Research Article

Displacement of Mountain Caribou From Winter Habitat by Snowmobiles

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ABSTRACT Mountain caribou are an ecotype of woodland caribou (*Rangifer tarandus caribou*) that live in subalpine forests in southeastern British Columbia, Canada, extending into northern Idaho and Washington, USA. These caribou are listed as Threatened in Canada, Endangered in the United States, and are the subject of recovery planning efforts in both countries. Many areas of mountain caribou winter habitat experience intensive use by recreational snowmobilers. During 4 surveys, we recorded caribou on all 4 census blocks with little or no snowmobile activity ($\bar{x}$ density = 0.41 caribou/km^2), but during 3 of 4 years, we observed no caribou on the census block with intensive snowmobile activity. The year we observed caribou on the snowmobile block, most were using areas inaccessible to snowmobiles. We used a Resource Selection Function (RSF) based on radiotelemetry data for the area to compare habitat quality among the different census blocks. The absence of caribou from the intensive snowmobile area during most years could not be explained by differences in habitat quality. The RSF predicted that the intensive snowmobile area could support 53–96 caribou (95% CI). We conclude that intensive snowmobiling has displaced caribou from an area of suitable habitat. We recommend that snowmobile activity be restricted from all or most high-quality mountain caribou habitat as part of the recovery planning process. (JOURNAL OF WILDLIFE MANAGEMENT 71(5):1539–1544; 2007)

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KEY WORDS British Columbia, displacement, mountain caribou, *Rangifer tarandus caribou*, resource selection function, snowmobiles.

Mountain caribou are an ecotype of woodland caribou (*Rangifer tarandus caribou*) that live in the mountains of southeastern British Columbia, Canada, and into northern Idaho and Washington, USA (Heard and Vagt 1998). These caribou are listed as Threatened in Canada, and Endangered in the United States. Both countries are involved in recovery planning efforts to maintain these caribou. One recognized threat to mountain caribou populations is disturbance on winter range by snowmobiles (Mountain Caribou Technical Advisory Committee 2002).

Mountain caribou live in a zone of very deep winter snowpack that makes it impossible to feed on ground vegetation in winter. Consequently, these caribou feed primarily on arboreal lichens during the winter months. Throughout late winter, caribou are located primarily in subalpine forest and subalpine parkland habitat in areas of gentle terrain (Terry et al. 2000, Apps et al. 2001, Johnson et al. 2004). These habitats contain abundant arboreal lichens and provide spatial separation from predators in the valley bottoms (Seip 1992).

Deep snow, open forests and gentle terrain also make these areas attractive to recreational snowmobilers. Snowmobile use in some areas is intensive with entire mountain tops criss-crossed with snowmobile tracks. Snowmobile activity is increasing within mountain caribou range as new forest roads increase accessibility, and improved snowmobile technology increases their ability to reach new areas.

There is concern among wildlife managers that disturbance by snowmobiles will displace mountain caribou from preferred habitat areas (Simpson 1987, Simpson and Terry 2000, Mountain Caribou Technical Advisory Committee 2002, Kinley 2003). The fright and flight response of caribou and reindeer to snowmobile disturbance has been documented (Simpson 1987, Mahoney et al. 2001, Reimers et al. 2003), but abandonment of preferred habitats has not been reported. Anecdotal observations suggest mountain caribou in British Columbia no longer use historic ranges where snowmobile activity is now common, but this relationship has been difficult to quantify. This lack of evidence has led to acrimonious debate during recovery planning regarding the need to restrict snowmobile activity within mountain caribou winter ranges.

On several winter flights to census mountain caribou we observed that one mountain block with very intensive snowmobile use had few or no caribou despite the presence of habitat that appeared similar to neighboring mountain blocks supporting hundreds of caribou. To more rigorously evaluate this relationship, we used a resource selection function (RSF) to quantify the relative value of habitats (Manley et al. 1993) across the different mountain blocks surveyed for caribou. We then used survey data for undisturbed blocks, our final RSF, and a habitat-based population density estimator (Boyce and McDonald 1999) to predict the expected number of caribou on the snowmobile block. We then compared the number of caribou observed in the intensive snowmobile area to the number of animals predicted based on habitat.

