WINTER HABITAT SELECTION AND CALVING STRATEGIES OF WOODLAND CARIBOU IN THE BESA-PROPHET

Part 1 of Project "An Ecosystem Approach to Habitat Capability Modelling and Cumulative Effects Management"

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This research comprised the majority of Dave Gustine's Masters of Science research at the University of Northern British Columbia.

Baseline information on woodland caribou (*Rangifer tarandus caribou*), their movements, and habitat associations is needed because of the potential for increased industrial development and recreational activity in the mountains of northern British Columbia. The overall goal of this study was to quantify habitat selection and calving strategies of female caribou in the Greater Besa-Prophet Area of the Muskwa-Kechika Management Area. We used radio-telemetry data obtained from global positioning satellite (GPS) collars on female caribou, remote-sensing imagery of vegetation communities, and assessments of predation risk from concurrent studies on grizzly bears (*Ursus arctos*) and wolves (*Canis lupus*) in the same area to assess habitat use and selection. We determined proportional use of different vegetation classes as well as of the biophysical zones used in pre-tenure planning and preliminary habitat suitability classes developed by the British Columbia Ministry of Environment. We developed resource selection models to quantify the combinations of variables that caribou selected or avoided from what was available to them particularly during the winter. These models showed that strategies often differed among individual caribou, but that there was generally a Mountain and an Eastern strategy. For all female caribou, spacing out from areas of high wolf risk was important in winter.

We identified 3 general calving areas for caribou in the Greater Besa-Prophet Area. For each of these, there were apparent trade-offs between forage resources and predation risk. Calving areas tended to be higher and steeper with lower wolf risk and lower vegetation biomass than the landscape in general. The calving sites were generally lower in bear risk, with access to higher quality vegetation, than the surrounding calving area. We collared and monitored caribou neonates during the first 2 months of life to identify cause-specific mortalities. Predators included bears, wolves, wolverines (*Gulo gulo*), and golden eagles (*Aquila chrysaetos)*. Wolverines were the main predator of caribou calves from late May until mid-June, whereas wolves were the main cause of mortality during the summer. For caribou that moved >1 km away from the calving sites during the first 2 months of life to areas with increased access to forage and relatively lower wolf risk, survival was more than twice as high as for those calves that remained in the calving area. We also documented pregnancy rates and body condition for adult female caribou to establish a baseline for current herd conditions.

This research provides an overview of habitat selection and use by caribou, a species that uses large portions of the landscape to meet its demands for wintering, calving, and breeding locations and which therefore is susceptible to disturbances within and across such a large landscape. The findings also help characterize the ungulate landscape of the Greater Besa-Prophet Area to better understand interactions within the large mammal predator-prey system.

INTRODUCTION

The northern ecotype of woodland caribou (*Rangifer tarandus caribou*) is blue-listed as a species of concern in British Columbia and is listed as threatened in Canada (Committee on the Status of Endangered Wildlife 2002). The 3 ecotypes of woodland caribou in British Columbia are distinguished primarily by foraging ecology during winter (Stevenson and Hatler 1985). The northern ecotype in the northern and western parts of the province tends to crater in snow to access terrestrial lichens and feeds on some arboreal lichens. This strategy is in contrast to the mountain ecotype of woodland caribou that inhabits more southern areas with greater snowfall and that forages almost exclusively on arboreal lichens in old-growth forests. The boreal ecotype of woodland caribou of northeastern British Columbia inhabits boreal forests year round and commonly craters for lichens in peatlands during winter. Recent studies, regional data, and anecdotal evidence suggest that many caribou populations are at low levels and are either stable or declining in most of Canada (Seip and Cichowski 1996, Bergerud and Elliott 1998, Heard and Vagt 1998, Mahoney and Virgl 2003, McLoughlin et al. 2003). The resiliency of caribou to endure stochastic events such as extreme winters or forest fires, changes in predator densities, and large-scale human disturbances that alter habitats is therefore a source of concern for land managers.

