GRIZZLY BEAR DENSITY AND MOVEMENT IN THE BOWRON RIVER VALLEY OF BRITISH COLUMBIA

Final Report

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ABSTRACT

We estimated population density of grizzly bears (*Ursus arctos*) in the Bowron River Valley in the central interior of British Columbia using mark-recapture estimates from hair sampling sites both along salmon (*Oncorhynchus* spp.) spawning streams and in adjacent upland areas. This design allowed us to document fall movements of bears from upland areas to the river when salmon were present. The grizzly population within the Bowron River Valley was of interest because about half the valley bottom forest was clear-cut logged in the 1980's. The census grid was centred on an area that was essentially a continuous 64,000-hectare clear-cut. Lower elevations were within the sub-boreal spruce (SBS) biogeoclimatic zone and upper elevations were in the Engelmann spruce-sub-alpine fir zone (ESSF).

Detection of grizzly bears was higher in ESSF forests than in the lower elevation SBS forests. Grizzly bear detection at upland sites was not related to the amount of recently logged forest within 500 m of the hair site in either SBS or ESSF ($P = 0.48$ and 0.88, respectively). No grizzly bear movements >13.5 km were detected from upland to river ($n = 13$) even though 12 bears were detected >13.5 km from the river, which was 24% of all grizzly bears identified in the study area. This suggests that mainly local resident bears used salmon streams. Grizzly density in the study area (31/1,000 km^2) appeared to represent the mid-point between the high densities of bears along the isolated divide of the Rocky Mountains, and the low densities that occur in SBS forests on the heavily disturbed interior plateau.

The large amount of logging in the Bowron valley did not appear to grossly affect bear distribution or density. However, logging creates early seral stands and some of these offer considerable foraging opportunities for bears. These opportunities will decline as forests regenerate hence the impact of large scale logging may only be discernable over the long-term. The Fuhr-Demarchi habitat-based population estimate was lower than the mark-recapture estimate, with the number used to calculate harvest being about one third of the current number of bears. The 20-year average kill of 1.8 bears/yr, only 2.4% of the current grizzly bear population estimate, is likely sustainable, especially given that hunters have shown strong selection for males (71% of the kill).

Doing fieldwork along salmon streams could reduce the cost of bear inventories in the interior. By sampling only along the river we generated a precise estimate of the number of bears using approximately 2/3 of the entire study area, for about ¼ the cost of sampling the entire upland portion of the study area. Unless topographic closure can be established, some effort to measure long distance movements is desirable. Information about home range size for each sex is helpful in establishing the area sampled by river sites before conducting fieldwork. Sampling along rivers should continue well beyond the peak of the spawning season because bears remain on the stream scavenging fish well after the peak of the run.

INTRODUCTION

The conservation of grizzly bears (*Ursus arctos*) in British Columbia (B.C.) is a high profile wildlife management issue. The issue encompasses both concern about land use practices, and also the impact of hunting and other human caused mortality. Developing and evaluating conservation measures are difficult because of lack of agreement on how many grizzlies occur in different areas. DNA-based mark-recapture inventories have been applied in many areas of the province to provide objective estimates of abundance to facilitate harvest management; however, these inventories are expensive. Sampling along salmon (*Oncorhynchus* spp.) streams could reduce the cost of large-scale inventories.

Mattson and Reinhart (1995) found that female grizzly bears feeding on spawning cutthroat trout (*Oncorhynchus clarki*) in the Yellowstone ecosystem made greater use of streams than males and that most bears that had >5% of their home ranges touching a spawning stream consumed trout. Some females may have made extra-territorial movements to streams. Most bears in coastal ecosystems move to streams when salmon are present (MacHutchon et al. 1993, Schoen et al. 1994); however, Schoen and Beier (1990) found that 14% of radiocollared bears never moved to streams during the salmon season. Often the bears that did not use salmon streams were females with young cubs. Even bears that used salmon streams were found away from streams 15% of the time during the salmon season, usually in the alpine. The majority of bear locations (55%) were in the riparian zone of salmon streams during the spawning season (Schoen and Beier 1990). Hildebrand et al. (1996) also demonstrated that coastal bears rely heavily on salmon in the fall while a few bears do not use salmon at all. In a following paper, Hildebrand et al. (1999) demonstrated that salmon are important to bears at both the individual and population level because the amount of meat in the diet was correlated with body size, litter size, and density.

Sampling along salmon streams has been used with good success in B.C. for removing hair samples from both grizzly and black bears (*U. americanus*; Boulanger and Himmer 2000, MacHutchon 2000, Mowat et al. 2002). For example, Mowat et al. (2002) sampled 47 km of salmon stream in the Herrick Creek drainage in east-central B.C. and detected 15 different bears 19 times during 4 trapping sessions using 10 different hair sites, for an estimate of about 1 bear per 2 km of stream. Capture success in the Herrick drainage suggests that it should be possible to estimate population size for grizzly bears by trapping along salmon streams, especially in areas with large salmon runs but, estimating density is complicated by the fact bears move to salmon streams from unknown distances.

In this study, we estimated population density of grizzly bears in the Bowron River Valley in the B.C. central interior using hair sampling sites both along salmon spawning streams and in adjacent upland areas. This design allowed us to document fall movements of bears from upland areas to the Bowron River when the salmon were present. The grizzly population within the Bowron River Valley was of interest because a very large proportion of the valley bottom forest was clear-cut logged in the 1980’s to salvage trees killed and damaged by spruce beetles (*Dendroctonus rufipennis*). The census grid was centred on an area that was essentially a continuous 64,000-hectare clear-cut. We were interested in determining how many grizzlies were living within this heavily logged area.

STUDY AREA

Our 2,494-km^2 study area was 90 km southeast of Prince George, B.C. The study area lies in the Southern Interior Mountains ecoprovince (Demarchi et al. 1990). The western third of the study area was part of the Bowron Valley ecosection while the eastern two-thirds was in the Cariboo Mountains ecosection. The study area encompassed most of the central reaches of the Bowron River watershed including major tributaries, Haggen and Indian Point creeks. The southern border of the study area was roughly the northern boundary of Bowron Lakes Provincial Park; the upper reaches of the Bowron River lie south of the Park boundary. The area outside of the study area to the south and east is largely undisturbed by human activities, while in the area to the north and west of the study area, logging and human settlement increase.

