GRIZZLY BEAR USE OF AVALANCHE CHUTES IN THE COLUMBIA MOUNTAINS, BRITISH COLUMBIA

by

ROGER KARIM RAMCHARITA
B.Sc., The University of British Columbia, 1993

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE STUDIES

(Department of Forest Sciences)

We accept this thesis as conforming
to the required standard

……………………………………

……………………………………

……………………………………

……………………………………

THE UNIVERSITY OF BRITISH COLUMBIA

September 2000

ABSTRACT

I examined spring season use of avalanche chutes by grizzly bears (*Ursus arctos* L.) in the Columbia Mountains, southeastern British Columbia. Sixty radio-collared grizzly bears were monitored between 1994 and 1998. The frequency of avalanche chute use, the selection of general habitat characteristics within avalanche chutes, and the selection of specific feeding and bedding sites within avalanche chutes by grizzly bears were documented.

Fifty-four percent (366/672) of all grizzly bear radio-locations during the spring season (May 1 to July 31) were in avalanche chutes. The proportion of radio-locations in avalanche chutes for the 37 grizzly bears that accounted for > 10 spring season radio-locations each ranged between 20% and 90% ($\bar{X}$ = 56% ± 18% [mean ± SD]). This variation was not attributable to differences in use between sex or age classes.

Within avalanche chutes, grizzly bears selected east and south aspects and areas dominated by grasses and forbs with minimal shrub abundance. Grizzly bears avoided very steep slopes but used all elevational parts of avalanche chutes - upper start zones, tracks, and lower runout zones. These patterns appeared to be tied to feeding site selection, because evidence of feeding was found at most telemetry locations investigated on the ground.

Grizzly bears selected feeding sites on the basis of forage value and visual cover. Most feeding sites were characterized by high forage value and low visual cover, but weak positive interaction between these two factors indicated that grizzly bears also selected feeding sites with slightly lower forage values but high visual cover. Bed sites were found both in forest adjacent to avalanche chutes and directly within avalanche chutes. All bed sites found in forests adjacent to avalanche chutes were < 25 m from the forest / avalanche chute edge.

The impact on grizzly bear use of avalanche chutes by two timber harvest activities was also examined. Grizzly bears avoided areas within avalanche chutes that were adjacent to cutblocks, possibly due to the removal of escape cover. In contrast, grizzly bears selected areas close to logging roads. Most logging roads traversing avalanche chutes in the study area had minimal vehicle traffic and were often situated close to areas with abundant food resources. I present suggestions for managing this important spring season habitat for grizzly bears.

TABLE OF CONTENTS

ABSTRACT .... **ii**

LIST OF FIGURES .... **v**

LIST OF TABLES .... **vi**

ACKNOWLEDGEMENTS .... **vii**

INTRODUCTION **1**

STUDY AREA **3**

METHODS **4**

- RADIO-TELEMETRY 4
- HABITAT SELECTION WITHIN AVALANCHE CHUTES 5
- FEEDING AND BEDDING ACTIVITY WITHIN AVALANCHE CHUTES 10
- ANALYSIS METHODS 13

RESULTS **15**

- FREQUENCY OF AVALANCHE CHUTE USE 15
- HABITAT SELECTION WITHIN AVALANCHE CHUTES 17
- FEEDING AND BEDDING ACTIVITY WITHIN AVALANCHE CHUTES 21

DISCUSSION **25**

- FREQUENCY OF AVALANCHE CHUTE USE 25
- HABITAT SELECTION AND FEEDING AND BEDDING ACTIVITY WITHIN AVALANCHE CHUTES 27

MANAGEMENT IMPLICATIONS **32**

- MAPPING HABITAT WITHIN AVALANCHE CHUTES 33
- RANKING HABITAT WITHIN AVALANCHE CHUTES 34
- CONSERVING AVALANCHE CHUTE HABITAT 36

LITERATURE CITED **39**

LIST OF FIGURES

FIGURE 1. STUDY AREA DIAGRAM. GLACIER NATIONAL PARK AND YOHO NATIONAL PARK ARE OUTLINED ON THE LEFT AND RIGHT SIDE OF THE DIAGRAM, RESPECTIVELY. **4**

FIGURE 2. BIWEEKLY PROPORTION OF 1,596 GRIZZLY BEAR TELEMETRY LOCATIONS THAT OCCURRED IN AVALANCHE CHUTES, AND DELINEATION OF SEASONS, IN THE COLUMBIA MOUNTAINS, B.C., 1994-1998. .... **6**

FIGURE 3. PHOTOGRAPH OF AN AVALANCHE CHUTE DEPICTING THE *COVER TYPES* MAPPED USING A SPOT PANCHROMATIC/LANDSAT TM MERGED SATELLITE IMAGE. COVER TYPES: **A** = GRASS-FORB, **B** = SHRUB, **C** = BARE SOIL-ROCK, **D** = FOREST... **7**

FIGURE 4. VARIATION IN FREQUENCY OF AVALANCHE CHUTE USE BY 37 GRIZZLY BEARS IN THE COLUMBIA MOUNTAINS, B.C., 1994-1998. ONLY BEARS WITH > 10 SPRING SEASON TELEMETRY LOCATIONS WERE INCLUDED IN THIS ANALYSIS.. **16**

FIGURE 5. GRIZZLY BEAR SELECTION OF HABITAT CHARACTERISTICS WITHIN AVALANCHE CHUTES IN THE COLUMBIA MOUNTAINS, B.C., 1994-1998. 90% BONFERRONI CONFIDENCE INTERVALS WERE USED; "+" INDICATES 'SELECTION', "-" INDICATES 'AVOIDANCE'.. **18**

FIGURE 6. FREQUENCY OF COVER TYPE OCCURRENCE ON DIFFERENT ASPECTS AND SLOPE GRADIENTS WITHIN AVALANCHE CHUTES IN THE COLUMBIA MOUNTAINS, B.C. PROPORTIONS WERE ESTIMATED USING THE 132 RANDOM POINTS PLOTTED IN AVALANCHE CHUTES FOR THE LOGISTIC REGRESSION ANALYSIS. **21**

FIGURE 7. GRIZZLY BEAR FEEDING SITE SELECTION PATTERNS WITHIN AVALANCHE CHUTES IN THE COLUMBIA MOUNTAINS, B.C., 1996-1998. 90% BONFERRONI CONFIDENCE INTERVALS WERE USED; "+" INDICATES 'SELECTION', "-" INDICATES 'AVOIDANCE'.. **23**

LIST OF TABLES

TABLE 1. ACCURACY OF COVER TYPE CLASSIFICATION BY SPOT PANCHROMATIC / LANDSAT 5 TM MERGED SATELLITE IMAGERY. AT 151 POINTS, THE COVER TYPE MAPPED BY THE SATELLITE IMAGE WAS COMPARED TO THE COVER TYPE INTERPRETED USING 1:15,000 SCALE BLACK AND WHITE AIR PHOTOS. **8**

TABLE 2. CHARACTERISTICS OF SAMPLES USED FOR HABITAT SELECTION ANALYSES INVOLVING TELEMETRY LOCATIONS AND RANDOMLY PLOTTED POINTS WITHIN AVALANCHE CHUTES......... **10**

TABLE 3. FORAGE SPECIES USED BY GRIZZLY BEARS AT 41 FEEDING SITES IN AVALANCHE CHUTES DURING THE SPRING SEASON; COLUMBIA MOUNTAINS, 1996-1998. SEVERAL SPECIES WERE OFTEN USED AT A SINGLE SITE. **12**

TABLE 4. RESULTS OF GOODNESS OF FIT (*G*) TESTS DESCRIBING GRIZZLY BEAR SELECTION OF HABITAT WITHIN AVALANCHE CHUTES IN THE COLUMBIA MOUNTAINS, B.C., 1994-1998. .... **17**

TABLE 5. RESULTS OF LOGISTIC REGRESSION ANALYSIS DESCRIBING GRIZZLY BEAR SELECTION OF HABITAT WITHIN AVALANCHE CHUTES IN THE COLUMBIA MOUNTAINS, B.C., 1994-1998. ...... **20**

TABLE 6. RESULTS OF GOODNESS OF FIT TESTS (*G*) COMPARING GRIZZLY BEAR FEEDING SITES TO RANDOM SITES WITHIN AVALANCHE CHUTES IN THE COLUMBIA MOUNTAINS, B.C. 1996-1998.............. **22**

TABLE 7. LOGISTIC REGRESSION ANALYSIS COMPARING 41 GRIZZLY BEAR FEEDING SITES TO 45 RANDOM SITES WITHIN AVALANCHE CHUTES IN THE COLUMBIA MOUNTAINS, B.C., 1996-1998............. **24**

ACKNOWLEDGEMENTS

Grizzly bear studies are complicated. You can't do it alone. Over the years, my work and my life have been touched by many people. Foremost among them are Dr. Bruce McLellan and Dr. Fred Bunnell, my co-supervisors. Their "hands-off" approach to graduate student management allowed me to grow and develop my own ideas, which nonetheless have been strongly shaped by our discussions about grizzly bears, science and life in general. Not once did they say no to my frequent requests for funding, materials and advice. Committee member Dr. David Shackleton has been a mentor ever since I was an undergraduate. For his guidance and encouragement over the years, thanks is not enough.

I am indebted to field assistants Karen Oldershaw, Cheryl Johnson, Corrina Wainwright and Kelly Stalker for thorough work and good company. Doug Adama and John Krebs (Columbia Basin Fish and Wildlife Compensation Program) and Dr. John Woods (Parks Canada) were central to the evolution of the project and assisted with funding, logistical support and advice throughout. Rob Sidjak went above and beyond the call of duty to develop the satellite image that I used. Digital maps were generously provided by Darcy Monchak, Val Beard (B.C. Ministry of Forests), Al Fedoruk (B.C. Ministry of Environment) and Clayton Apps (Aspen Wildlife Research). Arnold Moy (UBC) and Ian Parfitt (CBFWCP) helped with GIS problems whenever I got stuck. Tony Hamilton (B.C. Ministry of Environment) was very helpful in arranging funding, and Bob Jamieson (Bioquest Consulting International) provided excellent advice during the early stages of the project. Parks Canada employees John Flaa, Murray Peterson, Peter Kimmel and Wayne Martin helped substantially with logistics. Dave Mair (Silvertip Aviation), Mike Super and Janis Hooge collected the telemetry data and Don McTighe (Canadian Helicopters) safely ferried my crew around the remote corners of the study area. Bruce Davitt (Wildlife Habitat Lab at Washington State University) analyzed forage samples for nutritional content. Numerous discussions and heated debates with fellow grad students Scott Harrison, Dave Huggard, Rob Serrouya, Glenn Sutherland and James McCormick, and fellow grizzly bear researchers Marie Gallagher, Fred Hovey and Robin Munro provided a great forum for learning. Above all, I thank my family for their unwavering support and encouragement.

Funding was graciously provided by the Habitat Conservation Trust Fund, Forest Renewal B.C., B.C. Ministry of Forests, Parks Canada, Columbia Basin Fish and Wildlife Compensation Program, The University of British Columbia, Evans Forest Products, Downie Street Timber and the Revelstoke Community Forest Corporation.