Caribou serve as an indicator of landscape or ecosystem health because of their large landscape requirements and sensitivity to human and environmental disturbance (Murphy and Curatolo 1987, Schaefer and Pruitt 1991, Bradshaw et al. 1997, Stuart-Smith et al. 1997). Caribou may be most susceptible to disturbances during ‘critical’ times of the year (calving and winter) (Nellemann and Cameron 1998, Dyer et al. 2002), and identifying calving and wintering areas is an important step towards maintaining population persistence.

During calving, the ability of caribou to remain at low densities and distance themselves from predators and other prey species appears to play a significant role in calving success. In winter, caribou use a variety of habitats that allow access to forage resources with minimal energetic costs and reduced risks of predation. The introduction of disturbance to wintering and calving areas combined with a relatively low reproductive potential could have deleterious effects on caribou populations. These effects include loss of habitat (Joly et al. 2003, Weclaw and Hudson 2004) and elevated predation risk (James and Stuart-Smith 2000, Dyer et al. 2001, 2002). An increase in applications for industrial exploration and commercialized recreation in northern British Columbia accentuates the need for research to identify wintering and calving areas to ensure that access can be designed to minimize impacts.

Information from this study contributes both to the conservation of caribou and to effective land-use planning. Caribou are a highly visible species of special concern in the mountains of British Columbia. Knowledge of habitat selection including calving (attributes of calving areas and calving sites) and wintering strategies, body condition and pregnancy rates helps provide a foundation to maintain caribou populations and effectively document any impacts that anthropogenic or environmental disturbances may have on this species in the future.

PROJECT OBJECTIVES

The overall goal of this study was to quantify winter habitat selection and calving strategies of female caribou in the Greater Besa-Prophet Area. To do this we used global positioning satellite (GPS) radio-locations, remote-sensing imagery of vegetation communities, assessments of predation risk from concurrent studies on grizzly bears (*Ursus arctos*) and wolves (*Canis lupus*) in the same area, investigations of caribou calf survival, and habitat selection modelling. These data and analyses are helpful in characterizing the ungulate landscape of the Greater Besa-Prophet Area. They contribute to a better understanding of interactions within the large mammal predator-prey system.

Specific objectives were to:

1) monitor seasonal movements and range use by caribou;

2) document pregnancy rates and body condition;

3) determine which habitat attributes are most important in successful calving, and to assess differences among calving areas;

4) define winter habitat selection strategies; and

5) assess habitat use relative to pre-tenure zones in the Besa-Prophet Pre-tenure Planning Area.

STUDY AREA

The Muskwa-Kechika Management Area (MKMA) in northern British Columbia covers approximately 6.4 million ha. This study occurred in the Greater Besa-Prophet Area (740,878 ha, between 57°11' and 57°15' N latitude, and 121°51' and 124°31' W longitude) within the MKMA (Fig. 1). It encompassed the Besa-Prophet Pre-tenure Planning Area, which is designated as a special management zone that allows exploration and extraction of natural resources if concerns for wildlife populations are addressed prior to development. Currently the area is not affected by large-scale industrial activity, but applications for oil and gas exploration have increased. There is relatively little human disturbance because terrestrial access is restricted to low all-terrain vehicle/snowmobile activity in the southern portion of the study area.

Elevations range from 630 to 3,025 m, with treeline occurring between 1,450 and 1,600 m. The eastern portion of the Greater Besa-Prophet Area has relatively little topographic relief (~630-800 m) and is covered by hybrid spruce (*Picea mariana x glauca*), black spruce (*P. mariana*), or both. Sedge (*Carex* spp.) meadows with willow (*Salix* spp.) and alder (*Alnus* spp.) are common along watercourses. Quaking aspen (*Populus tremuloides*) and balsam poplar (*P. balsamifera*) grow on drier sites along the eastern edge of the mountains. In the mountainous western portion of the Greater Besa-Prophet Area, riparian white spruce (*P. glauca*) complexes with poorly drained willow-birch (*Betula glandulosa*) communities and sedge meadows dominate the valley bottoms (Lay 2005). Subalpine vegetation (1,400-1,700 m) varies with aspect, but generally consists of willow-birch and infrequent spruce or fir trees in krummholz form. Alpine areas consist of permanent snowfields, glaciers, barren rock with sparse or mat vegetation, and grasslands (Demarchi 1996).