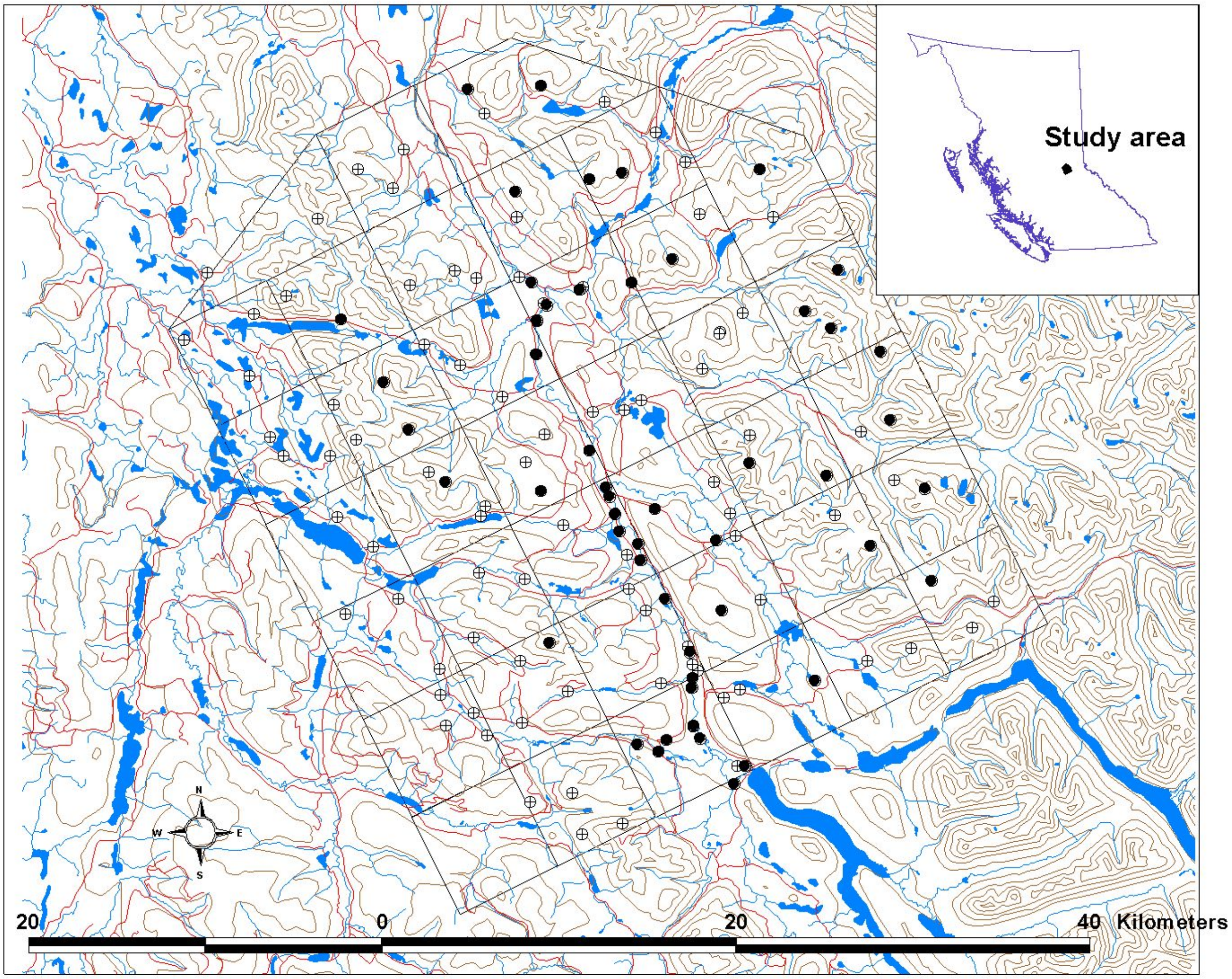
Lower elevations were within the sub-boreal spruce (SBS) biogeoclimatic zone and upper elevations were in the Engelmann spruce-sub-alpine fir (ESSF; Meidinger and Pojar 1991). A small proportion (1%) in the southeast corner of the study area was in the interior cedar-hemlock zone (ICH). Small patches of alpine existed in the western portion of the study area while larger and more continuous patches occurred in the east due to the more mountainous topography. Likewise, avalanche chutes were rare in the western portion of the study area, but common in the east.

Fifty percent of the SBS was logged about 20 years ago, forming a largely continuous 640-km2 clear-cut. Many of the roads used during logging have deteriorated and were impassable during our study. There were few roads and little logging in the ESSF, as much of this forest is protected for mountain caribou (*Rangifer tarandus caribou*) habitat.

There is a both a chinook (*Oncorhynchus tshawytcha*) and sockeye (*O. nerka*) salmon run in the Bowron River. The Bowron River chinook salmon spawn largely in the main stem of the Bowron River and in Haggen, Indian Point, and Antler creeks from mid-August to early September. The number of chinook within the Bowron system was estimated at 5,636 in 2001, with an estimated mean annual escapement of 6,168 for the previous 10 year period (D. Michie, Canada Department of Fisheries and Oceans, Kamloops, B.C.). Sockeye salmon enter the Bowron River slightly later than Chinook, with the majority migrating through the study area to spawn above Bowron Lake in Bowron Lakes Provincial Park. The number of sockeye within the Bowron River in 2001 was estimated to be 5,842 (N. Todd, Lheidli T’enneh Band, Prince George, B.C.) with a mean annual escapement of 8,990 for the 10-year period 1987–1996. A small number of sockeye migrate up Indian Point Creek and spawn above Indian Point Lake.

Hunting, fishing, camping, and all-terrain vehicle use occurred throughout the study area. Spring and fall grizzly bear hunting was permitted prior to spring 2001, and was controlled by quota. Hunters were encouraged to shoot males; the shooting of females accompanied by cubs was prohibited. The average annual kill over the past 20 years was 1.8 bears/yr. Seventy-one percent of the bears harvested were males.

Figure 1. The Bowron River valley grizzly bear survey area. Sites that detected grizzly bears are shown in solid circles, while sites that did not are depicted by open circles with a cross inside. Roads are in red and contours in light brown (100 m interval).