STUDY AREA

The study area was the winter range of the Hart Ranges caribou herd in central British Columbia (54°N, 121°W) about 100 km east of Prince George (Fig. 1). The core winter range was a series of discrete mountain blocks separated from the more contiguous Rocky Mountains to

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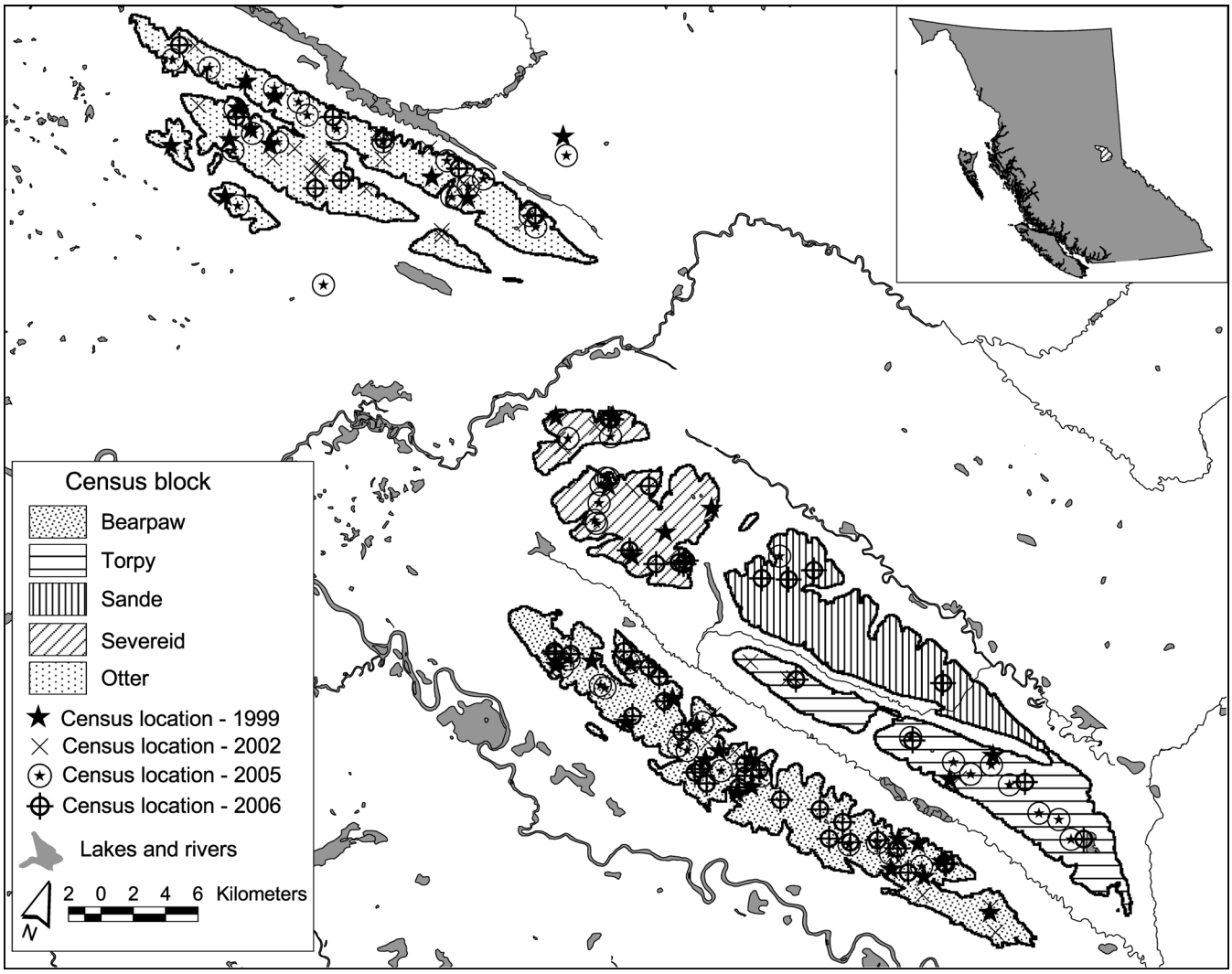

Figure 1. Map of the Hart Range study area in east-central British Columbia, Canada, showing the census blocks and locations of caribou during March surveys in 1999, 2002, 2005, 2006.

the east. We delineated 5 discrete mountain blocks (Fig. 1, Table 1) separated from each other by low-elevation valleys. Census data indicated that although some caribou occurred in the more rugged areas of the Rocky Mountains to the east, most of them lived on these gentler mountain blocks during winter.

