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Original Research

Grizzly Bears Use Large Cutblocks in Central British Columbia: Implications for Natural Disturbance-Based Forest Harvesting and Salvage Logging

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Abstract

In central British Columbia, Canada, large-scale logging and salvage operations to control an outbreak of the spruce bark beetle (*Dendroctonus rufipennis*) occurred in the late 1980s and early 1990s. In the mid to late 1990s, a mountain pine beetle (*D. ponderosae*) epidemic killed extensive areas of lodgepole pine (*Pinus contorta*) trees and widespread salvage logging ensued. We utilized GPS and VHF location data on 28 (16 females, 12 males) grizzly bears (*Ursus arctos*), 1998-2003, to determine how bears would respond to the resulting reduction in mature pine forests and increase in the number and size of cutblocks. Grizzly bears used pine stands less than expected and cutblocks more than expected, selecting for cutblocks in spring and summer but not in fall. Cutblock size influenced selection by bears during the spring and summer but not in fall with grizzly bears being 4 times more likely to select for very large cutblocks (6,600-7,000 ha) than smaller blocks. In spring, the best predictors of grizzly bear use of individual cutblocks were higher greenness values and larger block sizes. In summer, bears selected for larger cutblocks with higher greenness values, at higher elevations, and where the risk of human-caused mortality was greater. In fall, bears remained closer to block edges and used younger stands. Bears spent a significantly greater fraction of their time in cutblocks during the night than during the day and during 'active' versus 'resting' periods in all 3 seasons. Selection for large blocks suggests that bears may respond positively to a harvest regime that mimics the size of natural disturbances.

Key Words: Cutblock, Forestry, Grizzly Bear, Habitat Selection, Salvage Logging, *Ursus artcos*.

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INTRODUCTION

A mountain pine beetle (*Dendroctonus ponderosae*) epidemic killed lodgepole pine (*Pinus contorta*) trees over large areas (over 18M ha as of 2012 http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/facts.htm) in central British Columbia (BC) starting in the mid to late 1990s and peaking in 2005. In 2004, the *Forest Act* was amended to allow for the designation of mountain pine beetle salvage areas, and beetle-killed timber became the priority for salvage logging. Extensive salvage harvesting ensued resulting in a reduction in the amount of mature pine forest, and an increase in the amount of large cutblocks. The increased forest harvesting stimulated our interest in the effects of extensive logging on grizzly bears (*Ursus arctos).* Our study area contained some very large blocks that were the result of large-scale logging and salvage operations to control an outbreak of the spruce bark beetle (*Dendroctonus rufipennis*) in the late 1980s and early 1990s. There was no information available on grizzly bear use of cutblocks, forested stands, or other landcover types for BC's central interior plateau landscape. We were interested in knowing if the population of bears we were studying had similar landscape level selection patterns to Alberta foothills bears (Nielsen *et al.* 2004a).

Salvage logging for beetle-killed trees results in the creation of large cutblocks because extensive areas of forest are attacked and then die. Furthermore, recently developed ecosystem management recommendations to conserve biodiversity recognize that large cutblocks are ecologically appropriate for many forest types in the central interior of BC. The rationale of an ecosystem management approach is that if forests are managed to closely resemble natural forests by mimicking natural disturbance patterns, most native species that are adapted to those forests would be maintained (Bunnell 1995; DeLong and Tanner 1996). Alternatively, the more managed forests deviate from the natural forest condition the greater the probability that the abundance of native species would be changed. For sub-boreal forests in the interior of BC, following an ecosystem management approach to forest harvesting would result in cutblocks designed to mimic the size of historic fire patterns (DeLong 1998, 2002). Historically, in our study area wildfires were predominately >1,000 hectares (ha) and most were >10,000 ha (DeLong 1998) with a fire return interval of 80-125 years (Bunnell 1995). Since 1950, with effective fire suppression, clearcut logging has replaced wildfires as the primary stand replacing disturbance type (DeLong and Tanner 1996). We define clearcutting as the harvesting practice in which most or all trees in an area are uniformly cut down. As a consequence, the study area landscape was a mosaic of cutblocks and forests in various successional stages and of various sizes.

We utilized radio-collared data of grizzly bears, 1998-2003, to compare selection by bears for the predominant forested stand types versus cutblocks and non-forested but vegetated habitats. The predominant forested stand type in our study area was lodgepole pine followed closely by spruce (*Picea* spp.), thus making this landscape ideal for examination of grizzly bear selection of pine stands in relation to other forested stands and cutblocks. We were particularly interested in examining whether grizzly bears made use of large cutblocks because large cutblocks result from both extensive salvage logging and applying ecosystem management recommendations for these forest types. We focused on cutblocks to examine how the increased rate of logging may affect the use of landcover types by bears. These types of questions are timely for the development of sound management practices for bears inhabiting publically owned Crown 'working' landscapes (hereafter 'working forests') as the recent mountain pine beetle infestations increased the rate of harvesting throughout BC.

We began by examining whether grizzly bears inhabiting the working forest selected for forested pine stands in comparison to other forested areas and cutblocks using Geographic Information System (GIS) in combination with modeling resource selection. Specifically, our objectives were to determine if: (1) grizzly bears used forested pine stands in relation to other forested stand types and cutblocks more or less than expected; (2) grizzly bears made use of large cutblocks; (3) selection for cutblocks was similar across seasons; (4) bears remained close to security cover/edge while using cutblocks; and (5) bears used cutblocks more during diurnal than nocturnal periods. Once these attributes are properly identified then best management practices may be developed and applied for the conservation of grizzly bears inhabiting non-protected, 'working' landscapes, which should ultimately contribute to the maintenance of viable populations in working forests. We offer management recommendations based on the monitoring of grizzly bears that inhabited BC's central interior plateau.

STUDY AREA

The 877,600 ha (8,776 km^2) study area fell within the Prince George Timber Supply Area (PG TSA) located in central-eastern British Columbia, Canada (54°39'N, 122° 36'W; Figure 1) in the sub-boreal Spruce biogeoclimatic zone. The terrain was largely an undulating plateau landscape and there was no mountainous terrain or avalanche chutes. Elevations ranged from 590 m to 1,270 m. Drier areas were predominantly lodgepole pine while white spruce (*Picea glauca*) stands predominantly occurred in wetter portions (Table 1). Mixed stands of spruce and subalpine fir (*Abies lasiocarpa*) or spruce and pine also occurred. Coarser soils contained small remnants of interior Douglas-fir (*Pseudotsuga menziesii*) but most had been harvested. Riparian areas and regenerated stands disturbed by logging or fires were predominately trembling aspen (*Populus tremuloides*), cottonwood (*Populus balsamifera*) and paper birch (*Betula papyrifera*) (Meidinger *et al.* 1991).