"How many times since that far-off day I have wished that I could, even if just for a few short moments, look out onto the world through the eyes, with the mind, of a chimpanzee. One such minute would be worth a lifetime of research."

- Jane Goodall, *Reason For Hope*, 1999

INTRODUCTION

Avalanche chutes are an important spring season habitat for grizzly bears in some parts of their range (Mundy and Flook 1973, Zager *et al*. 1983, Simpson 1985, Schoen and Beier 1990, MacHutchon *et al*. 1993, Mace *et al*. 1996, Munro 1999, McLellan and Hovey 2001). In these areas, portions of avalanche chutes are often free of snow earlier than other habitats and they typically support several species of vegetation eaten by grizzly bears. Because avalanche chutes do not contain merchantable timber, little effort has been directed at understanding the use of avalanche chutes by grizzly bears and other wildlife species. As logging operations proceed out of timber dominated landscapes and into areas with a large amount of avalanched terrain, information on wildlife use of avalanche chutes is needed by managers (Kootenay Inter-Agency Management Committee 1997).

The potential for logging activities to impede use of habitat by grizzly bears is well documented. In particular, grizzly bears may be displaced if cutblocks adjacent to avalanche chutes remove escape cover (Blanchard 1983, Zager *et al*. 1983, McLellan 1990, USFS 1990) or if they avoid vehicle traffic on logging roads that traverse avalanche chutes (Zager *et al*. 1983, Archibald *et al*. 1987, Mattson *et al* 1987, McLellan and Shackleton 1988, Kasworm and Manly 1990). In response to these potential impacts, wildlife managers in southeastern British Columbia developed a system to identify and rank the relative importance to grizzly bears of habitats within avalanche chutes so that logging activities can be modified to protect important habitats (Kootenay Inter-Agency Management Committee 1997, Mowat and Ramcharita 1999). However, detailed information on grizzly bear use of habitat within avalanche chutes was limited. Four previous studies have been conducted on this issue. Three of these described and ranked vegetation types within avalanche chutes based on the abundance of grizzly bear food (Mace and Bissell 1984, Jamieson 1998, Quinn and Phillips 2000). Korol (1994) identified four general types of avalanche chutes that may have been used differently by grizzly bears. All of these studies utilized few, if any, observations of grizzly bears using avalanche chutes.

I initiated a study to quantify various aspects of avalanche chute use by grizzly bears. Unlike previous research on this issue, my study used observations of radio-collared individuals. I first report how frequently grizzly bears in the study area used avalanche chutes. I then document grizzly bear use of habitat within avalanche chutes using analyses at two spatial scales. At the larger scale, I use telemetry locations to document habitat selection patterns among variables that can be mapped and used by wildlife managers to rate avalanche chute habitat for grizzly bears (cover type, aspect, slope). I also examine if grizzly bears using avalanche chutes are influenced by adjacent cutblocks and vehicle traffic on logging roads. At the smaller scale, I document patterns of grizzly bear feeding and bedding activity within avalanche chutes. Here, I used two types of variables; those related to site features that can be linked to the larger scale variables (grass and forb abundance, shrub abundance, aspect, slope) and those more closely linked to grizzly bear behaviour (forage value and visual cover). I anticipated that investigations at these various spatial scales would reveal not only which characteristics of avalanche chutes are important to grizzly bears, but also why they are important and why avalanche chutes are used frequently.

STUDY AREA

I conducted this research in a 5,000 km^2 area of southeastern British Columbia (51^o $30^'$ N, 117^o $0^'$ W) which stretched from Glacier National Park eastward across the Columbia River Valley to Yoho National Park (Figure 1). Elevation ranged from 750 m to > 2100 m. The climate is dominated by movements of damp air from the Pacific Ocean (Kelley and Holland 1961), and is characterized by cold, snowy winters and moist, warm summers. Mean annual precipitation in valley bottoms is approximately 120 cm, with about half as snow. Three biogeoclimatic zones are present; Interior Cedar - Hemlock, Englemann Spruce - Subalpine Fir, and Alpine Tundra (Braumandl and Curren 1992). The mean number of frost-free days is approximately 120 (Braumandl and Curren 1992).

Human land-use includes 2 national parks with little human modification and provincial lands that had been extensively modified by timber harvesting, mining, agriculture and settlement. The Columbia River Valley, which bisects the study area north to south, is a wide U-shaped valley with considerable low elevation riparian areas and infrequent avalanche chutes. Due to extensive human settlement, grizzly bears are largely restricted to the surrounding steep and narrow valleys with abundant avalanche chutes (Munro 1999: 48,49).

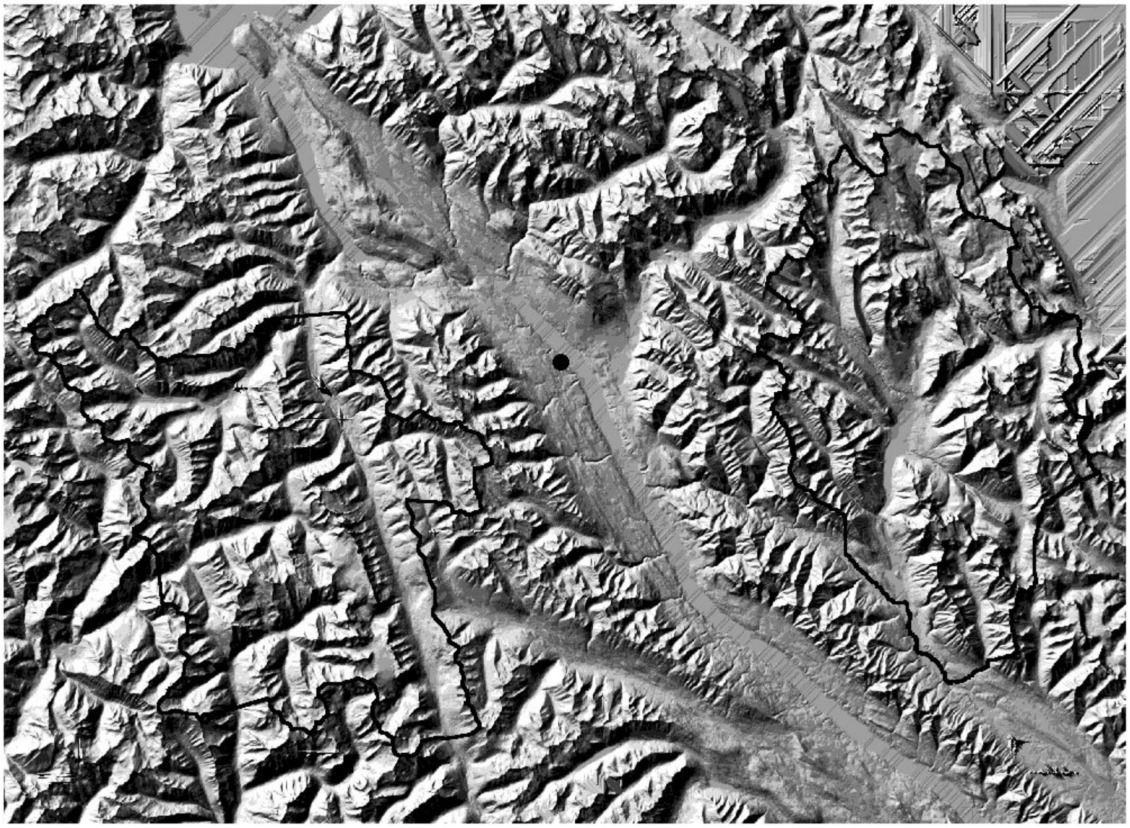

Figure 1. Study area diagram. Glacier National Park and Yoho National Park are outlined on the left and right side of the diagram, respectively. The black dot indicates the town of Golden, B.C.

METHODS

Radio-telemetry

Grizzly bears were captured and radio-collared between 1994 and 1998. Approximately 20 bears were monitored each year. These bears were located in daylight hours only, from fixed-wing aircraft at weekly intervals from den emergence in early May until den entrance in late October. Although all telemetry locations of grizzly bears were recorded, only those that were judged by the observer to be directly within an avalanche chute, and those recorded during spring (May 1 to July 31) were used in this analysis. Seasons were defined on the basis of changing frequency of avalanche chute use by grizzly bears in the study area (Figure 2). Telemetry locations were plotted onto a 1:50,000 scale topographic map to obtain UTM co-ordinates rounded to the nearest 100-m interval. I tested the spatial accuracy of the UTM co-ordinates assigned to telemetry locations and found that approximately 95% were within 264 m (n=15, $\bar{X}$ = 133 m, SD = 71 m). Most of this error was attributable to the plotting process that generated the UTM co-ordinates. The accuracy with which the observer judged a bear to be within an avalanche chute was thought to be high (B. McLellan, unpub. data).

Habitat Selection Within Avalanche Chutes

Digital data sources were assembled into a Geographic Information System (ArcView 3.1, ESRI Inc., Redlands, CA.). I identified all avalanche chutes in the study area by querying digital forest cover maps (Resources Inventory Branch 1995). I visually compared the resulting map of avalanche chutes against 1:15,000 scale black and white air photos and corrected any errors. Most errors occurred in national parks, where forest cover map reliability was low, so I digitized avalanche chute boundaries there using a SPOT panchromatic satellite image and airphotos as templates.

Cover types within avalanche chutes were mapped using two SPOT Panchromatic satellite images merged with a Landsat 5 TM satellite image (September 1, 3 1995; August 10, 1997 respectively) (Sidjak and Ramcharita, in prep.). Four cover types were

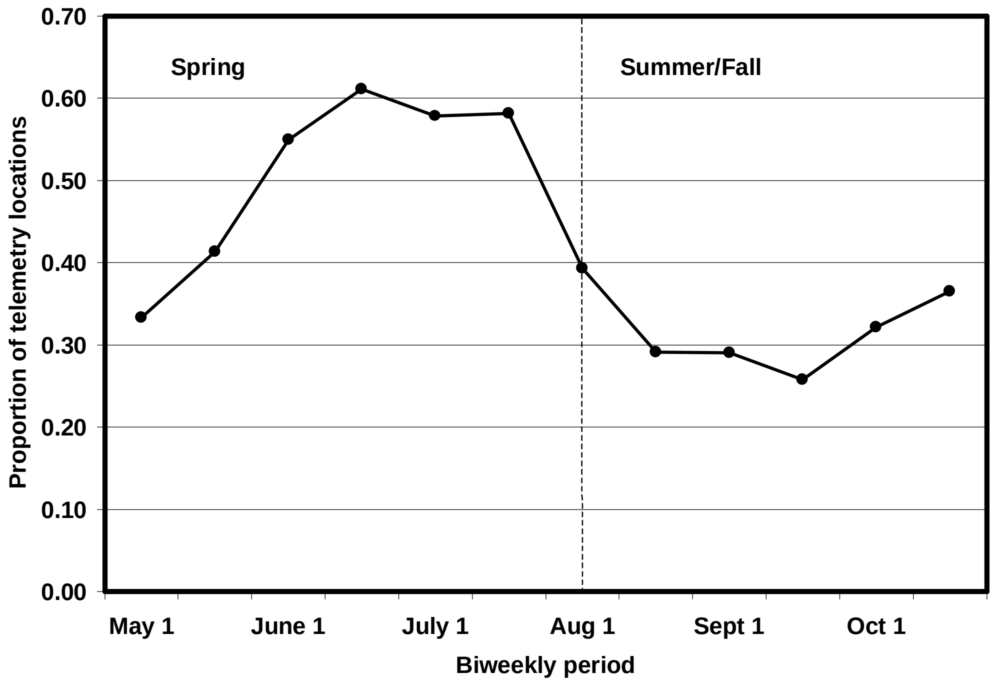

Figure 2. Biweekly proportion of 1,596 grizzly bear telemetry locations that occurred in avalanche chutes, and delineation of seasons, in the Columbia Mountains, B.C., 1994-1998.