Mountain blocks rose from valley bottoms at about 800 m to a maximum elevation of 2,100 m. Valley bottoms contained the Sub-Boreal Spruce (SBS) and Interior Cedar Hemlock (ICH) biogeoclimatic zones extending up to about 1,000 m (Delong 2003). Caribou primarily used subalpine forests above the valley bottom forest types. Immediately above the SBS–ICH was the wet, cool sub-zone of the Engelmann Spruce–Subalpine Fir Zone (ESSF) that extended from about 1,000 m to 1,300 m (Delong et al. 1994). The wet, cold sub-zone of the ESSF occurred from 1,300 m to tree line at about 1,500 m. At tree line, forests became an open parkland ESSF sub-zone that extended up to about 1,820 m. Treeless alpine habitat occurred above 1,820 m.

The ESSF zone contained a mixture of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*), with the proportion of subalpine fir increasing with elevation. The upper-elevation subalpine fir trees contained abundant amounts of arboreal lichens (*Bryoria* spp.), which provided the primary winter food of the caribou. The subalpine forests within the wet, cold ESSF zone had an annual snowfall of 782 cm, which created a snowpack that often exceeded 3 m in depth (Delong et al. 1994).

Forest harvesting was widespread in the valley bottoms, but upper-elevation ESSF forests were largely protected as caribou habitat and not available for forest harvesting. However, forest roads in valley bottoms provided access for snowmobilers. One of the 5 mountain blocks (Sande) was a recognized snowmobiling area and had very intensive snowmobile use throughout winter, whereas the other mountain blocks had no or very limited snowmobile use. A cabin providing overnight accommodation for snowmobilers encouraged use of the Sande area.

Table 1. Characteristics of the mountain blocks that we censused for mountain caribou in the Hart Ranges, British Columbia, Canada in March 1999, 2002, 2005, 2006.

Census block	Snowmobile activity	Area (km^2)
Otter	none or low	214
Bearpaw	none	223
Severeid	none	110
Torpy	none or low	143
Sande	intensive	134

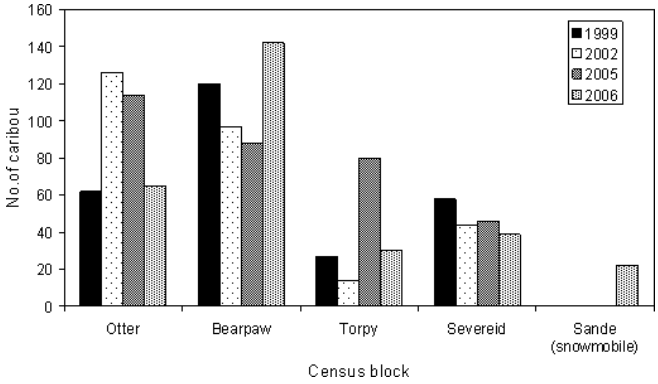

Figure 2. Number of caribou in each census block during March (1999, 2002, 2005, 2006) surveys in the Hart Range, British Columbia, Canada. The Sande block was the only one with intensive snowmobile activity.

METHODS

Caribou Census

We conducted censuses on caribou in March of 1999, 2002, 2005, and 2006 by flying the tree line of each mountain block in a helicopter searching for caribou or tracks. We conducted censuses within a day or two of new snowfall to ensure that tracks were fresh. When we located tracks, we followed them to locate and count caribou. We determined coordinates for each caribou group with a Global Positioning System (GPS). Previous studies using marked animals have found that on average, this census technique locates 87% of the mountain caribou within the census area (Wittmer et al. 2005).