The study area also contained 89,914 ha (~899 km^2) of non-forested but vegetated habitat and 72,050 ha (~720.5 km^2) of non-

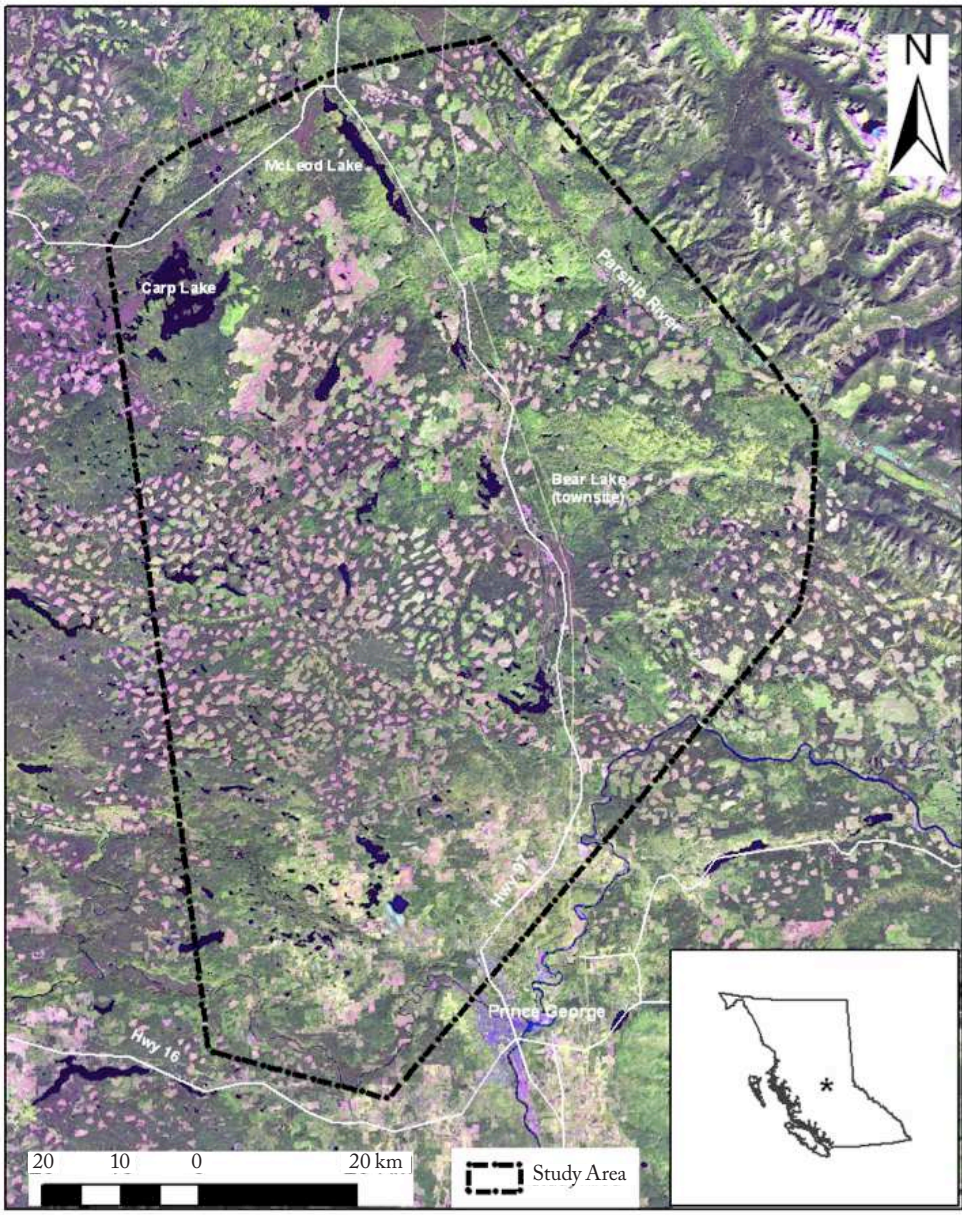

Figure 1. Location of our grizzly bear study area in the Prince George Timber Supply Area, British Columbia, Canada, 1998-2003. The figure shows the mosaic of cutblocks of various sizes as they occurred during the study years.

forested and non-vegetated habitat. The non-forested vegetated habitat consisted of 44,490 ha of shrub, 45,179 ha of herb and 244 ha of moss. The non-forested non-vegetated habitat consisted of 42,764 ha of lakes, 18,224 ha of rivers and 11,062 ha of other non-vegetated types (e.g., rock, exposed soil), which was considered non-bear habitat and removed from availability. We did not have any bear use points in the non-forested non-vegetative landscape. The majority of the study area was publicly owned forest lands. There were only a few provincial parks within the study area which were not large enough to contain the home range of a grizzly bear.

Historically, the dominant stand-replacing disturbance was wildfires (DeLong and Tanner 1996). The stand replacement disturbance cycle on the western portion of the plateau (Moist Interior Plateau) was about 100-125 years (DeLong 2002), with a dominant disturbance patch size >1,000 ha, and most of those were >10,000 ha (DeLong 1998). The historical percent of the total disturbed area by wildfire in the Moist Interior Plateau was 1.5% in a patch size distribution <10 ha, 7.7% for patch sizes 10-100 ha, 12.7% in patches 101-1,000 ha, 18% in patches 1,001-10,000 ha, and 60% in patches >10,000 ha (DeLong 1998). Climatic conditions become wetter as one moves east, and the plateau forests in that area (McGregor Plateau) had a historic stand replacing disturbance interval of 200-250 years, with a dominant disturbance patch size between 100-1,000 ha. The percent of the

Table 1. Percent composition of the study area based on GIS classification of landcover types in the Prince George Timber Supply Area, British Columbia, Canada.

Landcover Type	Percent	Composition
Pine >20 years	28	
Spruce >20 years	21	
Other >20 years	22	
Cutblock (>20 years)	19	
Cutblock 0-5 years		28
Cutblock 6-10 years		28
Cutblock 11-15 years		17
Cutblock 16-20 years		27
Non-forested, vegetated	10	
Total	100	100

total disturbed area by wildfire in the Wet Cool Interior Plateau was 2.3% in a patch size distribution <10 ha, 16.5% for patch sizes 10-100 ha, 43.7% in patches 101-1,000 ha, and 37.5% in patches 1,001-10,000 ha (DeLong 1998). Unburned patches (i.e., fire skips) generally constituted 3-15% of the total wildfire area (DeLong and Tanner 1996). Since the mid-1950s, forestry operations focusing on clearcut logging practices were the primary resource extraction industry (DeLong and Tanner 1996) and wildfires were actively suppressed. From 1970-1990, approximately 12% of the area had been harvested (DeLong and Tanner 1996). Forest harvesting created a large number of relatively small cutblocks, but some large cutblocks resulting from salvage logging of stands killed by spruce bark beetle were also available to the bears (Figure 1).

METHODS

Capture and monitoring

Bear capture followed the Canadian Council on Animal Care guidelines and principles and was approved by the University of Alberta's Animal Care Committee (protocol #307204). We immobilized bears using a dosage of 8 mg/kg of Telazol (tiletamine HCL/zolazepam HCL) administered either using the Palmer Cap-Chur Inc. system (Powder Springs, Georgia, USA) or jab stick. If additional immobilization was required, we used ketamine hydrochloride at a dosage of 2 mg/kg.