mapped (Figure 3). *Grass- forb* delineated areas dominated by herbaceous and / or graminoid vegetation and infrequent woody vegetation. *Shrub* delineated areas dominated by shrubby vegetation, most commonly alder (*Alnus* spp.) and willow (*Salix* spp.), but also several other species of deciduous shrubs that occurred in the study area. These shrubs were generally 1.5 m to 3 m in height. *Forest* delineated stands of mature conifer forest adjacent to avalanche chutes and small, narrow strips of timber within avalanche chutes. *Bare soil-rock* delineated areas that had been scoured to exposed soil or bedrock by the avalanching process and included talus patches that occurred infrequently. An unclassified category was included in the map to accommodate pixels for which the cover type could not be resolved by the satellite image. Approximately 20% of the pixels within or < 100 m from avalanche chutes were unclassified. I tested the overall accuracy of the satellite image classification by comparing the mapped classification of cover types at 151 points to their true membership which was visually interpreted using 1:15,000 scale black and white air photos. The overall accuracy was 60.3 % (excluding unclassified pixels), though the accuracy of the Grass-forb cover type was considerably lower (35.6 %) (Table 1). The image had a 10-m pixel size.

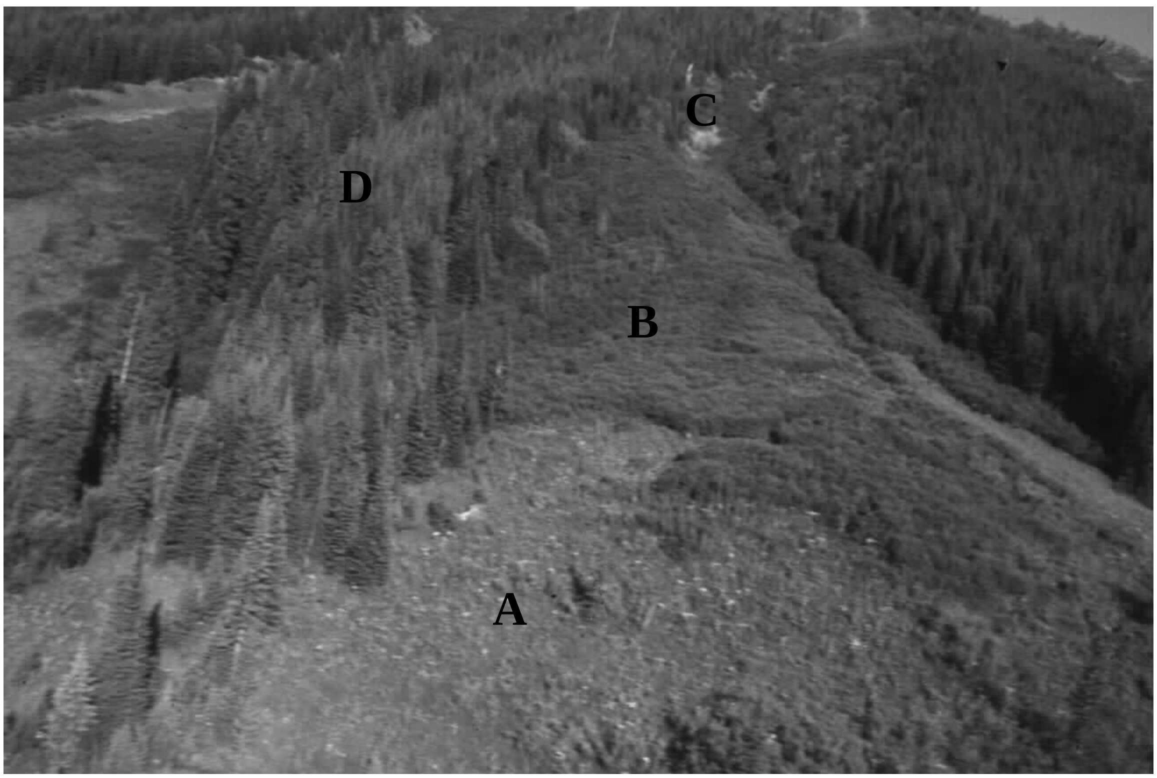

Figure 3. Photograph of an avalanche chute depicting the *cover types* mapped using a SPOT Panchromatic/Landsat TM merged satellite image. Cover types: **A** = Grass-forb, **B** = Shrub, **C** = Bare soil-rock, **D** = Forest.

Table 1. Accuracy of cover type classification by SPOT Panchromatic / Landsat 5 TM merged satellite imagery. At 151 points, the cover type mapped by the satellite image was compared to the cover type interpreted using 1:15,000 scale black and white air photos.

	Satellite Image							
Airphoto	**Forb**	**Shrub**	**Forest**	**Bare**	**Total**	**Correct**	**Omission**	**Commission**
Forb	16	28	0	1	45	35.6%	64.4%	52.9%
Shrub	16	35	2	0	53	66.0	34.0	52.7
Forest	1	10	23	0	34	67.6	32.4	8.0
Bare	1	1	0	17	19	89.5	10.5	5.6

Aspect and slope values were obtained from digital 1:20,000 scale Terrain Resource Information Management (TRIM) files with 50-m pixel size (Surveys and Resource Mapping Branch 1992). Logging road and cutblock locations were obtained from digital forest cover maps. Logging roads included all mainline, secondary and tertiary unpaved roads, but spurs were omitted because very few were drivable. Vehicle traffic levels on these roads were not measured, but most secondary and tertiary roads likely received < 2 vehicles per day. No roads were intentionally closed to the public. Cutblocks were defined as all areas where timber had been harvested and the regenerating stand was < 10 m tall. All cutblocks had been clear cut and regenerated using either manual planting or natural regeneration techniques.

Because the number of telemetry locations for each grizzly bear within an avalanche chute was small but the number of bears sampled was large, I pooled the telemetry locations across bears as suggested by Manly *et al*. (1993:5). The results of the analyses are therefore pertinent at the population level. To account for error in the UTM co-ordinates assigned to each telemetry location, I created a circular buffer with a 264 m radius around each telemetry location. Within each buffer I recorded the following values: proportion Grass-forb, proportion Shrub; proportion Forest; proportion Bare soil-rock; mean aspect; mean slope; linear distance from the center point of the buffer to the nearest logging road; presence or absence of a cutblock within the buffer. The proportions of each cover type within each buffer were calculated by first excluding unclassified pixels.

I generated random points and associated 264 m buffers to estimate the characteristics of avalanche chutes available to grizzly bears. I first defined the parts of the study area that were available to radio-collared grizzly bears by delineating the composite 95% adaptive kernel home range (Worton 1989) using all spring season telemetry locations across all bears, including those not associated with avalanche chutes (program Home Ranger, F.W. Hovey 1999). Random points were then generated within the avalanche chutes in the composite home range. The number of random points plotted was proportional to the total area represented by these avalanche chutes (i.e. 1 random point per 1 km^2 of avalanche chutes).

Although telemetry locations were distributed throughout the study area, the spatial extents of the various digital maps depicting the variables used in these analyses did not always cover the entire study area, nor were they identical. The TRIM map (variables: aspect and slope) covered the entire study area, the satellite image (variable: cover types) omitted the south-east portion of the study area, and digital forest cover maps (variables: logging road and cutblock) did not include areas within national parks. Therefore, each univariate analysis used only those telemetry locations and random points that were contained within the corresponding map boundaries. The multivariate analysis used only those locations and points that coincided with the area where all digital maps overlapped (Table 2).

Table 2. Characteristics of samples used for habitat selection analyses involving telemetry locations and randomly plotted points within avalanche chutes.

Analysis	Variable	# Points (Use+Random)	# Bears	# Points / Bear mean	SD	range
Goodness of fit	Aspect, Slope	715 (342+373)	44	7.7	5.3	1 to 20
	Roads, Cutblocks	519 (157+362)	35	4.5	4.1	1 to 20
	Cover Types	572 (292+280)	41	7.1	5.4	1 to 20
Logistic regression	All variables	249 (117+132)	33	3.5	2.9	1 to 11

Feeding and Bedding Activity Within Avalanche Chutes

From 1996 to 1998, a sample of telemetry locations that were directly within or < 100 m from avalanche chutes was investigated on the ground. Ground investigations occurred within five days of the corresponding telemetry location. Much of the study area was unroaded and thus investigation of a predetermined random sample of telemetry locations was logistically difficult. Effort was made to eliminate sampling bias by using a helicopter when funding permitted.

At each ground investigation, I searched for evidence of grizzly bear feeding and bedding activity in the avalanche chute, and in the adjacent forest to a distance of 100 m from the avalanche chute / forest edge. Evidence of feeding included stems of grasses and forbs that were grazed, and overturned soils where excavations for bulbs or corms occurred. Beds were typically depressions in the soil equal in size to a sleeping grizzly bear, that contained grizzly bear hair and often flattened vegetation. I ensured that the feeding or bedding activity recorded was likely attributable to the focal grizzly bear by noting the age of the activity and other evidence such as tracks, hair, and scat. When appropriate evidence of feeding or bedding was found, I established a 100-m^2 circular plot centered on the activity. The slope, aspect and a visual estimate of the percent ground cover of all plant species within the plot were recorded. Visual cover, defined here as the degree to which a grizzly bear was visually concealed from potential aggressors, was estimated using a cover pole (Griffiths and Youtie 1988). Feeding typically occurred at many points within the avalanche chute where the focal bear was located, but only a single plot was established for each investigation to avoid non-independence of samples. For investigations where scat was found (67 %), the plot was established at the feeding site nearest to the scat, as scat is presumably deposited randomly. For the remainder of the investigations, I subjectively established the plot at the feeding site that best represented the majority of the entire feeding bout in terms of the variables that I measured.

I also estimated the forage value at each plot to test the assumption that forage value is an appropriate indicator of avalanche chute habitat importance (Mace and Bissell 1984, Jamieson 1998, Quinn and Phillips 2000). Forage value was a function of two factors; forage quantity and forage quality. Forage quantity was represented by the percent ground cover of each known forage species. Forage quality was estimated by the concentration of digestible energy and digestible protein of the species. Forage species were identified from published literature (Simpson *et al*. 1985, McLellan and Hovey 1995) and field observations (Table 3). I grouped all forage species into five major forage types; Glacier Lily (*Erythronium grandiflorum*), Cow Parsnip (*Heracleum lanatum*), horsetails (*Equisetum* spp.), grasses and sedges (*Poaceae* and *Cyperaceae*) and palatable forbs (the remaining forage species that are eaten less frequently). I collected samples of each forage type from avalanche chutes during the spring season which were analyzed for digestible energy and digestible protein content using methodology outlined by Pritchard and Robbins (1990). The digestible energy and digestible protein values obtained for each forage type were indexed so that the forage type with the highest energy or protein value received a value of 1. The energy and protein indices were then averaged for each forage type to arrive at the relative forage quality index of each forage type. The quantity of each forage type (percent ground cover) within each plot was then multiplied by the forage quality index, and the sum taken over all forage types to arrive at the forage value index of each plot.