Habitat Modeling and Population Estimation

We developed 4 ecologically plausible RSF models to describe and predict the distribution of habitats for mountain caribou during late winter (29 Jan–31 Mar). We developed models using 211 telemetry locations collected from 28 female caribou. We paired each caribou location with 5 random locations that quantified the availability of habitats. Model development and application was similar to that reported by Johnson et al. (2004). In summary, we used conditional fixed-effects logistic regression to calculate RSF coefficients for 9 variables: 6 biogeoclimatic sub-zones (Meidinger and Pojar 1991), slope (polynomial term), and distance to tree line for alpine locations (eq 1).

$$w(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + \ldots \beta_k x_k) \quad (1)$$

We used Akaike's Information Criterion and multimodel inference to average coefficients across the 4 RSFs and account for model selection uncertainty (Anderson et al. 2000). We then applied averaged model coefficients to equation 1 and calculated RSF maps for each census block. We used percentiles calculated from observed caribou data to define breakpoints and stratify the continuous RSF values (w) into 10 classes. Each class represented a composite habitat class defined by the resource covariates included in the averaged models. We considered classes 1 and 2 as poor-quality habitats, classes 3–6 as medium-quality habitats, and classes 7–10 as good-quality habitats for mountain caribou.

Independent census data and RSF maps of habitats can be combined to estimate the expected density of animals for an area based on habitat values (Boyce and McDonald 1999). The RSF-based estimation procedure divides the observed population among RSF habitat classes according to strength of selection for an area of each class. Density within each class across the reference area can then be calculated and applied to other areas to estimate the number of animals that should occur based on habitat values.

We used census data for each survey from the 4 blocks with little or no snowmobile use to generate separate RSF-based density estimators ($n = 16$). We applied each estimator to the Sande block where we observed intensive snowmobile use and few caribou. These estimates represented the number of caribou that might have been expected based on habitat value in the absence of snowmobile activity. We also present simple density estimates exclusive of the habitat weighting factor.

Snowmobile Use

We recorded snowmobile sightings and tracks during all caribou census flights. In March 2006, we delineated the extent of intensive snowmobile activity on Sande ridge with a GPS. We plotted the location of caribou observed in 2006 relative to the intensive snowmobile area. We also used the RSF to quantify habitat quality within the intensive snowmobile area relative to the entire Sande block.

RESULTS

During all 4 censuses, we found caribou on the 4 mountain blocks where snowmobile use was low or absent (Fig. 2). During 3 of 4 years, we found no caribou on the Sande block that had extensive snowmobile use. We located tracks of one or two caribou on the Sande block during 2005, but we could not find the caribou. Those tracks were in a rugged portion of the block inaccessible to snowmobiles. During the March 2006 census, we found 22 caribou on the Sande block. However, 14 of those caribou were on a separate ridge inaccessible to snowmobiles and were over 2 km from the area of intensive snowmobile use (Fig. 3). We located 2 groups of caribou totalling 8 animals within the intensive snowmobile use area, but they were close to the edge and most of their tracks were in steeper terrain beyond the area used by snowmobiles.

Caribou density observed on the 4 blocks with little or no snowmobile use averaged 0.41 caribou/km^2, and ranged from 0.10 caribou/km^2 to 0.65 caribou/km^2 (Fig. 4). The Sande