We captured bears each year from August 1997 through the fall of 2002 in 2 main events that occurred in late April through early June, and September through October. We used a combination of capture techniques: Aldrich foot snares (Margo Supplies Ltd., High River, Alberta, Canada) placed at baited sites, aerial darting from helicopter, culvert traps, and free-range darting. We deployed a 12-channel Televilt GPS-Simplex™ Global Positioning System (GPS) collars (Televilt/TVP Positioning AB, Lindesberg, Sweden) or a VHF (very high frequency) collar (Lotek, Newmarket, Ontario, Canada) and/or ear-tag transmitters. One GPS collar was deployed in 1998 and programed to attempt 6 fixes every other day. In 1999, all GPS collars failed. In 2000, 1 collar was deployed and programmed to attempt 4 fixes per day; this collar remained active in 2001. In 2001, 7 GPS collars were deployed and were programmed to attempt 6 fixes a day but 2 of those collars experienced complete failures yielding no GPS data. In 2002, 3 GPS collars were deployed that attempted 12 fixes per day; 2 of the 2001 collars also remained functioning in 2002. In 2003, 1 of the 2002 collars remained functioning. Some bears had more than 1 GPS collar deployment because batteries required changing annually. Pacific Standard Time was used for all location fixes.

Regardless of collar type, all bears were monitored using a Cessna 185 single engine fixed-wing aircraft and occasionally a helicopter with a biologist present. We placed effort on obtaining low elevation and precise locations, and omitted any locations where the biologist was not confident of the position of the animal. We located bears twice a week from 1998 to 2000, weekly in 2001 and 2002, and every 2 weeks in 2003, dependent upon weather conditions. Effort expended in locating bears was largely determined by budget resulting in varying sample size by year. We took a Universal Transverse Mercator (UTM) coordinates with a hand-held 12-channel GPS unit and a back-up UTM with the plane's unit. We mapped and verified the locations of the bears that we took from the plane on 1:50,000 topographic maps. We did this to assure the coordinates taken from the plane matched the ground location.

We considered there to be no difference between locations obtained from GPS collars or VHF flights; although the 2 ways of obtaining the relocations differed, the point of the relocation should not. The only concerns we think occur with combining location methods is differing sample sizes between animals, and the temporal analyses because VHF flights are limited to daylight

hours. We account for the differing sample sizes in our resource modelling by weighting each location's importance by animal. Only GPS locations were used in the temporal analyses.

Geographic Information System attributes

We used 2 main GIS layers to build our cutblock layer for the Prince George Forest District: the Landscape Objective Working Group (LOWG) Resultants layer for the Prince George and Fort St. James Forest Districts; and, the Tree Farm Licenses Type 2 Resultant layers (Robinson 2003). These updated layers were the result of the 2010 LOWG meetings, but to adequately represent the landscape during the study years, we applied past depletion data to assure the landscape condition corresponded to the date of the bears' locations. For Tree Farm License 30, we used TFL30 VRI (vintage 2000) and TFL30 past depletions (1997-2008) provided by Canadian Forest Products Ltd. (Canfor). We also used past depletions for the Prince George TSA supplied by the following licensees: Canfor, BC Timber Sales, Lakeland Mills, and Winton Global. GIS layers were built by using the Vegetation Resources Inventory (VRI) provided by the BC Ministry of Forests and Range, Forest Analysis and Inventory Branch (January 2010 layers with past depletion data applied), and the Crown Forested Land Base definition as derived for the Prince George Timber Supply Area LOWG project. The TFL30 Type 2 Silviculture Analysis Resultant layer was compiled by Forest Ecosystem Solutions Ltd. for Canfor and applied specifically to this project. We used only bear locations within the PG TSA so we could maintain the same standard of GIS data throughout the analyses. For all polygon data the resolution was 1:20,000 and in vector format.

We used the VRI to derive attributes of forested area and cutblocks according to the date/year of the bears' locations including the stand age, the primary stand type (cutblock, forest, herb, shrub, non-vegetated, and water), size of the cutblocks in hectares, distance from the bear location to the nearest boundary (in metres), and the status of the closest boundary as defined by the primary stand types. For random locations, we removed locations that fell within lakes and rivers.

Stand age — Age of the stand was a continuous variable for forested stands; however, the non-forested, vegetated class did not contain age information. To avoid problems associated with the lack of ages for the non-forested, vegetated category (e.g., riparian habitat, meadows), we binned these locations into a non-forested, vegetated category. We also binned the age of the forested stands: young forests 21 to 45 years of age, mature forests 46 to 99 years, and old forests ≥100 years. We defined cutblocks as areas ≤20 years since logging. We also binned cutblocks into 5 year post-logging increments. For all categorical variables (e.g., stand age, landcover) used in resource selection function modeling, selection for or against the remaining covariates is in relation to the withheld categories.

Landcover Classification — We classified locations using the leading tree species as determined by the forest cover maps; we termed those stands "predominantly" that stand type. To determine the relative probability of use of cutblocks versus other stand types, we grouped the habitat into 2 broad categories: cutblock and other. We then further defined "other" as predominantly pine stands >20 years, predominantly spruce stands >20 years, other forested stands >20 years, and non-forested, vegetated. Other forested stands >20 years were a combination of mixed wood/deciduous, subalpine fir, interior Douglas-fir, black spruce (*Picea mariana*) and tamarack (*Larix laricina*), all of which occurred in relatively small proportions within the study area. Non-forested, vegetated categories included herb, meadow, field, shrub, and swamp and were defined using the BC Land Classification system for the TSA and using the non-forest descriptor. We again used the depletion data to determine the size and age of cutblocks according to the year of the bears' locations.

Size of cutblock and distance to edge — We considered immediately adjacent (i.e., touching each other) cutblocks to be the aggregate size of the combined harvested areas in hectares because the harvesting of adjacent areas normally occurred within a few years of each other, and from a biological perspective we assumed a bear would consider this area one large block. However, we defined the edge type to be the closest polygon boundary regardless of stand type because if we did not do so it would bias our results towards forested edges. Although the size of cutblock was a continuous variable, we also binned sizes into 500 and 1,000 ha increments which allowed us to better interpret the results of the multivariable analyses and to better define use.

Elevation and greenness — We built digital elevation maps (DEM) from Terrain Resources Inventory Maps (TRIM2; BC Ministry of Water, Land, and Air Protection, Victoria, Canada). We used this layer to obtain the elevation above sea level at a resolution of 25 m. Greenness is a standard term used in habitat selection studies to refer to a biomass measure of plant material that is actively producing chlorophyll. High greenness values indicate lusher, green vegetation while lower greenness values indicate sparse or senesced vegetation (Mace *et al.* 1999). Greenness was calculated for 4 satellite images (2 September and 2 August 1999 images) using ERDAS® Imagine (Atlanta, Georgia, USA) at a 30 m pixel resolution and a linear adjustment factor was used to calibrate values based on the extensive area of overlap. We assumed our greenness layer provided an index of the amount of green herbaceous phytomass as based on the work by Mace *et al.* (1999).

Mortality risk layer — The mortality risk layer represents the relative probability of human-caused grizzly bear mortality across the study area. This layer was built as per Ciarniello *et al.* (2009) where we used logistic regression to assess the relationship between the known location of 161 human-caused grizzly bear deaths within the study area and non-mortality telemetry relocations.

Negative coefficients indicate selection for areas with lower risks of human-caused bear mortality thereby having higher security for bears than positive coefficients.