METHODS

Survey design

The survey grid was centred on the Bowron River, which also corresponded to roughly the centre of the large clear-cut area. We divided the study area into 38 cells each approximately 64 km^2 in size (Fig

1). We conducted 3 consecutive trapping sessions between 2 August and 22 September 2001 and trapped 132 sites (Table 1). We put 2 sites in a number of cells each session in order to increase survey effort.

During each trapping session, we placed 1 or 2 capture sites in each cell for 15.3 (SE = 0.23) days on average. Trap sites were moved within each cell for each new session. We tried to ensure that each new site in a cell was located >1 km from all previous sites. We selected sites based on our subjective interpretation of the best grizzly bear habitat in that cell and the generalization that grizzlies move up in elevation as summer progresses when feeding on vegetation (Waller and Mace 1997, McLellan and Hovey 2001). In addition, we conducted sampling along 4 salmon spawning streams (Bowron, Haggen, Indian Point, and Antler) commencing 1 week after upland sites were first set. Here, sites were not moved and were checked every week for 5 sessions.

Field methods

Hair collection sites set in the upland consisted of liquid bait poured on a 1–1.5 m high mound of logs, stumps, moss and boughs, following methods outlined in Poole et al. (2001). We surrounded the mound with a single strand of barbed wire running around 3 or more trees at about 50 cm from the ground (Woods et al. 1999). For bait we used about 250 ml of rancid fish oil, 3 to 4 litres of rotted cow blood, and we hung a burlap sack with about 5 kg of rotten beaver (*Castor canadensis*) meat 5–8 m above the site. For the latter 2 trapping sessions we added a novel scent to each site to encourage previously detected bears to revisit sites. In session 2 we used fennel oil, and in session 3 we added beaver castor. We selected these scents based on trials using captive grizzly bears (Johnson and Kendell 2001). Scents were placed 2 m up in a tree within the site.

Along the river, 27 hair sampling sites were placed along bear travel routes adjacent to reaches which were known spawning areas for chinook salmon. No bait was used, and 1–3 strands of wire were strung across sand bars or trails to remove hair from passing bears. At 3 reaches, no adequate trail set could be established so we built a bait site as described above and baited it with blood and fish oil but not beaver meat.

Before sites were removed, all hair from each barb was collected and placed in a small paper envelope. Samples that were within 2 barbs of each other were considered as part of the same group (an entry or exit point for a bear). We also collected hair from the ground below the wire and from sticks in the bait pile, especially when samples on the wire were few. Each sample was labelled as to group number and the location of the sample with respect to others in the group. All samples were air dried and stored at room temperature.

All hair samples were examined under a microscope to assign species and assess the number of roots available. A portion of the hair samples collected was analyzed for microsatellites based on criteria and methods described in Mowat et al. (2002). We controlled genetic errors by following methods described in Woods et al. (1999); more details on error checking can be found in Mowat et al. (2002) and Mowat and Paetkau (2002).

Statistical analysis

The program MARK was used for estimation of population size and to test for variation in capture probabilities among trapping sessions and sexes (White and Burnham 1999). The logit link was used for estimation. A behavioural response was unlikely because there was no food reward at a site and traps were moved each session. Therefore, we did not consider behaviour models during model selection. The program MARK allows comparison of various models using Akaike's Information Criteria (AIC) values. AIC is a relative measure of model fit which is discounted as the number of parameters in the model increases; reductions in AIC of 2 or more are considered significant improvements in model fit and parsimony (Burnham and Andersen 1998). An increase in AIC signifies the model is less parsimonious than an alternative model. MARK also delivers an AIC weight for each model; this value is the relative fit of the model based on model complexity and deviance. We used MARK to investigate time variation and to compare capture probabilities among sexes. We also used the mark-recapture models in the program CAPTURE to test for random capture variation (often termed heterogeneity) because MARK cannot currently perform such a general test. We examined the tests in CAPTURE carefully for evidence of heterogeneity, while considering that these tests have low power when sample sizes are small (Otis et al. 1978, Boulanger and Krebs 1996). Prudence might suggest the use of a heterogeneity model in all cases (as suggested by Boulanger and McLellan 2001) because others have documented variation in capture probabilities among age classes of bear (Mace and Waller 1997), but heterogeneity models often show greater bias (Kendall 1999), especially when sample sizes are small, and often overestimate population size when no capture variation is present (Otis et al. 1978).

Population estimates are biased upwards when the assumption of geographic closure is not met (White et al. 1982). We used the closure test in CAPTURE and the method presented by Boulanger and McLellan (2001) to test for closure based on the average distance each individual was detected from the edge of the grid. We used a simplified version of their method as described in Mowat et al. (2002).

Habitat Selection

We compared the probability of detecting bears at river sites compared to upland SBS and upland ESSF sites. We examined the effect of forest age (i.e., cut blocks) on capture probabilities by comparing the amount of young forest (<40 years) within a 500 m radius around each upland site. Forest age was calculated using a GIS from 1:20,000 digital maps from the BC Ministry of Forests, Forest Inventory Program. We used logistic regression to test the relationship between forest age and the probability of detecting a grizzly bear. We used the logit function and tested assumptions regarding residuals. Statistical analysis was conducted using SAS Version8.02 (SAS Institute Inc., Cary, North Carolina, USA). Spatial analysis was conducted using ArcView and ArcInfo (Environmental Systems Research Institute, Redlands, California, USA).

Population size using habitat based extrapolation

We estimated grizzly bear population size in the study area using the provincial Fuhr-Demarchi method (Fuhr and Demarchi 1990) as described in Mowat et al. (2002). The high, midpoint and low habitat capability class ratings were reduced to current carrying capacity ratings by accounting for habitat loss, alteration, displacement and fragmentation within all biogeoclimatic/ecosection zones in the study area. The impact of human caused mortality was then considered in relation to the number of bears in the entire study area.

RESULTS

Hair collection and analysis

We collected 743 hair samples from 243 sites. We extracted DNA from 304 samples which were visually classified as grizzly, attempted multilocus genotyping on 231 samples and identified grizzly bears from 193 samples (84%). Fifty-three different grizzly bears were identified in the study. The proportion of sites in the upland that detected grizzly bears decreased through the study (Table 1), while detection increased with time at river sites (Table 2). There was a small reduction in black bear detections in upland sites (Table 1) probably because later in the study we moved more sites closer to the alpine where black bear detections are rare (Mowat et al. 2002). Black bears were detected along the river throughout the study (Table 2).