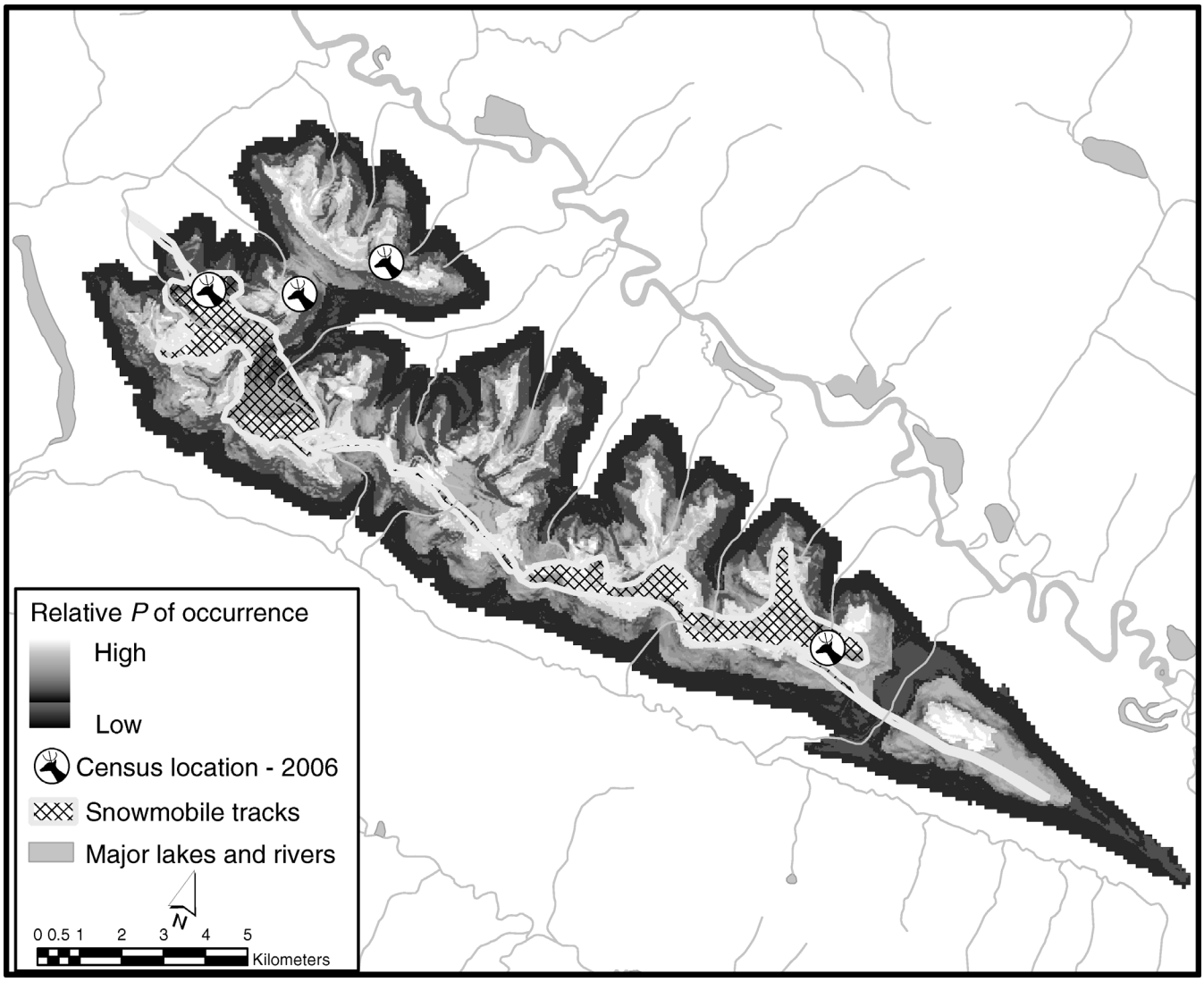

Figure 3. Map of the Sande block showing area of intensive snowmobile use in March 2006 relative to habitat quality and caribou locations, Hart Range, British Columbia, Canada.

block had zero caribou in 3 of 4 years but 0.17 caribou/km^2 in 2006. Based on caribou density on blocks with little or no snowmobile use, we would have expected to find an average of 54 caribou (95% CI = 43–66) on the Sande block during March, with a range from 9 caribou to 85 caribou.

The most parsimonious RSF model consisted of terms for biogeoclimatic zone, distance to tree line for alpine locations, and a polynomial term for slope (Akaike wt = 0.64), and was a good predictor of withheld caribou locations ($\bar{r}_s = 0.878$, $P < 0.001$). The RSF agreed with our general understanding of mountain caribou ecology: avoidance of low-elevation SBS habitats ($\beta = -4.676$, 95% CI = −6.354–−2.998) and selection for upper-elevation ESSF forests ($\beta = 1.440$, 95% CI = 0.967–1.912), parkland ($\beta = 2.177$, 95% CI = 1.698–2.656), and alpine tundra ($\beta = 1.537$, 95% CI = 0.674–2.400) in proximity to tree line.

The RSF analysis indicated some variability in habitat quality among the different census blocks (Fig. 5). The habitat quality on the Sande block was equal or superior to the other blocks that supported caribou. Thus, the absence of caribou during 3 of 4 years was not explained by the absence of good-quality habitat.