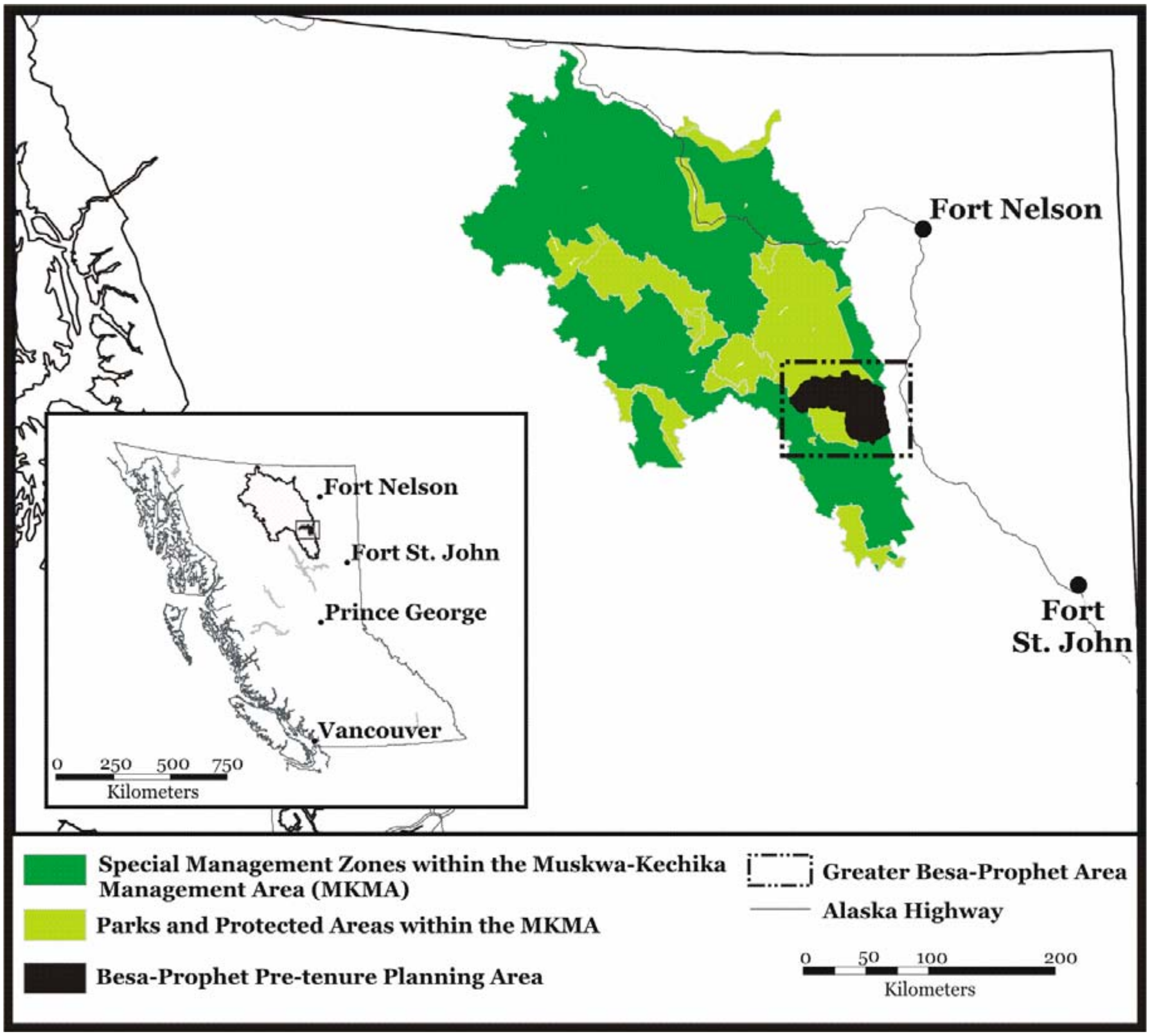


Figure 1. Greater Besa-Prophet study Area in relation to the Besa-Prophet Pre-tenure Planning Area in the Muskwa-Kechika Management Area of northern British Columbia.