Identification failures (sites where a grizzly bear detection was confirmed but an individual could not be identified) were more common at river sites than upland sites (19% versus 13% respectively; Tables 1–2). Similarly, the numbers of cases where a bear approached a site (as determined by tracks) but did not leave a hair sample (detection failures) were few in the upland (1) but much more common along the river (18). Detection and identification failures were greater at river sites, but a greater proportion of river sites were encountered by grizzly bears than upland sites.

Table 1. Bear hair capture results from upland areas of the Bowron River drainage August-September, 2001.

Session	No. sites sampled	Set dates	Check dates	Mean sampling duration in days (SE)	Sites with grizzly bear hair (%)	Sites with black bear hair (%)	Sites where grizzly bear ID failed (%)
1	41	2–6 Aug	16–20 Aug	14.0 (0.15)	14 (34)	19 (46)	3 (21)
2	47	5–20 Aug	30 Aug-2 Sept	14.0 (0.27)	9 (19)	13 (28)	0
3	44	17 Aug-2 Sept	15–22 Sept	17.9 (0.39)	8 (18)	10 (23)	1 (13)
Mean				15.3 (0.23)	(23)	(32)	(13)
Total	132				31	42	4

Table 2. Bear hair capture results from sites set along the Bowron River and major tributaries during August-September, 2001.

Session	No. sites sampled	Set dates	Check dates	Mean sampling duration in days (SE)	Sites with grizzly bear hair (%)	Sites with black bear hair (%)	Sites where grizzly bear ID failed (%)
1	17	4–8 Aug	13–18 Aug	7.7 (0.42)	3 (18)	4 (24)	0
2	14	14–18 Aug	21–22 Aug	6.8 (0.21)	5 (36)	5 (36)	1 (20)
3	26	13–22 Aug	27 Aug-1 Sept	10.0 (0.69)	8 (31)	10 (38)	2 (25)
4	27	27 Aug-1 Sept	3–5 Sept	6.7 (0.21)	8 (30)	9 (33)	2 (25)
5	27	3-5 Sept	12–21 Sept	10.8 (0.50)	12 (44)	8 (30)	2 (17)
Mean				8.6 (0.27)	(32)	(32)	(19)
Total	111				36	36	7

Detection of grizzly bears was higher in ESSF forests than in the lower elevation SBS forests, while black bears were detected equally in both biogeoclimatic zones (Fig. 2). Grizzly bear detection at upland sites was not related to the amount of recently logged forest within 500 m of the hair site in either SBS (Fig. 3) or ESSF (Fig 4; $P = 0.48$ and 0.88, respectively). Nor was detection success related to the amount of age class 8 (>140 years) forest or the amount of non-forested land in the window ($P > 0.36$ in all cases).

Figure 2. Grizzly bear and black bear detection success in the Bowron River valley, fall 2001. SBS = sub-boreal spruce and ESSF = Engelmann spruce/subalpine fir (Meidinger and Pojar 1991).

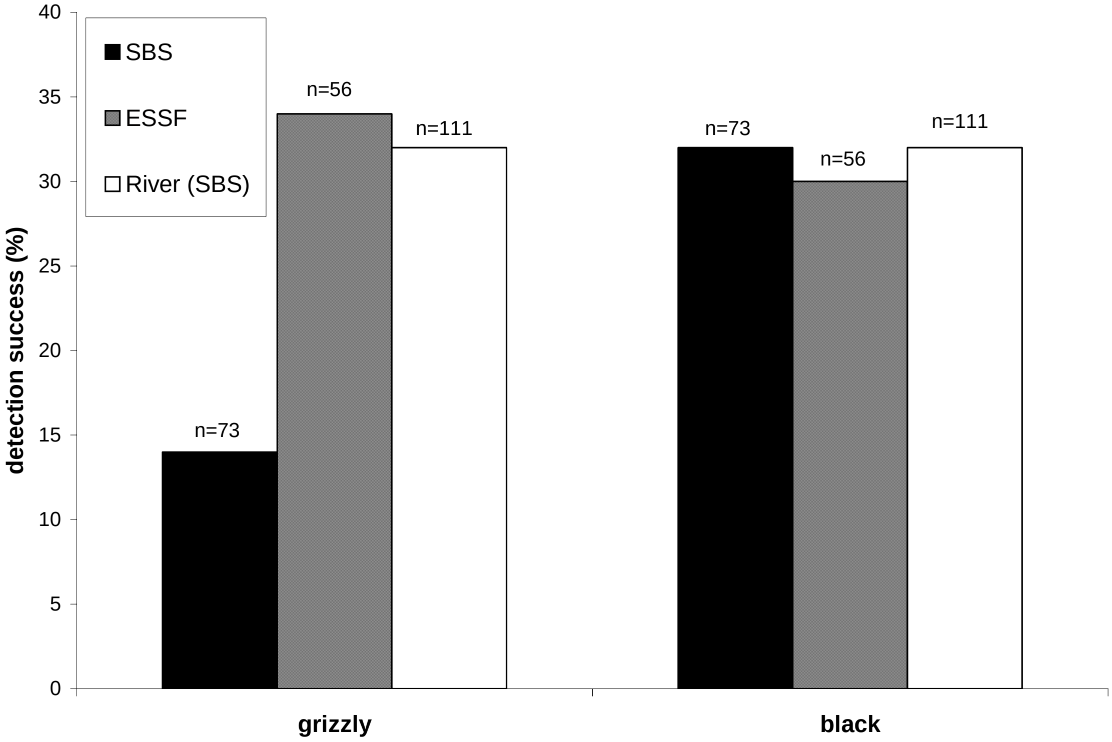


Figure 3. The number of upland sites in Sub-boreal Spruce that detected grizzly bears compared to the amount of logged area (age 1–40 years) in a 500 m window around each site. Relative selection is measured by Ivlev's index, which is scaled between 1 and –1 (Krebs 1989).