Table 3. Forage species used by grizzly bears at 41 feeding sites in avalanche chutes during the spring season; Columbia Mountains, 1996-1998. Several species were often used at a single site.

Forage Species	# (%) Of Sites Where Eaten
Cow Parsnip (*H. lanatum*)	16 (39)
Glacier Lily (*E. grandiflorum*)	15 (37)
Graminoids (*Poaceae* and *Cyperaceae*)	8 (20)
Sitka Valerian (*Valeriana sitchensis*)	7 (17)
Stinging Nettle (*Urtica dioica*)	4 (10)
Spring Beauty (*Claytonia lanceolata*)	3 (7)
Sweet-scented Bedstraw (*Galium triflorum*)	2 (5)
Mountain Sweet-cicely (*Osmorhiza chilensis*)	2
False Solomon's-seal (*Smilacina racemosa*)	2
Queen's Cup (*Clintonia uniflora*)	1 (2)
Twisted Stalk (*Streptopus* spp.)	1
Fringecup (*Tellima grandifora*)	1
Western Meadowrue (*Thalictrum occidentale*)	1
Indian Hellebore (*Veratrum viride*)	1

I estimated the availability of the categories within each variable by placing plots randomly within avalanche chutes. Due to access constraints, these plots were not situated completely randomly. All avalanche chutes accessible by roads or short hikes (< 2 km) were identified on 1:40,000 scale air photos. Avalanche chutes were randomly selected from this subset and three plots were placed within each. Plot locations were determined by outlining each selected chute on a 1:15,000 scale air photo and dividing it into three equal sections elevationally. A single plot was established within each section by travelling to its center and moving away from it at a randomly chosen bearing and distance, without leaving the section. The same measurements that were recorded at the grizzly bear feeding plots were recorded at these random plots.

Analysis Methods

I tested for differences in the frequency of avalanche chute use between male and female, and between adult (> 5 years old) and subadult (2 to 5 years old) grizzly bears using two-sample *t* tests of arcsine transformed data (Zar 1984: 239,126). For both habitat selection and feeding and bedding analyses, I compared grizzly bear use data with random data using univariate and multivariate methods. For univariate analyses, I grouped each independent variable into categories and used the log-likelihood ratio (*G*) to test goodness of fit between grizzly bear use and random data (Zar 1984: 52). For variables that were significantly different at $p = 0.10$, I then calculated simultaneous 90%

Bonferroni confidence intervals to identify which categories, if any, grizzly bears were selecting (Mendenhall 1971:193).

For multivariate analyses, I used logistic regression (Menard 1995). This technique allowed me to assess the relative importance of each independent variable and to search for interactions among significant variables. The dependent variable was the logit of the predicted probability of a grizzly bear feeding at a site as a function of the independent variables included in the model. Because the true probability of sampling a grizzly bear use site versus a random site was unknown (i.e. the ratio of grizzly bear use sites to random sites sampled was a function of the study design), the true intercept of the regression equation was also unknown. However, the form of the regression equation remains valid and the magnitude and sign (±) of the independent variable coefficients reflect the relative strength and direction of the relationship between each independent variable and the dependent variable (Manly et al. 1993: 126). I built two models for each analysis. The initial model contained all independent variables. The final model included only those variables that were significant at $p < 0.10$ in the initial model. The statistical significance of the final model was assessed using Chi-square tests of the reduction in the log-likelihood (-2LL) between the intercept-only model and the fitted model, and the substantive fit of the model was judged using Nagelkerke's R^2 (Nagelkerke 1991). The strength and direction of the relationship between each independent variable and the dependent variable was assessed by the magnitude and sign of the unstandardized variable coefficients, and their statistical significance was assessed using the Wald statistic (Menard 1995: 39). All independent variables were initially screened for colinearity by calculating Pearson linear correlation statistics (Zar 1984: 306). Where correlation values > 0.80 were found, only the variable that was most significant when both variables were included in the model was ultimately used. I searched for nonlinear relationships between the dependant variable and each independent variable using the Box-Tidwell test (Menard 1995: 61). When nonlinearity was detected, I estimated the likely relationship by plotting the mean logit of each category of the independent variables delineated for the univariate analysis. I classified aspect values into four categories (N = 316^o to 45^o , E = 46^o to 135^o , S = 136^o to 225^o , W = 226^o to 315^o) and tested them as categorical contrasts with the north aspect as the standard category. Thus, coefficients for the remaining three aspect categories estimate their own effect on habitat selection relative to that of the north aspect category. The Bare soil-rock cover type was excluded from the logistic regression to avoid redundancy resulting from the proportions of the cover types within each buffer summing to 1. I used SPSS 9.0 software (SPSS Inc., Chicago, IL.) for logistic regression, correlation and *t* test analyses. I conducted goodness of fit tests manually.

RESULTS

Frequency of Avalanche Chute Use

Between 1994 and 1998, 1,596 telemetry locations were collected from 60 grizzly bears. In total, bears were located 661 times (41%) in avalanche chutes. Fifty-four percent (366/672) of all spring season telemetry locations and 32% (295/924) of all summer-fall telemetry locations were in avalanche chutes. Intensity of avalanche chute use peaked between June 15 and July 15, when approximately 60% of all telemetry locations were in avalanche chutes (Figure 2). Of the 60 grizzly bears that were tracked, 37 were located > 10 times during the spring season. Among these bears, the proportion of telemetry locations in avalanche chutes during the spring season ranged between 20% and 90% ($\bar{X}$ = 56% ± 18% [mean ± SD]) (Figure 4). No differences in the frequency of avalanche chute use between male and female bears ($t = 0.201$, df = 35, $p = 0.842$), or between adult and subadult bears ($t = 0.654$, df = 35, $p = 0.517$) in this sample were detected.

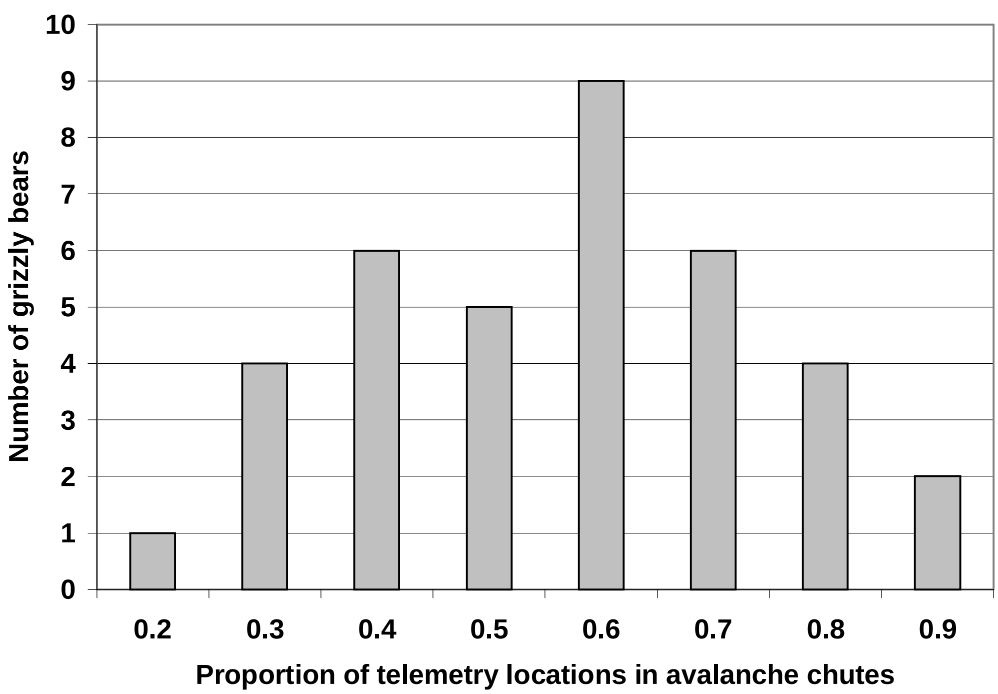

Figure 4. Variation in frequency of avalanche chute use by 37 grizzly bears in the Columbia Mountains, B.C., 1994-1998. Only bears with > 10 spring season telemetry locations were included in this analysis. The midpoint of each category is shown (e.g. 0.6 = represents proportions between 0.55 and 0.64).

Habitat Selection Within Avalanche Chutes

Results of goodness of fit tests suggested that grizzly bears used the categories within each variable disproportionately to their availability (Table 4). Grizzly bears selected south and east facing aspects and avoided north facing aspects within avalanche chutes (Figure 5). They also avoided very steep slopes (> 30º) and showed a trend towards selecting gentler slopes (Figure 5). Grizzly bears selected areas with abundant Grass-forb and Shrub cover types, and avoided areas with abundant Bare soil-rock (Figures 5). Bonferroni confidence intervals failed to detect selection or avoidance of any category within the Forest cover type, distance to logging road and presence / absence of cutblock variables. Trends towards increasing grizzly bear use with decreasing Forest abundance (Figure 5) and distance to logging road (Figure 5), and avoidance of areas in avalanche chutes with adjacent cutblocks were observed (Figure 5).

Table 4. Results of Goodness of fit (G) tests describing grizzly bear selection of habitat within avalanche chutes in the Columbia Mountains, B.C., 1994-1998.