ACTIVITIES/TECHNIQUES/FINDINGS:

Ranges and Movements

Forty-eight female woodland caribou were captured and fitted with GPS radio-collars (Simplex, Televilt, Lindesberg, Sweden) during the winters of 2001/2002 and 2002/2003. Because the GPS data loggers for 44 of the collars (22/yr) failed prior to calving, our data on use of summer, fall, and breeding habitats by caribou are limited. However, in 2004, 15 more animals were fitted with GPS collars (PosRec, Televilt, Lindesberg, Sweden) to obtain additional information. We programmed all GPS collars to record locations 4 times daily for 2 years. Data were retrieved during remote downloads 3 times per year, and when collars were recovered. This summary report concentrates on our analyses of data from 2001-2003, but we included information on body condition, pregnancy status, annual home ranges, and general habitat use from 2004 in our results. Telemetry locations from all years were combined to help propose Wildlife Habitat Areas and potential Ungulate Winter Range designations in the Greater Besa-Prophet Area (Gustine 2005b).

Annual home ranges for caribou were determined by minimum convex polygons (Jennrich and Turner 1969) around GPS locations for each individual. For animals with $\geq$150 locations and at least one year of data (n = 40), annual ranges averaged 545 km^2, with a minimum of 22 km^2 and a maximum of 2,147 km^2. There was considerable variation in use of the landscape by collared individuals. Fourteen caribou stayed in the Klingzut-Granger area and 14 animals ranged far and wide from east of the Alaska Highway to the west fork of the Muskwa River and to the Akie and Ospika watersheds and south of the Sikanni River (Gustine 2005b). Other individuals stayed in the area encompassing Besa-Neves, Duffield-Townsley, and Pocketknife watersheds; towards the head of Richards Creek; in the Buckinghorse-Neves area; around Neves, Lower Besa, and Townsley; and in the eastern section of the Greater Besa-Prophet Area.

Movement rates of caribou were highly variable within and among individuals at all temporal scales (i.e., day, week, and month). Pooled monthly movement rates and variation in rates, however, declined from approximately 100 m/hr in November to 40 m/hr in April (Fig. 2). In the follow-up study in 2004, movement rates of GPS-collared caribou during winter were similar, and tended to be lower than during summer and fall.

Movements and movement rates (m/hr) of individual caribou are useful in identifying biological events (i.e., calving and breeding) and large-scale events such as migratory movements. For example, our analyses of GPS locations with the highest rates of movement (>95th percentile) for an individual within a season from consecutive 6-hr fixes indicated that caribou select for different features of the landscape during migratory movements (as in Johnson 2000). Movements are also helpful in defining 'caribou seasons'. In the Greater Besa-Prophet Area, we defined caribou seasons that are distinguished by biological and ecological characteristics (Table 1). Greatest variability among individuals occurred in defining the pre-calving and calving seasons. The calving season was variable because the timing of arrival at calving areas varied among caribou. Some individuals that wintered near their calving location did not exhibit a pre-calving period per se. For other individuals, the average arrival date in a calving area was 23 May.