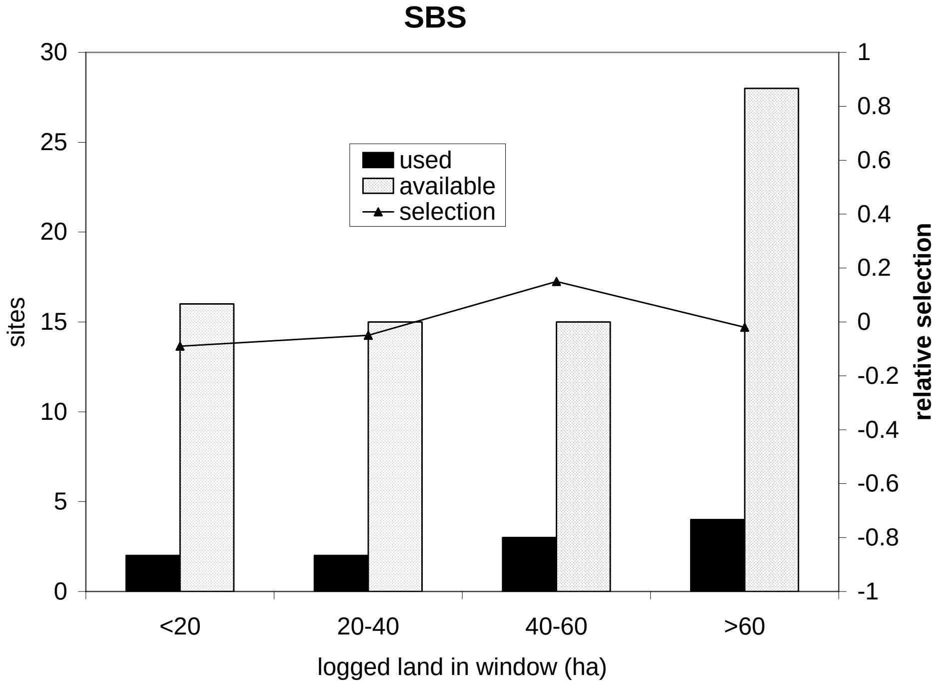
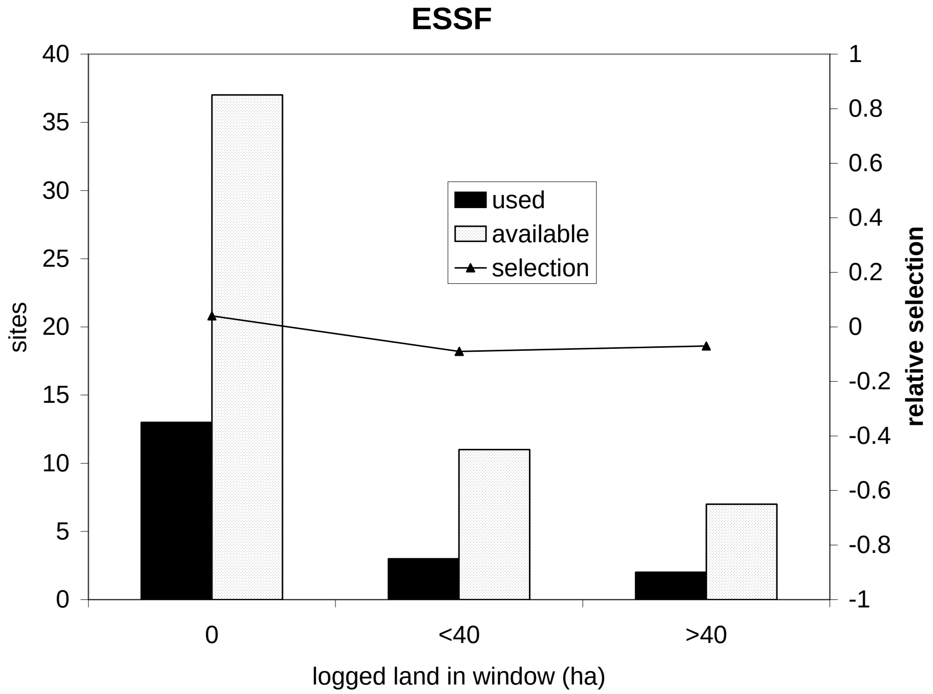


Figure 4. The number of upland sites in Engelmann Spruce-Subalpine Fir that detected grizzly bears compared to the amount of logged area (age class 1-2) in a 500 m window around each site. Relative selection is measured by Ivlev's index, which is scaled between 1 and –1 (Krebs 1989).



Bear movements

We detected 36 grizzly bear movements and grouped these based on whether the movement was within the upland, along the river, or between the upland and the river in either direction (Table 3). No movements >13.5 km were detected from upland to river ($n = 13$) even though 12 grizzly bears were detected >13.5 km from the river (12/53=24% of all grizzly bears known to be in the study area). This suggests that only local residents used salmon streams.

Table 3. Distance moved (km) between capture locations for grizzly bears in the Bowron River drainage, fall 2001.

Type of movement	Sex	*n*	Mean	Range
Upland to river	Male	4	10.4	2.5–13.5
	Female	9	9.4	2.5–13.4
Along river	Male	3	8.4	4.6–16
	Female	11	5.9	0.7–14
Within upland	Male	2	9.0	7.3–10.6
	Female	7	5.1	1.6–12.2

Grizzly bear population size and density

Mark-recapture databases were generated from: 1) upland sites, 2) river sites, and 3) upland and river sites combined. Sessions 2–3 and 4–5 were combined for river sites in order to align the data to the 3 upland sessions. There were 47 captures of 41 bears in the upland, 34 captures of 26 bears along the river, and 74 captures of 53 bears in the combined data (Fig. 5). Both the upland and river datasets were too small to test for capture heterogeneity adequately, and sample sizes were too small to utilize a heterogeneity model. There was no evidence for capture heterogeneity in the combined dataset based on the Goodness of Fit test in CAPTURE ($\chi^2 = 0.2$, 1 df, $P = 0.67$). We also tested for variation in capture probabilities among sexes using MARK; there was no evidence for capture variation among sexes. The model which accommodated variation among sexes (Model 4) was much less weighted than the comparable model, which did not accommodate different capture probabilities among sexes (Model 3; Table 4). The most parsimonious model (Model 1) incorporated no capture variation although a model that estimated separate capture probabilities for session 3 verses sessions 1–2 combined (Model 2) was given similar weighting and had measurably lower deviance (Table 4). We used Model 2 for population estimation.