Temporal use of cutblocks

Using GPS locations only, we examined the time of day grizzly bears were using the different stand types to determine temporal selection of habitats. We used time in decimals as a continuous variable. We also grouped time into 6 periods relative to sunrise and sunset: midnight to 1 hour before sunrise; sunrise plus 1 hour; 1 hour after sunrise until noon; noon until 1 hour before sunset; sunset plus 1 hour; and 1 hour after sunset until midnight. Sunrise and sunset times were calculated based on times provided by the National Research Council of Canada and varied with the date of the location. We further grouped the time blocks into nocturnal (sunset to 1 hour before sunrise) and diurnal periods (sunrise to 1 hour before sunset) periods to test whether grizzly bears were using blocks more under the security cover of darkness than during the daylight hours. We used a 2 x 2 contingency χ^2 with a significance level of $\alpha<0.05$ to test for the differences in the time periods grizzly bears were using cutblocks in comparison to the remaining landcover types.

We accounted for bear behaviour by categorizing the locations into 4, 6-h time-blocks that separated out times with a higher probability of a bear resting (11:01-17:00 and 23:01-05:00) versus being active (05:01-11:00 am and 17:01-23:00) based on the results contained within Heard *et al.* (2008). We did this because our earlier work found that bear behaviour (resting, active) relates to GPS bias that cannot be accurately accounted for by using correction factors based solely on landscape cover (Heard *et al.* 2008). We used a 2 x 4 χ^2 with a significance level of $\alpha<0.05$ to test for differences in the 4 behavioural time periods grizzly bears were using cutblocks in comparison to the remaining landcover types.

Seasons

We used bear locations from when bears moved >1 km from their den site for spring until bears were ≤1 km of their den sites because den site selection is known to differ from selection during the non-denning, active season (Ciarniello *et al.* 2005, 2007). We further separated the 'active' locations into spring (>1 km from a known den site to 14-July), summer (15-July to 20-September) and fall (21-September to 1-km of known den site) seasons. The principal factor used to delineate seasons was when bears shifted from primarily feeding on green vegetation in spring to the consistent use of berries and/or ants as the primary food source as determined by foraging data (Ciarniello 2006). We used Mann-Whitney *U*-test with a significance level of $\alpha<0.05$ to test for differences between seasons. We used analysis of variance (ANOVA) to determine whether the temporal use of cutblocks by grizzly bears differed by season.

Resource Selection Modeling

We removed water and rock landcover from the study area and then sampled random locations at an intensity of ~1 location/500m^2 (n = 16,775). To control for variation in our bear use locations, we weighted the use locations by individual bear and according to gender by applying importance weights according to the number of locations obtained on each individual bear. We examined the data for correlations between predictor variables. We did not detect collinearity >0.6 for our chosen variables. We pooled data among years because seasonal use did not change markedly and sample sizes prevented both seasonal and yearly stratification of data (similar to Nielsen *et al.* 2004a).

Grizzly bear relocations were the used values (1) and 0 was assigned to randomly generated locations across the study area. We examined resource selection ratios (Manly *et al.* 2002) by individual variable to determine the probability of use of landscape attributes at the population level using the following univariate equation:

$$w(\boldsymbol{x})=\exp(\beta_x) \quad (1)$$

where $w(\boldsymbol{x})$ denotes the relative probability of occurrence selection function, β_x is the selection coefficient for variable x, and the exponent of the coefficient is assumed to be the odds ratio. We used logistic regression to obtain beta coefficient estimates. We used 2nd and 4th order scales of analysis (Johnson 1980) combined with Manly *et al.* (2002) Design I where individual animals are not identified and measurements are made at the population level. For selection within cutblocks, we selected only those locations that occurred within the cutblock/patch (4th order), whereas we retained those random locations outside of cutblocks for questions pertaining to the selection of cutblocks in comparison to the remaining landscape of the study area (2nd order).

We used Resource Selection Functions (Manly *et al.* 2002) to determine how selection for some of the variables may change when multivariable statistical methods are applied because of the contribution of the other variables to bear habitat use. We again used 2nd (study-wide) and 4th (within patch) order scales (Johnson 1980) combined with a Design I sampling design for resource selection studies (Manly *et al.* 2002). We put forward models using the size and age of the cutblock, distance to the closest edge type, risk of human-caused mortality, greenness, elevation and season to determine the relative probability of use of cutblocks by grizzly bears. Using those variables we present 2 ecologically plausible RSF models examining the relative probability of use of cutblocks by spring, summer and fall seasons, respectively. We assumed the following log-linear model characterized the influence of covariates on relative use, $w(\boldsymbol{x})$:

$$w(\boldsymbol{x})=\exp(\beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \ldots \beta_p x_p) \quad (2)$$

where selection coefficients, β_I, for each of the covariates, x_i, for a vector $\mathbf{x}$, x_i for i = 1,2,. . .p, which was estimated using logistic regression. Again bear use locations were considered the used sites and assigned 1, whereas randomly generated locations

were used to determine availability and assigned 0. We used Stata (Stata Corporation, Texas, USA) to estimate models. The normalized Akaike weights (AIC_w) provides the probability that the candidate models are the best models (Anderson *et al.* 2000). Covariates with 95% confidence intervals that did not include 0 were considered to have good inference.

RESULTS

Grizzly bear use of the landscape

We gathered 5,510 locations on 28 (16 females, 12 males) grizzly bears outfitted with tracking devices. Bears were located in all landcover types within the study area with the majority of bear locations in a cutblock (n = 2,403, 44%). The number of locations within a cutblock polygon was twice the recorded use of the next highest cover type, spruce stands >20 years. In comparison, 19% of the study area was characterized as cutblocks while 21% was spruce stands. Grizzly bears were least often located in pine stands although this was the leading stand type within the study area (28%).

Grizzly bears had a low relative probility of use of pine stands and other landcover types compared to their use of cutblocks (Table 2). The estimated odds ratio for cutblock selection was 1.61 (95% C.I. = 1.46, 1.84) times that of the other landcover types. Although grizzly bears also appeared to avoid spruce stands and non-forested, vegetated stands the confidence intervals for model coefficients overlapped 0, suggesting a weak/noisy relationship resulting in poor inference for those cover types.

Temporal use of cutblocks by grizzly bears

Using GPS locations only, the time of day grizzly bears used cutblocks differed from times they used the remaining landcover types ($U_{5780489,5000558}$ = 2575055, P=0.014) although for both the majority of locations occurred 1 h after sunrise until 1 h before sunset (Table 3). Accounting for the difference in effort applied to obtaining locations, bears spent a greater fraction of their time in cutblocks at night (53%) than during the day (45%) (χ^2 = 28.47, df: 1, P<0.0001). We did not detect significant differences among spring, summer or fall regarding the times grizzly bears were located within cutblocks (ANOVA F = .753, df: 2, 2,697, P=0.47).

Grizzly bears were located more in cutblocks during the active period than the resting period (Table 4). The median time for grizzly bear use of cutblocks was approximately 11:00 h as compared with 13:00 h for landcover types other than cutblocks. Grizzly bears used cutblocks more during the active period than the resting period (χ^2 = 130.76, df: 3, P<0.0001).

Table 2. Relative probability of use by landcover type for grizzly bears inhabiting the Prince George Forest District, British Columbia, Canada, 1998-2003. The model was estimated by comparing the landcover type at use locations (1) with randomly generated available locations (0) and withholding "cutblock" as the reference category (eqn. 2). Bold text indicates those coefficients where CI does not overlap 0, suggesting a significant relationship.