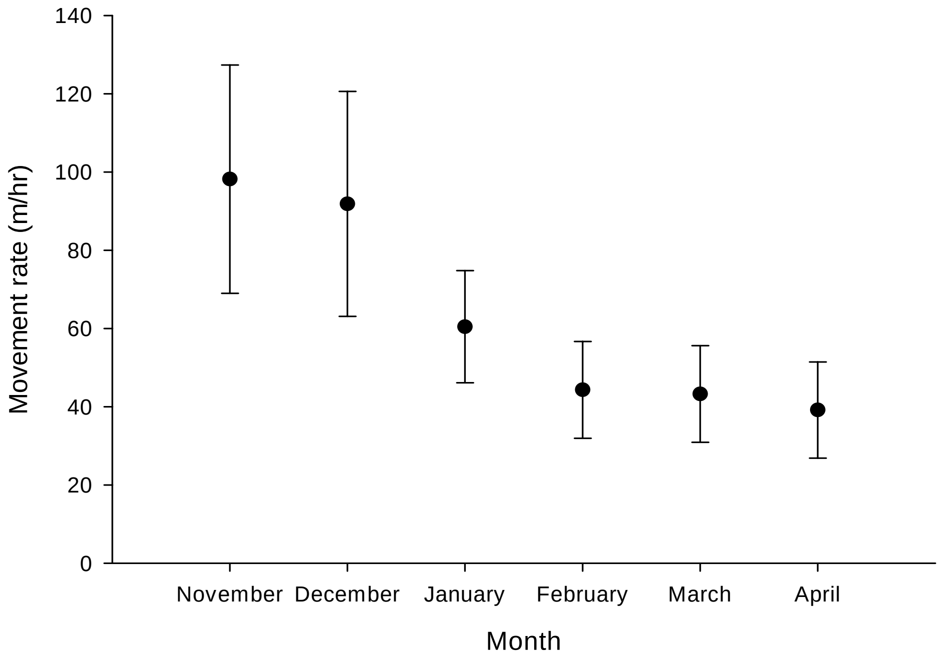


Figure 2. Movement rates (m/hr, mean ± SE) of 10 adult female woodland caribou averaged within a month by individual and then averaged across individuals, during winter (November-February) and late winter (March-April) months in the Greater Besa-Prophet area, 2001-2002.

Table 1. Dates and biological rationale for defining the seasons of woodland caribou in the Greater Besa-Prophet Area, northern British Columbia.

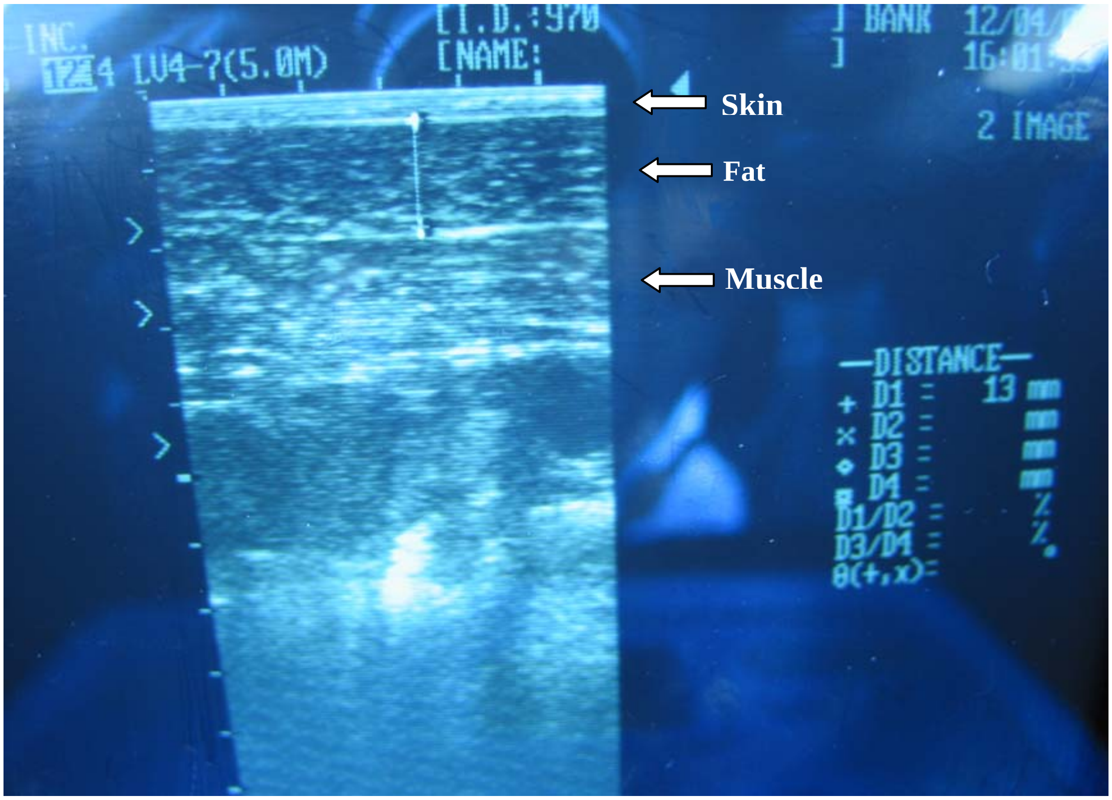
Season	Date	Biology
Winter	1 November – 28 February	Formation of sex-specific groups following rut
Late winter	1 March – 29 April	Smallest range size; lowest movement rates
Pre-calving	30 April – onset of calving	Increased movement and high variation in resource selection
Calving	Arrival to calving area – 14 June	Pregnant females disperse to calve alone or in small groups and remain in an area with their calves for 8-14 days after calving
Summer	15 June – 15 August	Females with and without calves typically form large groups at moderate to higher elevations
Fall	16 August – 30 September	Grouping behaviour from summer usually still evident, although at lower elevations; individuals start to move towards breeding areas
Breeding	1-31 October	Males and females form mixed sex groups; females come into estrus