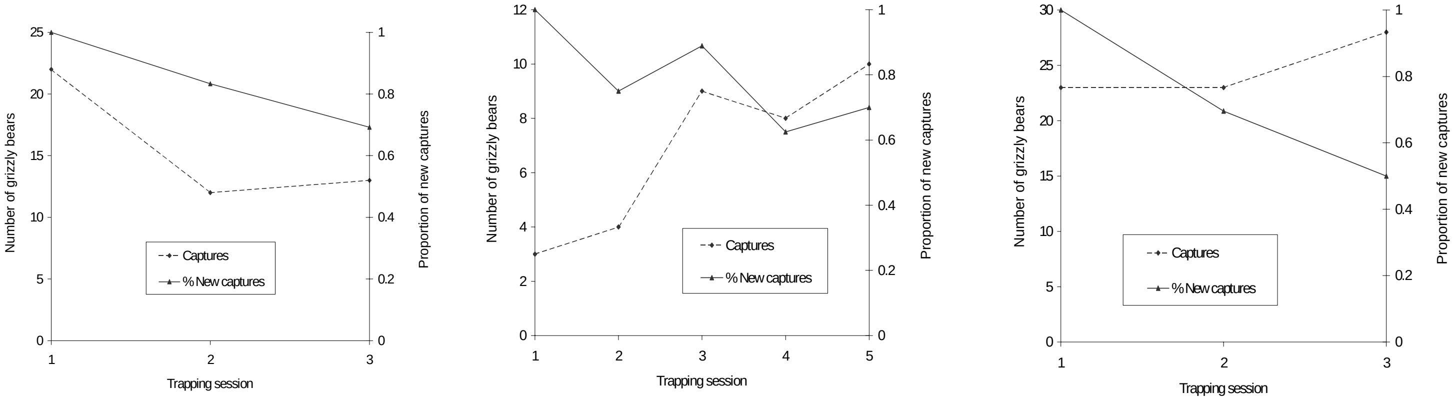
The test for closure in CAPTURE suggested a closed population ($z = 0.55$, $P = 0.71$). In addition, the use of distance from edge to exclude bears caught near the study periphery did not suggest any degree of closure violation (Fig. 6). The lack of detectable closure violation is not surprising given that few bears were caught near the study area boundary (Fig. 1).

Population estimate for the upland was 109 grizzly bears (95% CI 67–221) and 47 bears (33–85) for the river, using a time varying model in both cases. The population estimate using the combined data was 76 bears (63–104). The estimate for females (49 bears; CI 41–70) was double that for males (25 bears; CI 21–39). The combined density of grizzly bears in the study area was 30.9 bears/1,000 km^2 (25.7–42.3). Based on the movement data we assumed our river sites were trapping bears that lived in the 2 rows of cells on each side of the river. The estimated density for this area using only the river sites was 27.2 bears/1,000 km^2 (19.1–49.2). There was about 1 grizzly bear per 1.8 km of river, a similar number to that observed along Herrick Creek about 100 km further north (Mowat et al. 2002).

Table 4. Tests of model fit for combined upland and river sites for grizzly bears captured in the Bowron River drainage, fall 2001.

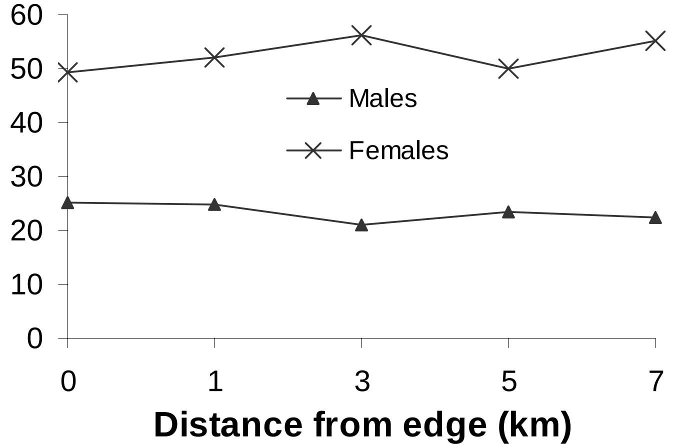
Model	AICc	Delta AICc	AICc weight	Parameters	Deviance
1. Time(null)*N(sex)	-48.947	0	0.56	3	12.693
2. Time(ses1-2combined)*N(sex)	-47.841	1.1	0.32	4	11.694
3. Time(full)*N(sex)	-45.709	3.2	0.11	5	11.694
4. Time(full*sex)*N(sex)	-39.674	9.3	0.005	8	11.161

Figure 5. Total captures and % new captures for grizzly bears caught: a) in the upland, b) along the river and, c) all bears combined, Bowron River drainage, fall 2001.



a) upland **b) river** **c) upland and river combined**

Figure 6. Core population corrected population estimates for the Bowron River grizzly bear population, fall 2001. Each estimate is calculated by removing bears whose mean capture distance (in km) is within the given distance from the edge of the study area boundary and then extrapolating the estimate of the reduced area to the full study area (Boulanger and McLellan 2001).



Fuhr-Demarchi population estimates

Habitat capability ratings for the 11 biogeoclimatic/ecosection zones in the study area ranged from 1 to 5, but by far the greatest impact on the grizzly bear population estimate was related to the extent and capability rating of the ESSFwk1. In both the Cariboo Mountains and Bowron Valley ecosections, the ESSFwk1 had a capability class rating of 2, indicating a density ranging from 51–75 bears/1,000 km^2. The ESSFwk1 made up 42% of the area but 83% of the bear capability when using the minimum of the capability density range. All of the SBS, 50% of the study area, had a class 4 capability rating (6–25 bears/1,000km^2). The resulting maximum potential population size ranged from 65 to 118 bears when using the low and high ends of the capability rating, respectively (Fig. 7).

The Fuhr-Demarchi population estimation method accounts for the impact of habitat loss, alteration and displacement/fragmentation. Almost all of the anthropogenic disturbance in the study area was related to logging which occurred about 20 years ago. About 50% of the SBS was logged but there was little logging in the ESSF.