Variable	Sample size (n)	Goodness of fit (*G*)	*P*
Aspect	715	48.83	< 0.01
Slope	715	19.14	< 0.01
Distance to logging road	519	10.65	0.01
Adjacent cutblock	519	3.28	0.07
Forest cover type	572	15.50	< 0.01
Shrub cover type	572	30.80	< 0.01
Grass-forb cover type	572	45.90	< 0.01
Bare soil-rock cover type	572	17.10	< 0.01

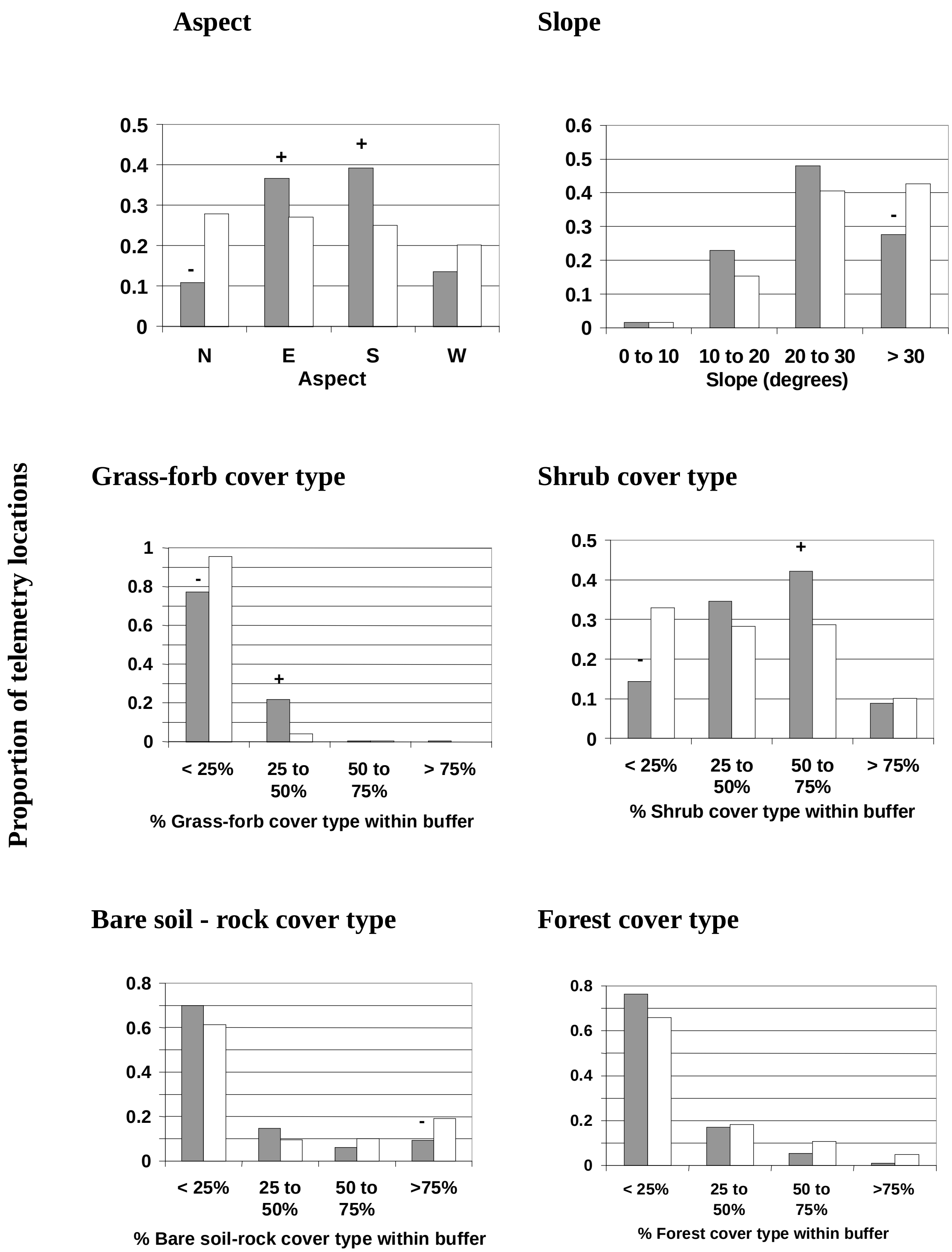

Figure 5. Grizzly bear selection of habitat characteristics within avalanche chutes in the Columbia Mountains, B.C., 1994-1998. 90% Bonferroni confidence intervals were used; "+" indicates selection, "-" indicates avoidance (■ = grizzly bear use, □ = available).

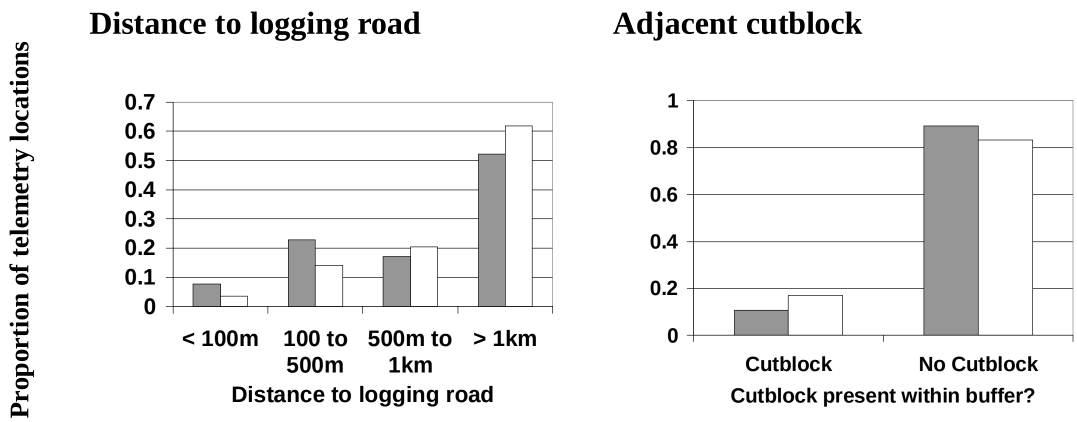

Figure 5. Continued

Aspect, Shrub cover type, Grass-forb cover type, and distance to logging road were the only variables included in the final logistic regression model (Table 5). Although the model was statistically significant (-2LL = 43.60, df = 6, $p < 0.0001$), it fit the data poorly ($R^2 = 21.4$). Sixty-eight percent of the observations were correctly classified (61% telemetry points, 73% random points). The probability of a grizzly bear using an area within an avalanche chute increased strongly with increasing amount of Grass-forb cover type. A positive, but weaker relationship between increasing amount of Shrub cover type and decreasing distance to logging roads was also demonstrated. Grizzly bears selected east facing habitat, but selection for south facing habitat was not shown. This analysis failed to detect selection of south aspect because it used a subsample of the univariate data (only those points that were included by all 3 digital maps were used) which did not include three grizzly bears that used avalanche chutes almost exclusively (these bears resided in Glacier National Park, which was not included by digital forest cover maps). The amount of Forest cover type, the average slope of the habitat and the presence of an adjacent cutblock had little influence on the habitat selection process. The Grass-forb cover type by aspect interaction term that was added to the model was not significant ($p = 0.20$).

The observed selection of Shrub cover type in both analyses was likely an error. Approximately 62% of the Grass-forb cover type was incorrectly mapped as Shrub cover type by the satellite image (Table 1). Thus, much of the observed use of the Shrub cover type was actually use of Grass-forb cover type.

Table 5. Results of logistic regression analysis describing grizzly bear selection of habitat within avalanche chutes in the Columbia Mountains, B.C., 1994-1998 (n = 117 grizzly bear telemetry locations, 132 random points).

Variable	Coefficient (ß)	***P***
Aspect		0.03
South	0.26	0.54
East	1.05	0.01
West	0.73	0.14
Distance to logging road	- 0.02	0.05
Amount of Shrub habitat	1.46	0.02
Amount of Grass-forb habitat	5.05	< 0.01

East and south facing avalanche chutes contained more Grass-forb and Bare soil-rock cover types than north and west facing avalanche chutes (Figure 6). All cover types were more abundant on steep slopes (> 20°) than gentler slopes (Figure 6), likely due to the preponderance of steep slopes in avalanche chutes.

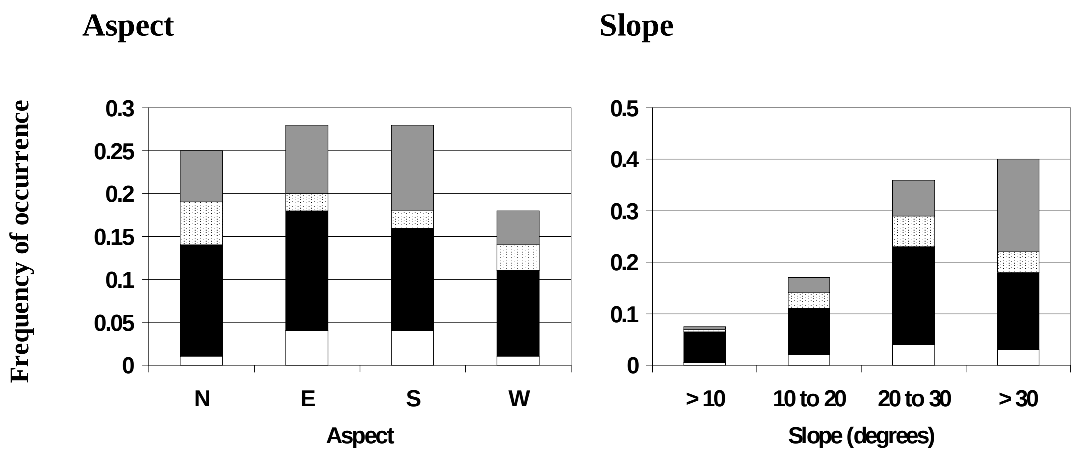

Figure 6. Frequency of cover type occurrence on different aspects and slopes gradients within avalanche chutes in the Columbia Mountains, B.C. Proportions were estimated using the 132 random points plotted in avalanche chutes for the logistic regression analysis
Bare soil-rock, Forest, Shrub, Grass-forb

<u>Feeding and Bedding Activity Within Avalanche Chutes</u>

I investigated 49 grizzly bear telemetry locations on the ground. I found feeding activity at 41 investigations (84%) and bedding activity at 13 (27%). Seven cases had both feeding and bedding activity. I found no evidence of either activity at only 2 (4%) of the investigations, and no measurements were recorded in these cases.

Grizzly bears fed on many species of herbaceous vegetation, most frequently cow parsnip and glacier lily (Table 3). Feeding on other potential food sources, such as ungulates and invertebrates, was not detected. I compared the characteristics of the 41 feeding sites to those of the 45 random sites. Results of goodness of fit tests suggested that feeding activity was influenced by the abundance of shrubs, grasses and forbs, forage value and aspect (Table 6). Grizzly bears avoided feeding sites dominated by

Table 6. Results of goodness of fit tests (*G*) comparing grizzly bear feeding sites to random sites within avalanche chutes in the Columbia Mountains, B.C. 1996-1998 (n = 41 feeding sites, 45 random sites).

Variable	Goodness of fit (*G*)	***P***
Shrub abundance	12.48	< 0.01
Grass and forb abundance	21.04	< 0.01
Forage value	42.17	< 0.01
Visual cover	5.85	0.12
Slope	2.64	0.45
Aspect	6.27	0.09

shrubs (i.e. > 75% shrub abundance) and selected sites with lower shrub abundance (Figure 7). Grass and forb abundance (which included glacier lily) was highly correlated with forage value ($r^2 = 0.894$) and the majority of sites available in avalanche chutes support a low quantity (< 25% cover) of grasses and forbs, and consequently minimal forage value (i.e. forage value index < 10). Foraging grizzly bears avoided these sites and selected those rare sites with high grass and forb abundance and high forage values (Figure 7). Most (79%) grizzly bear feeding activity was found on south and east aspects. South aspects were selected and north aspects were avoided (Figure 7). General patterns were also evident for the remaining variables. Sixty-one percent of all random sites in avalanche chutes had visual cover values > 75% (i.e. > 75% of the cover pole was concealed from view). Although grizzly bears used these site frequently, they tended to select sites with less visual cover (Figure 7). Because visual cover is correlated with shrub abundance ($r^2 = 0.569$), this result is consistent with the observed avoidance of sites that have very high shrub abundance. Sites with gentle slope gradients (<10°) were used much more frequently than expected, but most feeding sites occurred on steeper slopes (Figure 7).