Body Condition

The nutritional condition of ungulates can affect whether they breed, carry a fetus to term, and produce healthy offspring. Therefore condition affects population numbers. Reproductive status (pregnant vs non-pregnant) can easily be determined from blood samples taken from captured animals using serum progesterone concentrations (Russell et al. 1998). Quantifying body fat and body protein helps to describe nutritional condition of the animal. Ultrasonography can be used to estimate the thickness of rump fat, which correlates well with total body fat (%) in elk (*Cervus elaphus*, Cook et al. 2002), moose (*Alces alces*), deer (*Odocoileus hemionus*), and caribou (Stephenson 1998, 2002, unpublished). We collected blood samples (~10 ml) from most caribou collared during the winters of 2001/2002 and 2002/2003, as well as 2004; these were analyzed for progesterone concentrations at Prairie Diagnostics Services, Saskatoon, SK. In 2003 and 2004, we also took measurements on most captured caribou of the thickness (cm) of rump fat using a portable ultrasound machine (Medison Sonovet 600 with variable 4-6 MHz linear probe, Universal Medical Systems Ltd, Bedford Hills, NY) to determine relative body condition of pregnant and non-pregnant individuals in the Greater Besa-Prophet Area.

We obtained 67 blood samples for progesterone analyses: 25 in 2001/2002, 23 in 2003, and 19 in 2004. Pregnancy rates were similar between years: 91.7 ± 5.8 (mean ± SE) in 2002, 91.3 ± 6.0 in 2003, and 89.5 ± 7.0 in 2004), averaging 90.9 ± 3.5 across all years.

