spring, male black bears and some females selected rights-of-way. Both the highway and railway possess extensive rights-of-way where clover, grasses and dandelions were abundant. As well, *Equisetum* spp. was common on the railway bed. These foods were available to bears early in the year because rights-of-way are often the first areas to green-up. Furthermore, this composition of vegetation does not exist elsewhere in the study area.

Other researchers reported that black bears are attracted to road rights-of-way. Helligren and Vaughan (1988) found road margins were frequently used by female black bears in the Great Dismal Swamp, North Carolina, for feeding on food plants. Roads have also been found to attract black bears in other non-hunted populations (Carr and Pelton 1984, Garner 1986, Hellgren and Vaughan 1988, Clark 1991). Where bears are hunted, they generally avoid roads or, those that do not, are rarely available to be sampled (Hamilton 1978, Carr and Pelton 1984, Garner 1986). An additional attractant for bears on the railway are the small piles of grain that leak out of some railroad grain cars. Grain is a high quality food with crude protein ranges from 9-13% and starch content from 54-73% (Mattson 1992).

Bears have often been seen sleeping between the rails near such piles (Pat Wells pers. comm.). Within protected areas, black bears can habituate to human presence (McCullough 1982) and occupy areas close to humans (McCullough 1982, Mattson et al. 1992). This habituation can be considered adaptive as energy and time costs are reduced if the bears do not respond to non-threatening human-related stimuli (McCullough 1982).

In the summer, use of nearest T-corridor classes was less than expected for males and greater than expected for females. Like grizzlies, black bears shift to berries during

summer months. Males have larger home ranges that encompassed burns and cuts where berries such as *Vaccinium* spp. and *Shepherdia canadensis* are more plentiful. These habitat types were used by males but were located farther from T-corridors than the home range radius of most females. Females also shifted to berries, but did not travel to burns and cuts. They appeared to be able to meet their nutritional requirements from the scattered berry producing plants that grew within the timbered areas adjacent to the T-corridors.

Although from a dietary viewpoint, the vegetation along rights-of-way would benefit the black bear population, the high incidence of railway and highway mortality suggests that the gain may be negated. Not surprisingly, nearly 65% of railway mortalities occurred in the month of May. This is when the grasses, clovers and dandelions along the rights-of-way on the MacDonald CPR line are probably at their highest nutrient content. The park historical records also indicate that the TCH is a large cause of mortality for black bears but unlike the railway mortalities, highway kills remain constant throughout the bears' active season. This may reflect the high traffic volumes through out the year. The fact that males spent a greater proportion of time along the rights-of-way may have contributed to males being twice as likely as females to be killed on the TCH. In addition, males have larger home ranges, travel farther and are thus more likely to come in contact with the highway.

Black vs. Grizzly Bears

A comparison of habitat use near T-corridors by black bears and grizzly bears reveals that the majority of grizzly bears avoided the corridors while the majority of black

bears were attracted to the adjacent habitat during the spring. This tends to support the hypothesis that black bears tolerate human disturbance to a greater degree than do grizzly bears, and supports other researchers' findings that black bears exploit habitat nearer to roads more readily than grizzly bears (Aune 1994). Kasworm and Manley (1990) also observed differences in displacement zones for black and grizzly bears in the Cabinet Mountains of Montana, where grizzly bears were displaced further than black bears. The use of transportation rights-of-way by black bears and the lack of use of these areas by grizzlies suggests that black bears are better able to exploit disturbed habitats, which in turn may provide a competitive advantage to this species in roaded areas.

Although some individual grizzly bears used areas within 0.5 km of the T-corridors more than expected in the spring, they appeared to be exploiting different habitat types than the black bears. The grizzlies were observed using slide chutes while the black bears appeared to be using timbered areas and rights-of-way in valley bottoms. Since grizzlies and blacks often feed on similar food items, it has been suggested that in areas where the species are sympatric, they will shift either their spatial or temporal use of habitats to reduce competition. Kasworm and Manley (1990) suggested that where the species overlapped in habitat use, competition for food was intense. Schwartz and Franzmann (1991) observed two inter-specific encounters between black bears and grizzly bears. In both cases, the black bear fled when it detected the grizzly bear. The differential use of habitat types may also be partially related to the preferred food items of these two species. Black bears ate forbs found in mesic areas in the timber and the grasses, clovers and dandelions associated with the rights-of-way (pers. obs), while

grizzly bears exploited the forbs and glacier lily bulbs found in the slide chutes

(Wittenberg 1998).

MANAGEMENT IMPLICATIONS

The majority of grizzly bears were displaced from habitats adjacent to T-corridors. This finding was likely exacerbated by the communities, such as Golden, that lie adjacent to these corridors. I suspect that many of the bears that have attempted to use these areas have been killed in the past. McLellan et al. (1999) reports that the majority of bears die because people kill them including control kills for being too close to human habitation (McLellan et al. 1999). Consequently, the combination of habitat avoidance and high mortality rates for bears with home ranges that overlap the T-corridors and settled area together create the potential for habitat and population fragmentation. If development and settlement continue unabated it is likely the bear populations in the Columbia Mountains will become isolated from bear population in the Rocky Mountains. Because the Columbia valley north of the TCH has little human settlement and lower levels of recreational activity it provides the best opportunity for maintaining a habitat and population link between these two bear populations. Consequently, proper management may simply be limited to protection of this area from further development and settlement.

Although some bear were found to frequently use slide chutes adjacent to T-corridors in the spring, it does not necessarily imply that these structures had no detrimental effect on these bears. Preliminary data suggests that the corridors may be acting as a partial barrier to grizzly bear movement. To date, only two highway crossings by a collared female have been documented. Males were known to cross the TCH

occasionally but the actual location of crossings is not known. Factors influencing where bears cross the corridors should be identified before the TCH is twinned. Once these areas are identified measures to maintain and perhaps even increase permeability of the T-corridors should be investigated. At the very least, portions of the highway that contain these crossing zones should be protected from increased development. As a means to improve the permeability of the T-corridors underpasses are the obvious choice. Banff National Park has shown that adult male grizzly bears use these structures in attempt to access breeding females and during their spring and autumn migration in and out of the Bow Valley (Tony Clevenger pers. com.). Thus such underpasses would help to maintain genetic heterogeneity within the population and avoid isolation effects. Unfortunately, such formal underpasses are expensive to construct. If this is not possible, an alternative would be to enhance areas along the TCH that have the potential to act as crossing-underpasses for bears (eg, the underpass created by the Beaver valley river bridge). Such areas could be widened and enhanced to encourage bear use.

Rather than being displaced by T-corridors, black bears appear to be attracted to the habitat adjacent to them. Early spring green-up along the rights-of-way, in addition to grain on the railway tracks, provide the black bears with a unique food source. However, use of such food increases the bears' susceptibility to being hit by a vehicle. To discourage black bears from using rights-of-way and to reduce mortality, vegetation along rights-of-way should be replaced with less palatable plant species. Maintaining grain cars so they stop leaking grain and thoroughly cleaning up spills that occur would also reduce the number of bears on the tracks. In addition, with the advent of new and more powerful engines, trains can be equipped with more cars which, in turn, would

reduced the volume of traffic on the railway lines. Currently, however, this can only be achieved in some areas. The steeper railway grade in the mountains makes this approach impossible in our study area. However, it could reduce bear mortalities in other areas along the railway route.

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