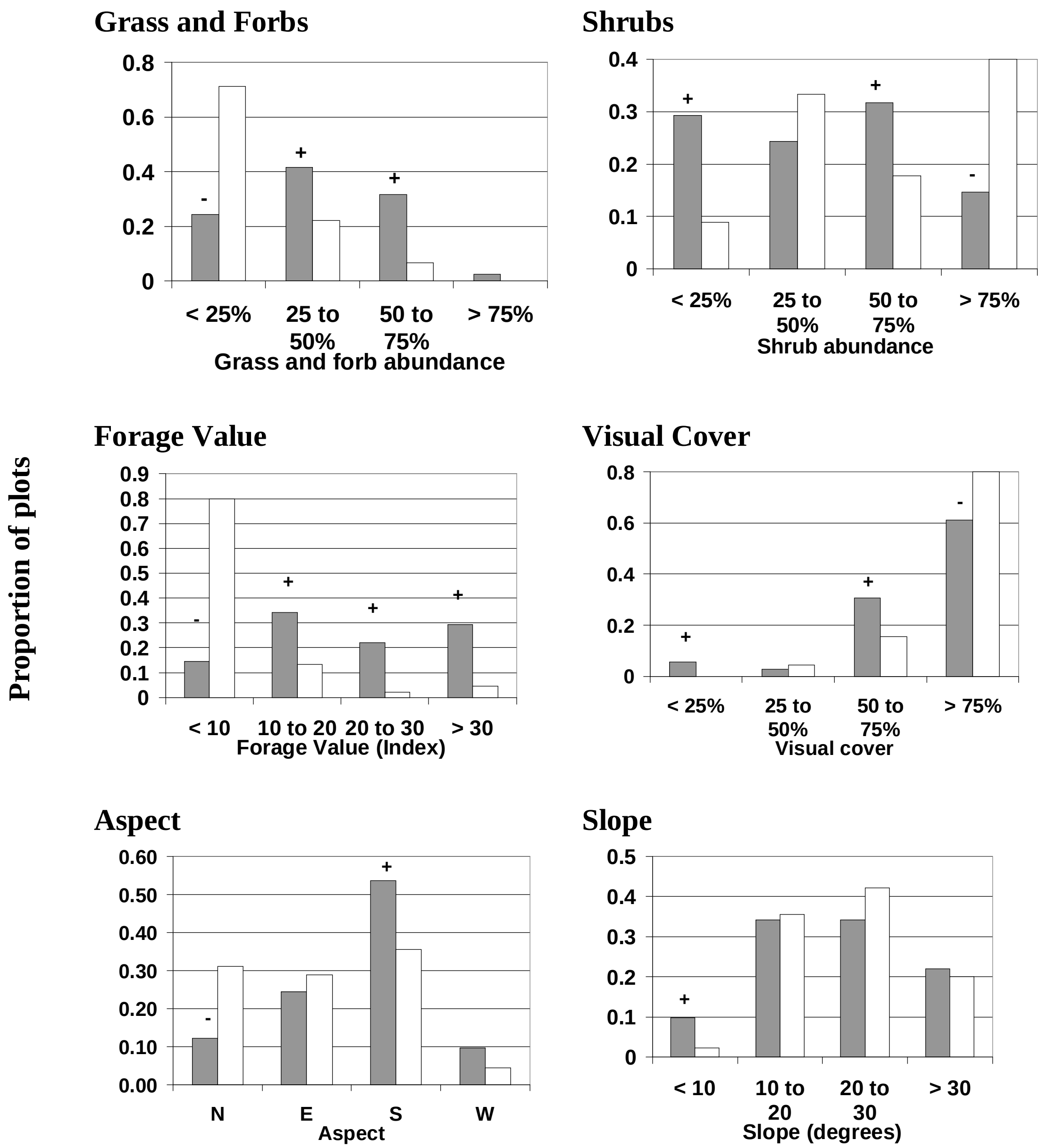

Figure 7. Grizzly bear feeding site selection patterns within avalanche chutes in the Columbia Mountains, B.C., 1996-1998. 90% Bonferroni confidence intervals were used. "+" indicates selection, "-" indicates avoidance (n = 41 feeding sites, 45 random sites) (■ = feeding sites, □ = random sites).

I excluded grass and forb abundance from the logistic regression model because of high colinearity with forage value and transformed the forage value variable into its natural logarithm to correct for nonlinearity in the logit. Forage value and visual cover were the only variables that were included in the final model (Table 7). The model provided a good fit to the data (-2LL = 65.7, df = 2, $p < 0.0001$, $R^2 = 57.7$). Eighty-six percent of the observations were correctly classified (89% random sites, 83% feeding sites). The probability of a grizzly bear selecting a site to feed at increased strongly with increasing forage value but decreased slightly with increasing visual cover. Shrub abundance, slope and aspect had virtually no influence on the feeding site selection process beyond what was accounted for by forage value and visual cover.

The model which included the interaction term forage value by visual cover fit the data well (-2LL = 61.8, df = 3, $p < 0.001$, $R^2 = 61.2\%$). The interaction term was significant, and had a weak positive association with feeding site selection (ß = 0.08, Wald = 4.00, df = 1, $p = 0.05$).

Table 7. Logistic regression analysis comparing 41 grizzly bear feeding sites to 45 random sites within avalanche chutes in the Columbia Mountains, B.C., 1996-1998. The natural logarithm of forage value was used in the regression to correct nonlinearity in the logit, but the co-efficient has been back-transformed into original units.

Variable	Coefficient (ß)	*P*
Forage value	82.87	< 0.01
Visual cover	-0.05	0.01

Too few grizzly bear beds were found to detect bed site habitat selection patterns. However, general trends in use of bed sites were observed. Five beds (38.5%) were found in forests directly adjacent to avalanche chutes. All of these were located < 25 m from the avalanche chute / forest edge. Of the 8 beds (61.5%) found directly within an avalanche chute, 2 were in areas dominated by alder shrubs approximately 2 m in height, 1 was in a forb dominated area, and 5 were in areas of interspersed shrubs and forbs. Most beds were located on south facing sites (south = 9 / 13, east = 3 / 13, west = 1 / 13, north = 0 / 13). Beds were frequently found on moderately steep slopes ($\bar{X}$ = 23° ± 6°, range = 8° to 38°), though in all cases the bed was situated on a small flat microsite often no larger than the bed itself.

DISCUSSION

Frequency of Avalanche Chute Use

Avalanche chutes were an important spring season habitat for grizzly bears in the Columbia Mountains. They represented approximately 15% of the study area (Munro 1999), but accounted for a much higher proportion of the spring season telemetry locations. In early spring, grizzly bears often used valley bottom riparian habitat adjacent to avalanche chutes. Increasing use of avalanche chutes coincided with increasing availability as snow receded. During the peak period of use between mid-June and mid-July, virtually all vegetated areas within avalanche chutes were available to grizzly bears. Lower intensity of use throughout the summer-fall season was caused by a shift in diet. During the summer-fall season, grizzly bear diet was dominated by berries (*Shepherdia* *canadensis* and *Vaccinium* spp.) which occurred infrequently in avalanche chutes (unpub. data).

The frequency that grizzly bears used avalanche chutes relative to other habitats during spring was likely the result of the prevalence of avalanche chutes across the landscape, their high forage productivity, and a deficiency of alternative habitat. Heavy snowfall in the study area combined with steep slopes created a landscape with numerous avalanche chutes supporting many plant species eaten by grizzly bears. This in itself would have resulted in frequent use of avalanche chutes during the spring season. The lack of alternative spring season habitat in the study area likely further increased their use. Previous studies have identified riparian habitat as an important alternative spring habitat (Servheen 1983, Zager *et al*. 1983, Simpson *et al*. 1985, Schoen and Beier 1990, MacHutchon *et al*. 1993, McLellan and Hovey 2001). A large portion of the riparian habitat in the study was found in the wide bottomed Columbia River Valley. Because this valley is subjected to extensive human settlement, grizzly bears were largely restricted to the surrounding narrow valleys with little riparian habitat.

The frequency of avalanche chute use during spring varied among individual grizzly bears. This could not be explained by differing use between sex or age classes. Intensity ranged from bears that used avalanche chutes approximately equal to their availability, to bears that used avalanche chutes almost exclusively. Grizzly bears that used avalanche chutes relatively infrequently were observed using forests and natural burns instead (unpub. data). Previous studies that examined habitat selection patterns among individual grizzly bears also noted substantial variation among individuals (MacHutchon *et al* 1993, Mace *et al*. 1996, Mattson 1997a, McLellan and Hovey 2001).

Grizzly bears are long-lived, widely ranging and intelligent animals and differences in behaviour among individuals is expected even within a single study area (Herrero 1978, Stirling and Derocher 1990).

Habitat Selection and Feeding and Bedding Activity Within Avalanche Chutes

Grizzly bears in the Columbia Mountains used avalanche chutes intensively because of the foraging opportunities available within avalanche chutes. Most telemetry locations investigated on the ground revealed evidence of feeding activity. As a result, the habitat selection patterns documented using telemetry data reflected where grizzly bears chose to feed.

The location of grizzly bear feeding sites within avalanche chutes was most strongly influenced by forage value. This result was expected, as reproductive parameters such as litter size, age at first reproduction and breeding interval are positively correlated with the nutritional status of female grizzly bears (Bunnell and Tait 1981, Knight and Eberhardt 1985, McLellan 1994). As grasses and forbs provided the only source of forage within avalanche chutes, grizzly bear feeding sites had more grasses and forbs than expected by availability. Thus, strong selection of the Grass-forb cover type was associated with the abundance of forage species that it contained.

In contrast to the Grass-forb cover type, the Shrub, Bare soil-rock and Forest cover types typically contained minimal forage and were used rarely. As noted previously, apparent selection of the Shrub cover type was likely an error due to misclassification in the satellite image. The availability of potential feeding sites dominated by shrubs (>75% shrub abundance) was much greater than how frequently grizzly bears used these sites. However, grizzly bears did use areas with substantial shrub abundance for feeding activity in two ways. First, more than half of all feeding activity occurred at sites that contained between 25% and 75% shrub abundance. These sites were frequently found along the transition between the Grass-forb and Shrub cover types, and were almost always mapped as the Shrub cover type. Their high frequency of use was attributable to moderate forage value and high visual cover provided at these sites. Second, some nutrient rich and moist sites dominated by shrubs (> 75% shrub cover) also supported food species such as Cow Parsnip and Glacier Lily. Fifteen percent of all feeding activity sites sampled were found in these areas. Shrub dominated sites supporting an abundance of food have also been noted in the Columbia Mountains by Quinn and Phillips (2000: 46), in southeastern B.C. by Vandehay (1991: 67) and in northwestern Montana by Mace and Bissell (1986). Substantial grizzly bear feeding activity at sites with both shrubs and an herbaceous understory demonstrate the importance of both forage and visual cover to grizzly bears. The significant positive interaction term between forage value and visual cover indicates that visual cover compensates for lower forage value at sites where both factors are available.

My results support the assumption that forage value is an appropriate indicator of avalanche chute habitat quality (Mace and Bissell 1984, Jamieson 1998, Quinn and Phillips 2000), but suggest that visual cover should also be incorporated. Although forage value was the most important factor influencing feeding site selection, grizzly bears made substantial use of feeding sites that contained moderate forage value and high visual cover.