The impact of habitat loss was due to roads and logging landings. We estimated their impact at 3% in the SBS and 0.5% in the ESSF. By definition, the loss impact in these roaded areas was 1.0 and, in general, roads were in areas we considered representative bear habitat, so we assigned a relative habitat value of 1.0.

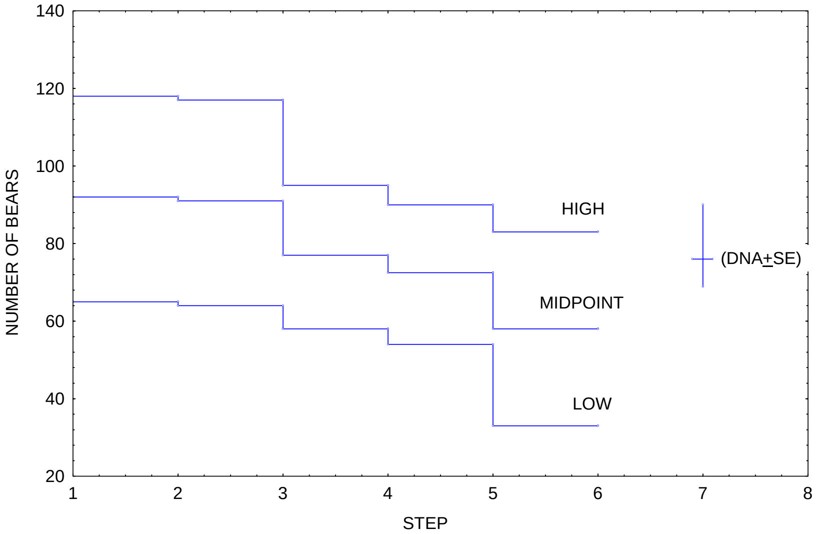
The impact of habitat alteration was based on the Fuhr-Demarchi procedure that assumes that logging adversely alters bear habitat value by changing natural succession patterns and forest age class distributions. We judged that logging reduced the habitat value by 50%, that the altered area was representative bear habitat, and impacted 10% of the ESSF, 10% of the ICH, and 100% of the SBS.

We considered fragmentation and displacement impacts together assuming that some bears may be displaced from roads and other areas used by humans. The proportion of the area from which bears were displaced depended on road density with the road's zone of influence probably affecting 100% of the SBS, where road density was high and 10% of the ESSF and ICH in the western (Cariboo Mountains) part of the study area. The eastern ESSF (Bowron Valley) was isolated from the continuous high quality ESSF bear habitat in the east by the Bowron clear-cut (SBS) so we judged that 100% of that area was affected. There was little active logging and therefore low traffic volume in this zone. We estimated the displacement/ fragmentation impact at 10% everywhere else.

The final step in calculating of the Fuhr-Demarchi current grizzly bear population estimate involves accounting for the number of bears shot by hunters. The maximum sustained yield as prescribed by the BC Wildlife Branch (Ministry of Environment, Lands and Parks 1999) is related to the current carrying capacity.

Because the current carrying capacity for the study area was between 22 and 36 bears/1,000 km^2, the prescribed maximum sustained yield of known hunting kills was 3%/yr. Assuming that the maximum sustained yield for grizzly bears occurs at 80% of K (Taylor 1994), then the maximum number of bears that can be shot each year was between 1.3 and 2.1 bears/ yr (e.g., at the low end of the capability rating 0.03 x 0.8 x 55 = 1.3). The known annual hunting kills averaging 1.8 grizzly bears/year, exceeded the maximum sustained yield at the low end of the capability rating and would have resulted in a decline to 33 bears after 20 years. Because the average annual hunter kill was less than the maximum sustained yield at the high end of the capability rating, hunting would have been sustainable at 83 bears which is about 90% the current carrying capacity. The final Fuhr-Demarchi population estimates of 33 and 83 bears represent densities of 13 and 33 grizzly bears/1,000 km^2 (Fig. 7).

Figure 7. Grizzly bear population estimates based on the Fuhr-Demarchi habitat-based method for the Bowron Valley study area. Lines represent stepped down bear estimates, starting from the high, midpoint and low habitat capability ratings for habitat loss, habitat alteration, displacement/fragmentation and human caused mortality. The horizontal lines at "Step 7" represent the DNA-derived point estimate (±SE).



DISCUSSION

Population density

Grizzly density in this study area (31/1,000 km^2) was comparable to the densities found in the mountainous portion of the Parsnip/Herrick study 100 km to the northeast (Mowat et al. 2002). In the Parsnip/Herrick mountains (Hart Ranges), the overall density was 49 bears/1,000 km^2, but bears were concentrated in alpine and subalpine areas along the continental divide. Bear detection rates were lower in valley bottoms dominated by a mix of logged and mature SBS forests than areas dominated by undisturbed ESSF forests at high elevations. Grizzly densities were much lower (11/1,000 km^2) in SBS forests on the plateau portion of the Parsnip/Herrick study area. Therefore, the density observed in the Bowron appears to represent the mid-point between the high densities of bears along the isolated divide of the Rocky Mountains, and the low densities that occur in SBS forests on the heavily disturbed interior plateau. It is unclear if this population trend is primarily due to differences in habitat capability, human caused habitat changes, or direct human caused mortality.

The large amount of logging in the Bowron valley did not appear to affect bear distribution at the stand scale because detection success was unrelated to forest age. Logging did not appear to have a large negative affect on bears at the landscape scale either because the density did not appear greatly lower than might be expected. Further, the population estimate using only the river sites (47 bears; CI 41–70) and the resulting density of 27 (19–49) grizzly bears/1,000 km^2 was similar to the overall density for the study area. The movements we documented suggest that the bears detected along the river may have lived largely within the SBS, which had been largely logged. The absence of grizzly bears in the western part of the study area is likely due to the increasing proximity to human dwellings and disturbance than to isolation or fragmentation of the western ESSF forests by the logging history in the SBS.

However, while the above evidence suggests no large impact of the recent logging on bear numbers, we have no empirical measure of population trend of bears. Logging creates early seral stands and some of these offer considerable foraging opportunities for bears. These opportunities will decline as forests regenerate hence the impact of large scale logging may only be discernable over the long-term. Monitoring population trend of this population would be useful in interpreting the full impact of large-scale forest harvesting on this grizzly bear population.