			95% CI	
Landcover Type	β	S.E.	Lower	Upper
Pine >20 years	**-1.500**	**0.122**	**-1.740**	**-1.261**
Spruce >20 years	-0.159	0.085	-0.326	0.007
Other >20 years	**-0.227**	**0.088**	**-0.399**	**-0.055**
Non-forested, vegetated	-0.158	0.103	-0.360	0.044

Table 3. Percent of grizzly bear GPS locations in cutblocks versus all remaining landcover types relative to sunrise and sunset for the Prince George Forest District, British Columbia, Canada, 1998-2003. Number of relocations is provided in parentheses.

	Cutblock Only	Remaining Landcover Types
Time Block	% (n)	% (n)
Midnight to 1 hr before sunrise	14 (303)	11 (275)
Sunrise +/- 1 hr	7 (151)	5 (114)
1 hr after sunrise until noon	32 (713)	34 (824)
Noon until 1 hr before sunset	21 (471)	30 (725)
Sunset +/- 1 hr	8 (175)	7 (160)
1 hr after sunset until midnight	18 (389)	14 (343)
Total	100 (2,202)	100 (2,441)

Attributes of cutblocks used by grizzly bears during the annual foraging season

On average, bears used larger cutblocks ($\bar{x}$= 2,817 ha, SE = 63, range 1.5-6,980 ha) greater than their availability ($\bar{x}$= 1,154 ha, SE = 36, range 1-6,980 ha). When using cutblocks, 43% of bear locations were in cutblocks <500 ha; however, the estimated odds ratio for selection for this patch size was 0.75 suggesting that overall they were used slightly less than their availability (Table 5). The majority of cutblocks (68%) within the study area were <500 ha, and only 3% were very large (6,600-7,000 ha, Figure 2). Bears were approximately 4 times more likely to select very large cutblocks than the other available sizes. A total of 76% of bear relocations in cutblocks was in small (<500 ha, 43%) and very large (6,600-7,000 ha, 33%) blocks.

Grizzly bears used cutblocks at higher elevations than available throughout the study area ($U_{8165406,7405585}$ = 2357332, P<0.001;$\bar{x}_{[use-cut]}$ = 913, SE = 2.2, range 681-1,161 m;$\bar{x}_{[available-cut]}$ = 843, SE = 1.6, range 594-1,169 m); however, the use of higher elevations differed by season (ANOVA F = 226.9, df: 2, 2400, P<0.0001). Grizzly bears used cutblocks that had a higher risk of human-caused mortality ($U_{5780756, 9790235}$ = 2892350, P<0.0001) although that also differed by season (ANOVA F = 12.24, df: 2, 2,400, P<0.0001).

Grizzly bears did not appear to select areas within a cutblock that were near or far from the edge of the block ($U_{6707268,8863722}$ = 3815469, P=0.98); however, results were again dependent upon the season (ANOVA F = 9.89, df: 2, 2,400, P<0.0001). Grizzly bears also used cutblocks that were adjacent to another cutblock ($w(x)$ = 1.04, 95% CI = 0.82, 1.33) or a forested stand ($w(x)$ = 0.97, 95% CI = 0.77, 1.22) or 'other' edge type ($w(x)$ = 0.98, 95% CI = 0.65, 1.46) similar to their availability.

Overall bears tended to use younger aged stands greater than

Table 4. Percent of grizzly bear GPS locations in cutblocks as compared with all 'other' landcover types used by grizzly bears during active and resting periods for the Prince George Forest District, British Columbia, Canada, 1998-2003. Number of observations is provided in parentheses.

	Active 05:01-11:00	Resting 11:01-17:00	Active 17:01-23:00	Resting 23:01-05:00
Cutblocks	32 (701)	15 (338)	30 (656)	23 (507)
Other Landcover	33 (811)	21 (505)	31 (756)	15 (369)

Table 5. Estimates of the size of cutblocks used by grizzly bears binned into 500 and 1000 ha increments. Estimates were obtained by comparing the size of the cutblock grizzly bears were located within against randomly generated available locations within cutblocks (eqn 1). The percent available refers to the amount of that size cutblock in relationship to the cutblocks within the study area.

Block Size (ha)	Percent Available	β	S.E.	95% CI[1] Lower	Upper	$w(x)$ Odds Ratio
<500	68.2	**-0.29**	**0.120**	**-0.522**	**-0.052**	**0.75**
500-1,000	5.6	-0.04	0.182	0.395	0.317	0.96
Combined <500-1,000		**-0.32**	**0.13**	**-0.57**	**-0.07**	**0.72**
1100-1,500	5.6	0.20	0.190	-0.177	0.569	1.22
1600-2,000	4.3	0.58	0.300	-0.013	1.164	1.78
Combined 1,100-2,000		**0.41**	**0.19**	**0.04**	**0.77**	**1.50**
2,100-2,500	2.4	-1.33	0.722	-2.750	0.080	0.26
2,600-3,000	1.5	**-1.50**	**0.310**	**-2.107**	**-0.892**	**0.22**
Combined 2,100-3,000		**-1.41**	**0.486**	**-2.361**	**-0.457**	**0.24**
3,100-5,000	0					
5,100-5,500	0.1	0.28	1.120	-1.911	2.478	1.33
5,600-6,000	4.3	**-0.90**	**0.394**	**-1.672**	**-0.125**	**0.41**
Combined 5,100-6,000		**-0.84**	**0.37**	**-1.57**	**-0.11**	**0.43**
6,100-6,500	5.3	0.21	0.350	-0.476	0.895	1.23
6,600-7,000	2.7	**1.30**	**0.129**	**1.051**	**1.558**	**3.69**
Combined 6,100-7,000		**0.77**	**0.16**	**0.44**	**1.09**	**2.15**

[1] Bold text indicates those coefficients where the CI does not overlap 0, suggesting good inference.