Selection of east and south aspects by grizzly bears was probably caused by greater availability of the Grass-forb cover type on these aspects than on north and west aspects. Further, east and south aspects have higher cumulative daily temperatures than north and west aspects (Geiger 1971) and were free of snow earlier. The non-significance of the aspect by Grass-forb cover type interaction did not support this observation, but the small sample of early spring telemetry points in the database may have precluded a significant result.

Slope gradient was not a significant factor in either habitat selection or feeding activity analyses, as grizzly bears used a wide variety of slopes. Trends towards selecting gentler slopes were observed, but the majority of both feeding activity and telemetry locations were located on slopes > 20°. Use of steep slopes was likely due to greater overall availability of the Grass-forb cover type on steep slopes than on gentle slopes. It appears that grizzly bears were not limited to using the lower runout zones of avalanche chutes but instead made use of all parts. Similar results were reported by both previous studies that considered which parts of avalanche chutes grizzly bears used. Korol (1994: 91) found that of 96 telemetry locations in avalanche chutes, 41%, 31% and 27% were in the upper start zones, tracks, and lower runout zones respectively. Servheen (1983) noted that more telemetry locations were in the start zones than in the runout zones.

Grizzly bears used a wide array of habitat features for bedding. In particular, beds were found in both the forest adjacent to avalanche chutes and in the avalanche chutes themselves. This result may explain why substantial use of the Forest cover type was not detected. Data on grizzly bear bed sites associated with avalanche chutes in the Flathead River Valley in southeastern British Columbia support this trend. Five of 11 beds (45%)

were found directly within avalanche chutes and the remainder were found in adjacent forest (B. McLellan, unpub. data). In the Columbia Mountains, Simpson *et al*. (1985) observed 32 beds in the spring season and noted that 24 (75%) were in forest < 100 m from foraging areas. They also observed 3 instances of grizzly bears bedding on patches of snow in avalanche chutes, presumably to avoid heat stress. Less flexibility in bedding habitat was described by Blanchard (1983), and Mysterud (1983) in studies that did not focus exclusively on avalanche chutes. These authors found that 99% of 233 beds and 94% of 119 beds respectively, were located in forested habitat. The results of my study, and those of McLellan (unpub. data) and Simpson *et al*. (1985), suggest that grizzly bears using avalanche chutes are not entirely reliant on adjacent forest for bedding, but frequently find suitable bedding habitat directly within avalanche chutes themselves. Further, the frequency with which beds were found in areas of interspersed shrubs and forbs and on steep slopes underscores the importance of these areas to grizzly bears.

The potential for cutblocks and vehicle traffic on logging roads to displace grizzly bears from avalanche chute habitat is of interest to wildlife managers. Grizzly bears in my study selected areas within avalanche chutes that were close to logging roads. This result contradicts those of Zager *et al.* (1983), Archibald *et al.* (1987), McLellan and Shackleton (1988), and Kasworm and Manly (1990), who found that grizzly bears avoided habitat adjacent to logging roads. Traffic volumes on logging roads in this study area were not measured. However, my personal observations indicated that vehicle traffic on logging roads outside of the Columbia River Valley was largely restricted to mainlines and a few secondary roads. These roads led to areas of consistent human activity, such as active logging and tree planting operations, and popular trail heads. The majority of logging roads that traversed avalanche chutes, however, were secondary and tertiary roads which likely received < 2 vehicles / day. Although McLellan and Shackleton (1988) noted that even small levels of vehicle traffic displaced grizzly bears from adjacent habitat, Zager *et al.* (1983), Archibald *et al.* (1987), and Kasworm and Manly (1990) found that the degree of displacement was influenced by the level of vehicle traffic. The lack of grizzly bear avoidance of logging roads in my study was likely caused by low traffic volume on most logging roads that traversed avalanche chutes. With little traffic on logging roads, habitat close to logging roads may have been selected because grizzly bears may have used roads for travel. Zager (1980: 79) noted that grizzly bear sign was occasionally found on secondary and closed roads in his study area, but rarely on mainline roads. I did not find evidence of substantial use of logging roads by grizzly bears in this study area but cannot rule out the possibility. Selection of areas close to logging roads may also have been due to the proximity of logging roads to the Grass-forb cover type. Many logging roads, particularly secondary and tertiary logging roads, were routed across slopes > 20° in this study area. These areas contained the majority of the Grass-forb cover type frequently used by grizzly bears.

Marginally significant avoidance of areas in avalanche chutes with an adjacent cutblock was detected in the univariate analysis. Seventeen percent of all random buffers contained cutblocks compared to 11% of buffers around grizzly bear telemetry points. Cutblocks can displace bears from adjacent avalanche chute habitat through short and long term mechanisms. In the short term, logging crews can displace bears when they are working. Mattson *et al*. (1987), Waller (1992), and Mace and Waller (1996) documented grizzly bears avoiding areas where localized human activity occurred. Other authors have found no evidence of displacement (Simpson *et al*. 1985, McLellan and Shackleton 1989). I was unable to address short term displacement of grizzly bears in this study. The potential long term effect of timber harvest derives from the removal of adjacent forest which may serve as escape cover for grizzly bears using avalanche chutes. Escape cover is defined here as habitat into which a grizzly bear can flee when threatened. Blanchard (1983), Zager *et al*. (1983) and Mattson (1997b) documented grizzly bears avoiding areas > 100 m from forest edges, presumably to remain close to escape cover. By increasing the distance to escape cover, cutblocks may deter grizzly bears from using the areas in avalanche chutes adjacent to them. The results of my study tentatively support this conclusion.

MANAGEMENT IMPLICATIONS

The current strategy for managing grizzly bear avalanche chute habitat in southeastern British Columbia is contained in the Kootenay / Boundary Land Use Plan Implementation Strategy (KBLUP) (Kootenay Inter-Agency Management Committee 1997). This regional-scale land use plan was developed over several years and involved professional forest and wildlife managers and representatives from industry and special interest groups. Management recommendations resulting from the present study are framed within the KBLUP context, and incorporate recommendations made by Mowat and Ramcharita (1999) in a recent review of grizzly bear habitat management issues in southeastern British Columbia.

It should be noted that management recommendations resulting from this thesis are pertinent only to areas of the Kootenay Region with similar climate and terrain. Unpublished data from the Flathead Valley, southeastern B.C., indicate that the vegetation patterns within avalanche chutes and grizzly bear use of avalanche chutes in that area are substantially different from those patterns documented in the Columbia Mountains (B.McLellan and R. Ramcharita unpub. data).

Mapping Habitat Within Avalanche Chutes

Mapping avalanche chute habitat can be accomplished using satellite imagery (Sidjak and Ramcharita *in prep*), and / or visual interpretation of 1:15,000 scale black and white air photos (Mowat 2000). Satellite images cover large areas and are relatively inexpensive to use, but they identify only general cover types within avalanche chutes, and provide less accuracy than air photo interpretation. The SPOT / Landsat 5 satellite image used in this study misclassified a substantial amount of the Grass-forb cover type, frequently classifying it as Shrub cover type. Landsat 7 satellite imagery has recently become available and work is underway to assess whether this imagery can provide a more accurate map of cover types within avalanche chutes than that provided by the SPOT / Landsat 5 image (Sidjak and Ramcharita *in prep*). The overall goal of this work is to provide an inexpensive and accurate map of avalanche chute habitat at the forest district and regional scales.

Visual air photo interpretation enables detailed vegetation classes to be identified within avalanche chutes with high classification accuracy (Mowat 2000). Mowat (2000) provides a methodology for mapping cover types within avalanche chutes in the Kootenay Region using visual air photo interpretation. Because of the amount of labour involved with the interpretation process, this method is ideally suited to mapping at the drainage and sub-drainage scales.

Ranking Habitat Within Avalanche Chutes

Once cover types have been identified by satellite images and / or air photos, they can be ranked using the results of this study. As mentioned above, the results of this study may not be applicable in other, climatically different areas in the Kootenay Region. Forage value is clearly the most important factor, but grizzly bears also select areas with less forage value but high visual cover. The following suggestions for ranking habitat reflect these results.

1) Cover types dominated by grasses and other forage species with little shrub cover are strongly selected and should be designated as high quality habitat.
2) Grizzly bears also made substantial use of areas with interspersed shrubs and grasses / forbs (i.e. between 25% and 75% shrub abundance with an understory of grasses and forbs), where forage value was moderate but visual cover was high. Feeding and bedding activity was frequently found in these areas, and they should also be designated as high quality habitat. These sites can be mapped on air photos but not on satellite images.

3) Moist and nutrient rich shrub-dominated sites (i.e. > 75% shrub abundance) within avalanche chutes supporting understory forage species were also used and should also be designated as high quality habitat. These sites are difficult, if not impossible to map using either methodology. Field inspection of shrub dominated sites for forage species should occur during the early to mid spring season before Glacier Lily and Spring Beauty senesce.
4) The majority of shrub dominated sites supported minimal understory forage. These sites and areas of bare soil and rock were rarely used by grizzly bears and should be designated low quality habitat.
5) This study was unable to explicitly address the relative quality of more detailed habitats that can be mapped using air photo interpretation. Similarly, site visits by wildlife managers prior to logging road and cutblock implementation will reveal much more variation in the vegetation patterns within avalanche chutes than was represented by the broad classes included here. In these situations, relative habitat quality should be estimated on the basis of forage value, but should also acknowledge that high visual cover compensates for lower levels of forage value. Field inspections should occur early to mid spring.
6) Habitat types with abundant food and visual cover should be designated as high quality habitat regardless of the aspect or slope gradient where they occur. Selection of east and south aspects was due to the greater availability of the Grass-forb cover type on these aspects and not a greater intensity of use

per unit area. Similarly, grizzly bears used the Grass-forb cover type over the entire range of slope gradients.

Conserving Avalanche Chute Habitat

The KBLUP recommends establishing buffer zones around entire avalanche chutes that are important to grizzly bears. These buffer zones vary in width from 50 m around important avalanche chutes which are situated in areas with > 2 chutes / km or < 500 m between chutes, to 100 m around important avalanche chutes which are situated in areas with < 2 chutes / km or > 500 m between chutes. Partial cutting systems that remove approximately 20% of the basal area within the buffer can be used on one side of the avalanche chute. Observations of grizzly bears using avalanche chutes in this study have resulted in the following refinements to the KBLUP guidelines:

1) Buffer zones need not be established around entire avalanche chutes. Although grizzly bears were observed using all parts of avalanche chutes across the landscape (i.e. start zones, tracks and runout areas), they used only specific areas within individual avalanche chutes. Cover types within avalanche chutes containing high to moderate combinations of forage value and visual cover are intensively used and can occur anywhere in an avalanche chute. Buffer zones can be focused on these areas and may satisfy grizzly bear preference for nearby escape cover. Buffer zones should extend a minimum of 50 m elevationally above and below these areas to ensure full access to escape cover.

2) Buffer zone width should be contingent upon the density of avalanched terrain in the opposite manner than is suggested in the KBLUP. Avalanche chutes which occur as part of large avalanche chute complexes (i.e. > 2 chutes / km or < 500 m between chutes) should have buffer zones at least as wide as suggested for avalanche chutes that occur in isolation (i.e. < 2 chutes / km or > 500 m between chutes). Escape cover in avalanche chute complexes may already be limited due to infrequent forest adjacent to avalanche chutes. Further reduction in adjacent forest availability may discourage grizzly bears from using these areas. This reinforces the recommendation of McLellan and Hovey (2001) to avoid developing the upper portions of drainages that contain an abundance of avalanche chutes and minimal forest.