Application of the RSF-based density estimation technique to 4 years of census data and 4 reference blocks resulted in an average estimate of 75 caribou (95% CI = 53–96) for the Sande block. However, estimates were quite variable across years and blocks ranging from 13 animals to 136 animals. Overall, the average number of caribou on Sande ridge was significantly lower than would be expected based on simple density or the RSF-based density estimates.

We observed intensive snowmobile use on the Sande block every year, and in 2006 we determined that the area of intensive snowmobile use covered 1,597 ha of the 14,400-ha census block. However, snowmobile activity was concentrated on the best-quality habitat with little use of the poor habitat classes (Fig. 6). The intensive snowmobiling area covered 51% of the Class 10 habitat and 36% of the Class 9 habitat on the Sande block.

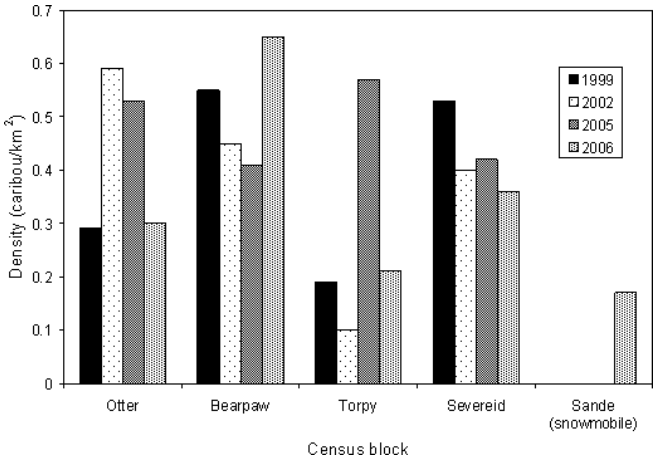

Figure 4. Caribou density in each census block during March (1999, 2002, 2005, 2006) surveys in the Hart Range, British Columbia, Canada. The Sande block was the only one with intensive snowmobile activity.

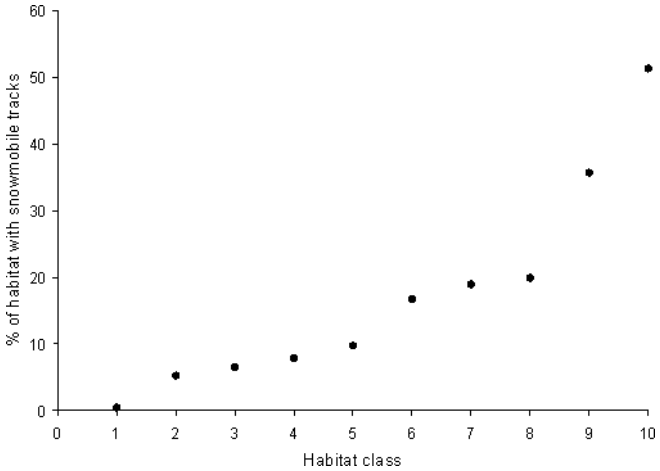

Figure 6. Percentage of each caribou habitat quality class (Class 1–2 = Poor; Class 3–6 = Medium; Class 7–10 = Good) on the Sande block that had extensive snowmobile use in March, 2006, Hart Range, British Columbia, Canada.

DISCUSSION

We conclude that intensive snowmobile activity on mountain caribou winter range resulted in displacement of caribou from high quality habitat. In most years, caribou were completely absent from the mountain block that experienced intensive snowmobile use. When some caribou did use that mountain block, most used areas that were inaccessible to snowmobiles. The low level of caribou use in the area with snowmobiles could not be attributed to poorer quality habitat as habitat modelling indicated that the area provided habitat that was equal or superior to the other mountain blocks where caribou were consistently found. The number of caribou using the snowmobile area was always significantly lower than the number expected based on habitat quality.