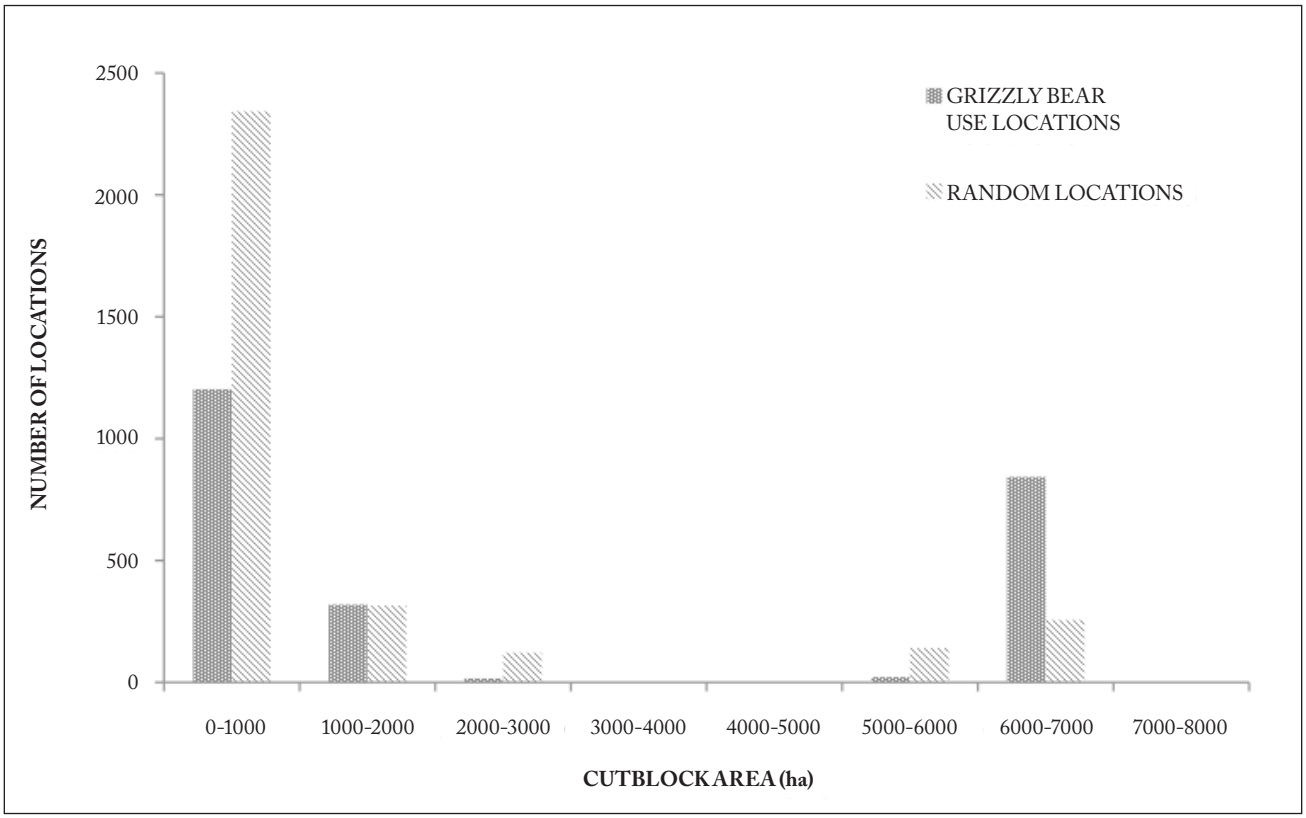

Figure 2. Number of grizzly bear use and random locations by cutblock size in the Prince George Timber Supply Area, British Columbia, Canada, 1998-2003.

their availability ($U_{6552770,9018220}$ = 3664364, P=0.01). Grizzly bears appeared to select for regenerated young stands that were 19 and 20 years in age followed by blocks aged 1 to 3 years. Cutblocks ranging in age from 6 to 15 years tended to be used in proportion to their availability. Grizzly bears used regenerating stands with higher greenness values ($U_{7100263,8470727}$ = 3422474, P<0.0001).

Grizzly bears did not appear to select areas within a cutblock that were near or far from the edge of the block ($U_{6707268,8863722}$ = 3815469, P=0.98); however, results were again dependent upon the season (ANOVA F = 9.89, df: 2, 2,400, P<0.0001). Grizzly bears also used cutblocks that were adjacent to another cutblock ($w(x)$ = 1.04, 95% CI = 0.82, 1.33) or a forested stand ($w(x)$ = 0.97, 95% CI = 0.77, 1.22) or 'other' edge type ($w(x)$ = 0.98, 95% CI = 0.65, 1.46) similar to their availability.

Overall bears tended to use younger aged stands greater than their availability ($U_{6552770,9018220}$ = 3664364, P=0.01). Grizzly bears appeared to select for regenerated young stands that were 19 and 20 years in age followed by blocks aged 1 to 3 years. Cutblocks ranging in age from 6 to 15 years tended to be used in proportion to their availability. Grizzly bears used regenerating stands with higher greenness values ($U_{7100263,8470727}$ = 3422474, P<0.0001).

Variation in selection factors affecting grizzly bear use of cutblocks among seasons

The majority of the attributes of cutblocks that were used by grizzly bears during the annual foraging season were affected by the season of use (i.e., spring, summer or fall). In spring, grizzly bears were estimated to select cutblocks approximatley 1.7 times (70% larger proportionally) more than the available landcover types (Table 6); selection of cutblocks was on average more than one and a half times more likely than the other landcover types. In summer, the odds of grizzly bears selecting for a cutblock decreased to approximately 40% larger proportionally and continued to be selected. In fall, grizzly bears had a low relative probability of use of cutblocks as compared to the other available landcover types being located in them less than available across the study area.

Because grizzly bears used cutblocks differently during spring, summer and fall, we examined relative selection for each season separately to determine the factors that contributed to use by season. In spring, grizzly bears selected for larger cutblocks ($\bar{x}_{[use]}$ = 2,078 ha, $\bar{x}_{[avail]}$ = 1,154 ha) with higher greenness values ($\bar{x}_{[use]}$ = 8.2, $\bar{x}_{[avail]}$ = 6.3); these 2 covariates were the best predictors of grizzly bear use of cutblocks in spring (Table 7). In the second ranked model, grizzly bears appeared to also select for closer distances to the edge of the cutblock and lower elevations; however, these two parameters had confidence limits that overlapped 0. The second ranked model had a ΔAIC value >2.0, indicating that that model was not comparable to the top ranked model.

Table 6. Estimates of grizzly bear selection for cutblocks by spring, summer and fall in the Prince George Forest District, British Columbia, Canada, 1998-2003. Seasonal estimates were obtained by comparing grizzly bear locations within cutblocks against randomly generated available locations (eqn 1).

			95% CI[1]		$w(x)$
Season	β	S.E.	Lower	Upper	Odds Ratio
Spring	0.536	0.114	0.758	0.313	1.71
Summer	0.325	0.109	0.539	0.111	1.38
Fall	-1.206	0.149	-0.914	-1.498	0.30

[1]For all seasons the coefficients do not overlap 0, suggesting good inference.

In summer, grizzly bears selected cutblocks with higher greenness values ($\bar{x}_{[use]}$ = 10,$\bar{x}_{[avail]}$ = 6.3) and at higher elevations ($\bar{x}_{[use]}$ = 950 m,$\bar{x}_{[avail]}$ = 843 m); these 2 covariates were the best predictors of grizzly bear use of cutblocks in summer (Table 8). The ΔAIC value for the second ranked model was 1.32 indicating some support. Grizzly bears also selected for larger cutblocks ($\bar{x}_{[use]}$ = 3293 ha,$\bar{x}_{[avail]}$ = 1154 ha) and cutblocks with a higher risk of human-caused mortality.

The best predictors of grizzly bear use of cutblocks in fall were closer distances to the edge of the block and younger cutblocks (Table 9). Model 2 had a ΔAIC value of 1.43 indicating that the first and second ranked models were comparable; however, the selection for blocks with higher greenness scores was not a good indicator of use for fall. The size of the block did not appear to be of significance to bears in the fall.

In spring and summer, the size of the cutblock was important but

Table 7. Spring only model estimating the relative probability of use of cutblocks for grizzly bears when they were >1 km from den site in spring to 14 July for the Prince George Forest District, British Columbia, Canada, 1998-2003. Models were estimated by comparing the grizzly bear use locations in cutblocks (1) with randomly generated available locations in cutblocks (0) for the spring only (eqn 2).

				95% CI[1]				
	Covariate	β	S.E.	Lower	Upper	AIC	ΔAIC	AIC_w
#1	Size of Cutblock	**$1.00E^{-04}$**	**$4.56E^{-05}$**	**$1.08E^{-05}$**	**1.90^{-04}**	620.24	0.00	0.73
	Greenness	**0.033**	**0.008**	**0.018**	**0.048**			
#2	Size of Cutblock	**$1.05E^{-04}$**	**$4.60E^{-04}$**	**$1.51E^{-05}$**	**$1.96E^{-04}$**	623.15	2.91	0.17
	Distance to Edge	-0.001	0.001	-0.004	0.001			
	Greenness	**0.033**	**0.008**	**0.016**	**0.049**			
	Elevation	$-1.10E^{-04}$	8.47^{-04}	-0.002	0.002			

[1]Bold text indicates those coefficients where the CI does not overlap 0, suggesting good inference.