3) No data are available to evaluate how wide a buffer zone should be, and whether partial cutting within the buffer should be permitted. Buffer zone widths and the suitability of partial cutting within buffer zones as prescribed by the KBLUP were based on the professional judgement of experienced wildlife biologists. In the absence of data which suggest otherwise, buffer zones should be at least 50 m wide and removal of approximately 20% basal area could be permitted. However, all grizzly bear beds in adjacent forest were found < 25 m from the forest / avalanche chute edge. Only a small number of beds were found in this study, and it is possible that grizzly bears bed even farther than 25 m from the forest / avalanche chute edge. Thus, inorder to conserve bedding habitat, consideration should be given to prohibiting any timber removal in areas < 50 m from important habitats within avalanche chutes.

4) Logging roads should be routed with reference to the cover types within avalanche chutes and not just an avoidance of the lower runout zones. Grizzly bear activity was

noted in all parts of avalanche chutes, and a large portion of high quality habitat was found in the track and start zones. Logging roads could be routed > 100 m from high quality habitat types and vehicle traffic kept to a minimum.

5) Avalanche chutes are important habitat for many wildlife species in addition to grizzly bears (Jamieson 1998, Krajick 1998, Korol and Boulanger 1999). There is no basis for assuming that protection of areas within avalanche chutes or even entire avalanche chutes that are important to grizzly bears will provide sufficient habitat protection for other wildlife species. Although the recommendations provided here, in the KBLUP, and in Mowat and Ramcharita (1999) may maintain avalanche chute habitat for grizzly bears, a broader approach incorporating the requirements of other wildlife species should be undertaken given the increasing intensity of logging activity in areas dominated by avalanche chutes.

LITERATURE CITED

Archibald, W.R., Ellis, R. and Hamilton, A.N. 1987. Responses of grizzly bears to logging truck traffic in the Kimsquit River Valley, British Columbia. Int. Conf. Bear Res. and Manage. 7:251-257.

Blanchard, B.M. 1983. Grizzly bear - timber relationships in the Yellowstone area. Int. Conf. Bear Res. and Manage. 5:118-123

Braumandl, T.F. and Curren, M.P. 1992. A field guide form site identification and interpretation for the Nelson Forest Region. B.C. Ministry of Forests, Victoria, B.C. 311pp.

Bunnell, F.L. and Tait, D.E.N. 1981. Population dynamics of bears - implications. Pages 75-98 *in* C.W. Fowler and T.D. Smith, eds. Dynamics of large mammal populations. John Wiley and Sons, New York, NY.

Geiger, R. 1971. The climate near the ground. Harvard University Press, Cambridge Massachusetts. 609pp.

Griffiths, B. and Youtie, B.A. 1988. Two devices for estimating foliage density and deer hiding cover. Wildl. Soc. Bull. 16:206-210.

Herrero, S. 1978. A comparison of some features of the evolution, ecology and behaviour of black and grizzly / brown bears. Carnivore 1:7-17.

Jamieson, B., Adama, D. and Smith, P. 1998. Forest management input: avalanche path habitat classification. Report for Columbia Basin Fish and Wildlife Compensation Program. Nelson, B.C.

Kasworm, W.F. and Manley, T.L. 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. Int. Conf. Bear Res. and Manage. 8:79-84.

Kelley, C.C. and Holland, W.D. 1961. Soil survey of the Upper Columbia River Valley in the East Kootenay District of British Columbia. Report No. 7, British Columbia Soil Survey, British Columbia Department of Agriculture. 107pp.

Knight, R.R. and Eberhardt, L.L. 1985. Population dynamics of Yellowstone grizzly bears. Ecology 66:323-334.

Kootenay Inter-Agency Management Committee 1997. Kootenay / Boundary land use plan – implementation strategy.

Korol, B. and Boulanger, J. 1999. A preliminary vegetation classification of avalanche paths in the West Slopes Bear Study Area. Report for Columbia Basin Fish and Wildlife Compensation Program, Nelson, B.C. 107pp.

Korol, J.J. 1994. Classification of avalanche paths in northwestern Montana. Ph.D. thesis, Univ. Montana. 124pp.

Krajick, K. 1998. Animals thrive in an avalanche's wake. Science 279:1853.

Mace, R.D. and Bissell, G.N. 1986. Grizzly bear food resources in the flood plains and avalanche chutes of the Bob Marshall Wilderness, Montana. Pages. 78-91 *in* G.P. Contreras and K.E. Evans, eds. Proceedings – Grizzly Bear Habitat Symposium. USDA For. Serv., Gen. Tech. Rep. INT-207.

Mace, R.D. and Waller, J.S. 1996. Grizzly bear distribution and human conflicts in Jewel Basin Hiking Area, Swan Mountains, Montana. Wildl. Soc. Bull. 24:461-467.

Mace, R.D., Waller, J.S., Manley, T.L., Lyon, L.J. and Zuuring, H. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. J. Appl. Ecol. 33:1395-1404.

MacHutchon, A.G., Himmer, S. and Bryden, C.S. 1993. Khutzeymateen Valley grizzly bear study: final report. B.C. Min. Environment, Lands and Parks, Wildl. Rep. No. R-25. 105 pp.

Manly, B.F.J., McDonald, L.L. and Thomas, D.L. 1993. Resource selection by animal, statistical design and analysis for field studies. Chapman and Hall, London. 177pp.

Mattson, D.J., Knight, R.R. and Blanchard, B.M. 1987. The effects of developments and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. Int. Conf. Bear Research and Manage. 7:259-273.

Mattson, D.J. 1997a. Use of Lodgepole Pine cover types by Yellowstone grizzly bears. J.Wildl. Manage. 61:480-496.

Mattson, D.J. 1997b. Selection of microsites by grizzly bears to excavate Biscuitroots. J. Mammology 78:228-238.

McLellan, B.N. 1990. Relationships between human industrial activities and grizzly bears. Int. Conf. Bear Research and Manage. 8:57-64.

McLellan, B.N. 1994. Density-dependent population regulation of brown bears. Pages 15-24 *in* M. Taylor, ed. Density-dependent population regulation in black, brown and polar bears. Int. Conf. Bear Res. and Manage. Monograph Series no. 3. 43pp.

McLellan, B.N. and Hovey, F.W. 1995. The diet of grizzly bears in the Flathead River Drainage of southeastern British Columbia. Can J. Zool. 73:704-712.

McLellan, B.N. and Hovey, F.W. 2001. Habitats selected by grizzly bears in a multiple use landscape. Journal of Wildlife Management, *in press*.

McLellan, B.N. and Shackleton, D.M. 1988. Grizzly bears and resource-extraction industries: effects of roads on behaviour, habitat use and demography. J. Appl. Ecol. 25:451-460.

McLellan, B.N. and Shackleton, D.M. 1989. Grizzly bears and resource-extraction industries: habitat displacement in response to seismic exploration, timber harvesting and road maintenance. J. Appl. Ecol. 26:371-380.

Menard, S. 1995. Applied Logistic Regression Analysis. Sage University Paper series on Quantitative Applications in the Social Sciences, 07-106. Thousand Oaks, CA.

Mendenhall, W. 1971. Introduction to probability and statistics. Duxbury Press, Belmont, CA.

Mowat, G. 2000. Avalanche chute mapping using air photos: mapping and rating avalanche chutes for grizzly bears in the Kootenay Region of British Columbia. Report for British Columbia Min. Environment, Lands and Parks, Nelson, B.C. 14pp.

Mowat, G. and Ramcharita, R.K. 1999. A review of grizzly bear habitat use and habitat management options for the Kootenay Region of British Columbia. Report for British Columbia Min. Environment, Lands and Parks, Nelson, B.C. 34pp.

Mundy, K.R.D. and Flook, D.R. 1973. Background for managing grizzly bears in the national parks of Canada. Canadian Wildlife Service Report Series-No.22. 34pp.

Munro, R.H. 1999. The impacts of transportation corridors on grizzly and black bear habitat use patterns near Golden, B.C. M.Sc. Thesis, University of British Columbia. 55pp.

Mysterud, I. 1983. Characteristics of summer beds of European brown bears in Norway. Int. Conf. Bear Res. and Manage. 5:208-222.

Nagelkerke, N.J.D. 1991. A note on a general definition of the coefficient of determination. Biometrika 78:691-692.

Pritchard, G.T. and Robbins, C.T. 1990. Digestive efficiencies of grizzly and black bears. Can. J. Zool. 68:1645-1651.

Quinn, M.P. and Phillips, J. 2000. Avalanche paths in TFL 14: inventory, description, classification and management. Report for Crestbrook Forest Industries.

Resources Inventory Branch 1995. Relational data directory 2.0. British Columbia Ministry of Forests, Victoria, British Columbia, Canada.

Schoen, J. and Beier, L. 1990. Brown bear habitat preferences and brown bear logging and mining relationships in southeast Alaska. Alaska Dept. Fish and Game, Study No. 4.17. 90pp.

Servheen, C. 1983. Grizzly bear food habits, movements, and habitat selection in the Mission Mountains, Montana. J. Wildl. Manage. 47:1026-1035.

Sidjak, R. and Ramcharita, R.K. *in prep*. Mapping avalanche chute habitat in the Kootenay Region of British Columbia. Report for B.C. Min. Environment, Lands and Parks, Habitat Management Section, Nelson, B.C.

Simpson, K., Hebert, K.B. and Woods, G.P. 1985. Habitats and management of grizzly bear in the Columbia Mountains, British Columbia. B.C. Min. Environment., Fish and Wildlife Branch, Nelson, B.C., 48pp.

Stirling, I. and Derocher, A.E. 1990. Factors affecting the evolution and behavioural ecology of the modern bears. Int. Conf. Bear Res. and Manage. 8:189-204.

Surveys and Resource Mapping Branch 1992. British Columbia specifications and guidelines for geomatics. Content series vol. 3. Digital baseline mapping at 1:20,000. Release 2.0. B.C. Ministry of Environment, Lands and Parks, Victoria, British Columbia. 208pp.

United States Forest Service 1990. CEM - a model for assessing effects on grizzly bears. U.S. Forest Service, Northern Region, Missoula, Montana. 24pp.

Vandehay, A. M. 1991. Vegetative productivity of grizzly bear habitat components in southeastern British Columbia. M.Sc. thesis, University of Montana. 105pp.

Waller, J.S. 1992. Grizzly bear use of habitats modified by timber management. M.Sc. thesis, Montana State University. 64pp.

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.

Zager, P.E. 1980. The influence of logging and wildfire on grizzly bear habitat in northwestern Montana. Ph.D. thesis, University of Montana. 130pp.

Zager, P.E., Jonkel, C.J. and Habeck, J. 1983. Logging and wildfire influence on grizzly bear habitat in northwestern Montana. Int. Conf. Bear Res. and Manage. 5:124-132.

Zar, J.H. 1984. Biostatistical Analysis. Prentice-Hall Inc., Engelwood Cliffs, N.J. 718pp.