The Fuhr-Demarchi habitat-based population estimate is lower than the mark-recapture estimate for the Bowron Valley study area, with the number used for hunting management only about one third of the current number of bears. Although there is no correlation between direct field mark-recapture population estimates and estimates based on the Fuhr-Demarchi habitat based process (Mowat et al. 2002), the Fuhr-Demarchi system appears to systematically underestimate actual population size (this study, Mowat et al. 2002) suggesting that the current method of managing hunting in B.C. is conservative. The relatively high density we found in the SBS suggests that either the SBS capability rating is too low, or the assumption that logging adversely affects habitat suitability is incorrect, or both. Because other factors also affect the calculation of the Fuhr-Demarchi estimate (e.g., hunting mortality) it is impossible to refine the technique based on a comparison with actual bear densities.

The 20-year average kill of 1.8 bears/yr, which is 2.4% of the current grizzly bear population, is likely sustainable (Taylor 1994), especially given that hunters have shown strong selection for males (71% of the kill).

Movement to salmon streams

Grizzly bears did not appear to leave their home ranges to reach salmon along the Bowron River. Mowat et al. (2002) found that 2 males made long distance movements (35 and 48 km) to Herrick Creek during the salmon season. Similar movements were not detected here but only 4 male bears were detected moving to the river in this study. Mean movement distances to the river for females were double those observed in the Hart Ranges by Mowat et al. (2002). Either females made extra-territorial movements to get to salmon streams or, more likely, female home ranges in the relatively flat part of the Bowron River are larger than in the very rugged Hart Ranges. Ciarniello et al. (2001) found that bears living on the flatter plateau portion of their study area had home ranges 7X larger (on average) than bears residing in the mountainous portion. Seip et al. (2002) radio tracked 4 grizzly bears living 20-60 km east of our study area. There were fall salmon runs in several local streams, yet none of these bears appeared to move down to the salmon bearing portions of the creeks, within or outside their home ranges, during the salmon season although, radio locations during the salmon season were few for 2 bears.

Access to the Bowron River by grizzly bears may be limited by human use of the river edge and human land uses near the river. Perhaps site level disturbance of grizzly bears by humans allowed the high use of the river corridor by black bears during the salmon season (Table 2), which is unusual in areas where grizzly bears are abundant (Miller et al. 1997, Jacoby et al. 1999, Mowat et al. 2002). At the lower end of the chinook spawning area there is a campsite that is heavily used by people during the salmon season. At the upper end of the river housing development is occurring along the river; some houses are being built adjacent to heavily used spawning beds. Roads have been built along much of the river and a massive logging effort during the 1980’s to control forest pests removed forest cover along a large portion of the river.

DNA-based inventory methods for bears

It appears that a large number of bears can be sampled along salmon streams in the continental interior with relatively small effort. We generated a precise estimate of the number of bears using approximately 40 lineal km of river (tributaries not included) with about 18 crew days (2 people) of effort and the use of a truck and boat. A much less precise estimate of the number of bears in the upland was generated with 24 crew days of effort, which included $25,200 in helicopter costs and much greater truck costs. By our crude estimates the upland sampling covered roughly one third more area than the river sampling. Also, our river estimate would likely have been more precise had we trapped for 1 additional session because bear detections increased right up to the end of our river sampling. Bears were likely scavenging for spawning mortalities at this time.

The problem with sampling along salmon streams is calculating bear density. Density is usually needed for examining past harvest impacts or setting future harvest quotas, but management decisions can also be based on population trend. We spent considerable effort attempting to document movement distances and still our results for males were weak because we caught few males overall and none on the western periphery of our study area. Even in areas where bears are more abundant and the population distribution more homogenous, it will be difficult to get robust measures of bear movement distances. Field costs to measure movement distances could be reduced if sampling were restricted to only those upland areas beyond the distance bears are known to move to the river. In this study for example, it appears that it was unnecessary to sample the upland in the 2 rows of cells nearest the river in order to determine if bears were moving beyond their normal home ranges. Upland sampling could have been concentrated further away from the river giving a better estimate of long distance movement rates.

Paczkowski (2002) also showed that hair snares were efficient at catching grizzly bears along interior streams. He caught 6 males and 1 female in 11 snares in 1 14-day session along about 1.5 km of river when several thousand spawning kokanee were in the river. He caught no bears in 1 2-week session using 12 snares distributed up to 30 km away in the surrounding uplands. These data suggest that the bear density in the surrounding uplands was low and that bears could be coming from relatively long distances and still be within their normal home ranges.

MANAGEMENT RECOMMENDATIONS

Because DNA survey methods are so expensive, there will likely always be some need to use habitat-based extrapolations, like the Fuhr-Demarchi method, to predict bear abundance across broad areas. However, at present the Fuhr-Demarchi technique is so subjective that different individuals can come up with widely differing results for the same area. Thus, there is a need to modify the method so that it is objective, repeatable and testable (Heard 2001). In the short term, we suggest that managers should use DNA-derived population estimates in various regions as benchmarks to help calibrate the Fuhr-Demarchi method. This study showed that the habitat capability rating for the SBS was too low, but our results do not indicate how much higher the rating should be because the habitat suitability reductions regarding the effect of logging may also be in error. The use of empirical methods to extrapolate abundance based on habitat analysis of survey data should also be considered (Boyce and MacDonald 1999), although tight-fitting statistical models often do not work well when applied to other areas. The results of this study support the suggestion by Mowat et al. (2002) that the Parsnip plateau density be considered representative of the surrounding plateau SBS forests and the Hart Ranges density be considered representative of the ESSF, SBS, and Spruce-Willow-Birch (SWB) forests and alpine tundra on the west slopes of the Rocky Mountains.

Conducting fieldwork along salmon streams could reduce the cost of bear inventories in the interior. Unless topographic closure can be established (for example as in Boulanger and Himmer 2000), some effort to measure long distance movements would be desirable. Information about home range size for each sex would be helpful in establishing the area sampled by river sites before going in the field. Sampling along rivers should continue well beyond the peak of the spawning season because bears remain on the stream scavenging fish after that time.

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