Table 8. Summer only models indicating the relative probability of use of cutblocks for grizzly bears from 15 July to 20 September inhabiting the Prince George Forest District, British Columbia, Canada, 1998-2003. Models were estimated by comparing the grizzly bear use locations in cutblocks (1) with randomly generated available locations in cutblocks (0) for the summer only (eqn 2).

				95% CI[1]				
	Covariate	β	S.E.	Lower	Upper	AIC	ΔAIC	AIC_w
#1	Greenness	**0.021**	**0.008**	**0.005**	**0.037**	588.59	0.00	0.46
	Elevation	**0.007**	**0.001**	**0.005**	**0.009**			
#2	Size of Cutblock	**6.05^{-05}**	**2.75^{-05}**	**6.58^{-06}**	**1.15^{-04}**	589.91	1.32	0.24
	Greenness	**0.025**	**0.008**	**0.009**	**0.041**			
	Elevation	**0.007**	**0.001**	**0.005**	**0.009**			
	Risk of Human-caused mortality	**19.687**	**9.073**	**1.903**	**37.471**			

[1]Bold text indicates those coefficients where the CI does not overlap 0, suggesting good inference.

Table 9. Fall only models indicating the relative probability of use of cutblocks for grizzly bears from 21 September to until within 1-km of a known den site for the Prince George Forest District, British Columbia, Canada, 1998-2003. Models were estimated by comparing the grizzly bear use locations in cutblocks (1) with randomly generated available locations in cutblocks (0) for the fall only (eqn 2).

				95% CI[1]				
	Covariate	β	S.E.	Lower	Upper	AIC	ΔAIC	AIC_w
#1	Distance to Edge	**-0.007**	**0.002**	**-0.011**	**-0.003**	145.81	0.00	0.58
	Age of Cutblock	**-0.126**	**0.045**	**-0.214**	**-0.038**			
#2	Distance to Edge	**-0.146**	**0.046**	**-0.237**	**-0.056**	147.24	1.43	0.28
	Age of Cutblock	**-0.007**	**0.002**	**-0.011**	**-0.003**			
	Greenness	0.022	0.013	-0.003	0.046			

[1]Bold text indicates those coefficients where the CI does not overlap 0, suggesting good inference.

not for fall. The primary differences between the spring and fall models as compared to the summer model were the risk of human-caused mortality, elevation, and the greenness response. For spring and fall, the risk of human-caused mortality did not appear to have an influence on the relative probability of use by grizzly bears of cutblocks; in summer, however, grizzly bears selected for blocks that had a high risk of human-caused mortality. Grizzly bears also selected for cutblocks that occurred at higher elevations during the summer, which was not detected for spring or fall. In fall, unlike spring and summer, grizzly bears had a higher relative probability of use in younger cutblocks and at closer distances to the edge of the block.

DISCUSSION

Grizzly bears in central BC used forested pine stands less than expected even though pine stands were the predominant landcover type in the study area. Conversely grizzly bears selected cutblocks, but attributes influencing their selection varied among seasons. Grizzly bears in our study area selected for cutblocks most strongly in spring, less so in summer, and avoided them during fall. Our results are similar to those reported for grizzly bears in the foothills of Alberta (Nielsen *et al.* 2004a; Stewart *et al.* 2012). Nielsen *et al.* (2004a) reported selection by grizzly bears for cutblocks during the early foraging season (hypophagia), use in proportion to availability for summer (hyperphagia), and avoidance for fall (late hypophagia). Weilgus and Vernier (2003) also found that grizzly bears did not avoid cutblocks even in landscapes with open road access, but bears in their area also selected for natural openings such as burns.

Other studies have found that bears rarely used cutblocks but did use burns extensively (Zager *et al.* 1983; Waller 1992; McLellan and Hovey 2001). We attribute the difference in findings to 3 reasons. First, whereas those researchers included burns and cut blocks as different habitat types, fire had been actively suppressed in our study area since the 1950s so we used landscapes in early successional stages. Second, because their study areas contained burns, available habitat was different than our area and offered bears another choice. Third, while they often relocated bears during daylight hours, we had the advantage of using some nighttime locations. Burns likely produce superior foraging habitat for bears (Zager *et al.* 1983) but, since 1950 in the PG TSA, wildfires have been effectively suppressed and cutblocks were the only source of early seral vegetation thereby providing regenerating vegetative forbs and shrubs (Nielsen *et al.* 2004b). It is possible that the results may be similar if early seral vegetation was the independent variable in all studies and round the clock relocations were used.

Grizzly bears used and selected for very large cutblocks and based on that we conclude that following an ecosystem management (i.e., natural disturbance) approach to forest harvesting will foster use by grizzly bears inhabiting working forests. Stewart *et al.* (2012) also showed that grizzly bears selected for larger disturbances. We think that bears selected cutblocks because they are the alternative large-scale disturbance that has replaced wildfires in our study area (DeLong 1998). Similar to Nielsen *et al.* (2004a), we suggest that grizzly bears used cutblocks comparable with how they would have used habitats burned by wildfire – capitalizing on the increased foraging opportunities that removal of the canopy provides. In areas where fire is actively suppressed, a lack of alternative large-scale disturbances can result in a decline in the population of grizzly bears (McLellan and Hovey 2001). Alternativey then, if forage abundance as it relates to plant productivity is correlated with bear density, as it has been found to with salmon (Hilderbrand *et al.* 1999), it is possible that harvesting those pine stands, which were avoided by bears, could result in increased forage, and therefore increased carrying capacity of bears (Mowat *et al.* 2013).

The temporal use of cutblocks was assumed to reflect disturbance. In areas with a higher human encounter rate, bears fed more in cutblocks during the night presumably to avoid humans (MacHutchon *et al.* 1998; Gibeau *et al.* 2002) although it is also possible that open canopy landscapes were used more at night because they were cooler (Nielsen *et al.* 2004b). Further, in some circumstances, food may be more important than security. We found that grizzly bears spent a significantly greater fraction

of their time in cutblocks at night than during the day which we suggest based on our microsite work to represent foraging bouts (Ciarniello *et al.* 2014) under the cover of darkness when encounters with humans would be much less likely (MacHutchon *et al.* 1998; Gibeau *et al.* 2002). We varied our darkness times according to sunrise and sunset and the temporal use of cutblocks was similar across spring, summer and fall. If temporal use of cutblocks was a result of thermal demands, we would have expected fall and spring, which are cooler than summer to differ from summer. In order to account for the bimodal circadian activity pattern that our earlier work revealed was related to bear behaviour and environment, we binned time into 2 active and 2 resting periods (Heard *et al.* 2008); grizzly bears used cutblocks significantly more during active than resting periods. To determine what the bears were doing at the relocation sites, we ground visited a subset of the locations (Ciarniello *et al.* 2014). Distinct behaviour activities were noted to be dependent upon the landcover type; grizzly bears used cutblocks differently than forested stands and in particular they rested more in forested areas and fed more in cutblocks (Ciarniello *et al.* 2014).