Other studies have reported local displacement of caribou and reindeer by snowmobiles (Simpson 1987, Simpson and Terry 2000, Mahoney et al. 2001, Reimers et al. 2003), but we found complete displacement from an entire mountain block in most years. Local displacement may result in increased energetic costs to caribou or reindeer (Tyler 1991, Reimers et al. 2003). However, complete displacement from high-quality habitats could force caribou into inferior habitats where they have greater risk of mortality from avalanches, predation, or nutritional and energetic stress. Given that mountain caribou populations are Threatened or Endangered, and most populations are declining (Wittmer et al. 2005), any additional negative population pressure will be detrimental to recovery efforts.

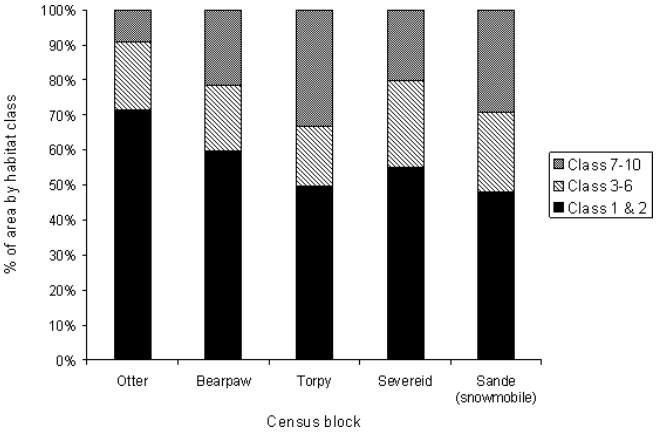

Figure 5. Percent of caribou winter habitat in each habitat quality class (Class 1–2 = Poor; Class 3–6 = Medium; Class 7–10 = Good) for each census block from 1999 to 2006 based on a Resource Selection Function. Hart Range, British Columbia, Canada.

It is important to note that our estimates of caribou density for the Sande block represent a range of possible values, not the exact number of caribou expected in the absence of snowmobiles. As demonstrated in a companion study (C. Johnson, University of Northern British Columbia, unpublished manuscript), population density will influence the distribution and abundance of animals among reference areas and, consequently, the range of predictions. Only where a reference population is at ecological carrying capacity can we be assured that estimates are not biased by interannual variation in distribution. Unfortunately, this assumption is difficult to test under field conditions (but see Boyce and Waller 2003). Although variation in density can limit accuracy and precision of the technique, the bias should result in conservative estimates. If future surveys report greater animal densities in reference blocks across our study area, for example, caribou estimates for the Sande block should increase accordingly. Predictions, however, also are sensitive to occupancy patterns that result from caribou over-fitting or under-fitting patches (relative to habitat quality), and inherent error and uncertainty in RSF scores and maps (C. Johnson, unpublished manuscript). The impact of these latter factors could lead to estimates that inflate the true impact of snowmobiles on caribou distribution.

Although intensive snowmobile activity may seem limited to a fairly small proportion of the total range of a mountain caribou herd, it is important to note that snowmobile use was concentrated on the highest quality habitat types,

whereas there was little use of the poor-quality caribou habitat. The majority of the best habitat class on the Sande mountain block was being intensively used by snowmobiles. Snowmobilers appear to be selecting for the same features preferred by mountain caribou.

Preisler et al. (2006) found that elk (*Cervus elaphus*) responded to disturbance from all terrain vehicles at distances >1,000 m. If a similar zone of influence applies to snowmobiles and caribou, the impact of the intensive snowmobile area would extend over most of Sande ridge, which would explain why in most years caribou avoided the entire mountain block.

MANAGEMENT IMPLICATIONS

It is not known if displacement from the Sande block has had negative population impacts for this caribou herd because they had alternative areas of good-quality habitat available. However, if snowmobile activity continues to expand to more areas of high-quality habitat, caribou would eventually be displaced to poorer quality habitat. Caribou forced into poorer quality winter habitat may experience an increased risk of accidental deaths from avalanches in steeper terrain, increased energy expenditure required to move through deeper snow or steeper terrain, reduced forage availability, or increased risk of predation. Those factors would have negative impacts on population growth and compromise recovery efforts. To limit the threat of snowmobiling to caribou recovery, we recommend that snowmobiling should be restricted from high-quality mountain caribou winter habitat, or at least limited to a small proportion of the total high-quality habitat for each herd.

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