We were interested in knowing if bears would use further distances from major edges of cutblocks as an indication of the amount of habitat that they would make use of within a large block as well as a measure of security for bears. We assumed closer distances to edges indicated a measure of increased security for the bear (Gibeau *et al.* 2002), although it may also reflect selection by bears for increased edge effects where forage productivity may be greater (Nielsen *et al.* 2004b). We recognize that security cover for bears can occur at finer scales than we were able to measure by the GIS layers; that is, a patch of faster regenerating shrubs or trees may be large enough to hide a bear but we did not have the ability to ascertain this from the GIS layers. Therefore, the results for distance to edge are at a broad scale, and because of this, we consider significant relationships to respresent a behavioural response by bears. For all seasons combined (i.e., annual foraging season), we did not detect grizzly bears to select closer distances to the edge of the block. When examining individual seasons (i.e., seasonal models), fall was the only season where bears selected closer distance to the edge of cutblocks. Fall coincides with the hunting season for a number of species in our study area, and our earlier work showed that grizzly bear deaths were highest in fall and further that the majority of bear deaths were caused by humans while hunting other species (Ciarniello *et al.* 2009). We suggest that closer distances to a major edge for fall reflects the choice for higher security than would be required during spring or summer.

Habitat selection models within the cutblock differed by season. We suggest the differences among seasons are in part attributable to environmental variables such as snow depth and timing of melting and berry productivity, whereas distance to the edge of the cutblock, which we assumed to reflect increased security measures while foraging and/or edge effects, appeared to be most important to bears in fall. The relationship may also be driven by a combination of food and security (Pineau 2014).

Individual seasonal models revealed that in spring, grizzly bears selected for larger cutblocks with higher forage productivity (i.e., higher greenness values). The trend was for bears to remain at closer distances to the edge of the block, and those cutblocks tended to be at lower elevations, although this was a weak relationship when examined using multivariable statistics. We anecdotally noted that cutblocks were snow-free earlier in spring thereby providing for foraging opportunities on emergent vegetation earlier than closed canopy stands. We suggest that the use of cutblocks in spring reflects the earlier opportunities for feeding.

During summer, grizzly bears selected for cutblocks with higher greenness values and those blocks tended to occur at higher elevations. We think that the selection for higher elevation cutblocks is related to foraging on blueberries (*Vaccinium* sp.) during the summer (Ciarniello *et al.* 2014). Blueberries produce better at higher elevations due to increased water drainage and prolonged sunlight (Klinka *et al.* 1989; Gault 2011), which suggests increased forage productivity for bears in the higher elevation cutblocks. Stewart *et al.* (2012) also showed that grizzly bears selected for higher elevations; however, they attributed the selection to avoidance of humans. Since we did not have any montane habitat in our study area, it is unlikely that the differences in elevation across the plateau were great enough to limit human access. The size of the cutblock was also important to grizzly bears during the summer with the trend being selection for larger blocks. Summer was the only season where the risk of human-caused mortality was a ranked model covariate; grizzly bears selected for cutblocks with a higher risk of human-caused mortality than the surrounding matrix of cutblocks. Our earlier work showed that summer was the season with the lowest number of grizzly bear deaths (Ciarniello *et al.* 2009), and we suggest that higher forage productivity in large, high elevation cutblocks may outweigh the risks associated with human-caused mortality during the summer. Distance to the edge of the cutblock did not improve the summer models and therefore was not a model covariate. Similar to our findings, Pineau (2014) did not detect avoidance of the interior of cutblocks by grizzly bears during summer.

Unlike spring and summer, grizzly bears selected forests over cutblocks in fall. Possibly the avoidance of cutblocks was attributed to fall being closer to the den-up season where forests were selected for over other landcover types (Ciarniello *et al.* 2005); however, it is also possible that landcover selection patterns were more unpredictable in fall due to timing coinciding with the hunting of other game species, which may result in the potential attraction of bears to game/remains killed by hunters (Ciarniello *et al.* 2009). The best predictors of grizzly bear use of cutblocks in fall were closer distances to a major edge of a block and selection for younger age cutblocks. We suggest that closer distances to the

edge of cutblocks are a response to the need for increased security while using cutblocks, particularly if the blocks selected by bears are in an earlier stage of regeneration and therefore lack forest cover for hiding. In fall, forbs and shrubs begin to senesce and we suggest the use of younger cutblocks at this time reflects the opportunity for foraging on early seral disturbance related forbs, such as digging for the roots of dandelion (*Taraxacum officinale*) (Ciarniello *et al.* 2014). Our results are similar to Pineau (2014) who found that bears selected for the cutblock-edge interface in fall and that selection exceeded the use of the interior of the block by bears.

MANAGEMENT CONSIDERATIONS

Within the working forest, the challenge for grizzly bear management is how to manage the land-base to maintain forest characteristics that are selected for by bears while minimizing their risk of human-caused mortality. This is of particular importance in areas where the harvesting of stands promotes large cutblocks (e.g., infected mountain pine beetle stands, ecosystem management approach). High logging rates may greatly reduce the area that can provide security cover resulting in fewer core areas large enough to provide security. We identify forest management practices that are consistent with the long term maintenance of grizzly bears in central BC. We have based our recommendations on the assumption that forestry practices are moving towards a natural disturbance based approach (i.e., larger blocks based on wildfire cycles) as identified in the *Forest Practices Code* (Forest Planning and Practices Regulation 2010).

One of the potential benefits of moving towards an ecosystem management/natural disturbance regime is that the larger blocks produced will be used by grizzly bears. Salvage logging of mountain pine beetle-attacked stands will also reduce the amount of mature pine forest which is avoided by grizzly bears, and increase cutlbocks which are selected by the bears. However, the potential benefit of large cutblocks to bears could be outweighed if larger blocks contribute to higher grizzly bear mortality (Kristan 2003; Battin 2004). One of the potential negative impacts is that new road networks created for salvage logging will increase the risk of bears being killed by people. Numerous studies on grizzly bears have concluded that the roads associated with resource extraction activities allow for increased human access into formerly roadless areas leading to increased grizzly bear mortality (Mattson *et al.* 1996; McLellan *et al.* 1999; Schwartz *et al.* 2006; Nielsen *et al.* 2008). Our earlier work showed that grizzly bears were not displaced from within block roads and the majority of non-natural bear deaths were associated with the access provided by on-block road networks (Ciarniello *et al.* 2006).

Nielsen *et al.* (2008) modeled the 100-year persistence of grizzly bears in Alberta based on a natural disturbance forestry regime and concluded that a natural forestry based regime would not benefit grizzly bears because of the road access which would ultimately lead to higher human-caused mortality and therefore offset any gains in increased habitat quality for bears (Nielsen *et al.* 2008). However, the deactivation and control of road networks was not considered in their modeling. Using small cutblocks with a traditional 3-pass system requires the maintenance of a high active road density over the entire landscape whereas the roads on a large salvage block or natural disturbance blocks will grow in with the exception of mainlines passing through the area. If management of harvesting activities is directed at reducing those features associated with grizzly bear mortality (e.g., road access, seasonal variations in use) while also increasing those related to bear use of blocks (e.g., forage productivity), then we think that grizzly bear mortality could be better controlled than with the traditional 2 or more pass system. To fully determine the net benefit of large cutblocks to bear populations, one needs to compare the foraging benefits to the potential for large cutblocks to contribute to higher grizzly bear mortality.

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