We took measurements of the thickness of rump fat on 39 female caribou (n = 20 in 2003, n = 19 in 2004). In late January and early February, maximum thickness of rump fat for more than two thirds of the animals was less than 0.5 cm (Fig. 3). One of the animals captured in 2003 was <1.5 years of age (non pregnant) and therefore, not included in the analyses of other adult animals. We estimated total percent body fat using an unpublished linear equation for caribou from the measurements of rump fat: body fat (%) = 5.76 + [2.27*(thickness of rump fat (cm)] (T.R. Stephenson, unpublished data). Pregnant caribou had more rump fat, and therefore higher estimates of percent body fat (7.1 ± 0.15 %, mean ± SE) than non-pregnant caribou (6.1 ± 0.06 %). Estimates of body fat ranged from 6.0-9.6 % in 34 pregnant caribou and 6.0-6.2 % in 4 non-pregnant animals (Table 2). Crête et al. (1993) suggested that body fat must be 7.8 % in autumn-early winter for pregnancy to occur and Ouellet et al. (1997) noted that the threshold is probably lower (~6.0 %). Five of the 10 animals that we measured with ≤6.2 % body fat were pregnant and of the 4 animals with 6.0 % body fat, only one was pregnant (Table 2). The measurements we made in late January and early February reflect fat levels that were probably less than those during breeding because animals would have used some of those body fat stores during early winter. The observed similarities in rump fat for the non-pregnant caribou suggest that animals with body-fat levels of 6.0-7.0 % in winter may have approached the limit needed for pregnancy in fall. Some of the pregnant caribou in the Greater Besa-Prophet Area were probably also near this limit. Nonetheless, the neonatal calf weights for caribou (males: 8.09 kg ± 0.52 SE, n = 19; females: 7.78 ± 0.28 kg, n = 31) in our study area (see Calving Strategies below) were similar to the 10-year average of calf weights (males: 8.04 ± 0.07 kg, n = 244; females: 7.50 ± 0.07 kg, n = 267) of barren-ground caribou in excellent condition (Denali herd; Adams, 2005). Therefore, assuming that most breeding animals in the population are pregnant and that calves are healthy, the caribou in the Greater Besa-Prophet Area seem able to accommodate the range of environmental factors currently present in a relatively undisturbed area.



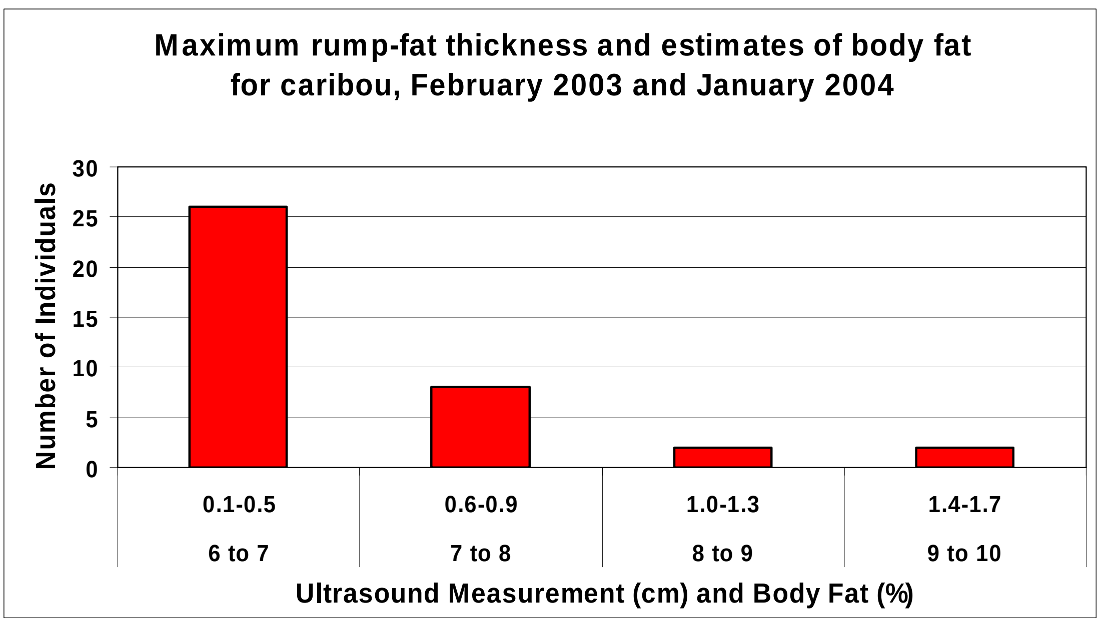


Figure 3. Maximum rump fat thickness determined by ultrasonography for caribou in the Greater Besa-Prophet Area. Total body fat was calculated from T.R. Stephenson (unpublished data) as: body fat (%) = 5.76 + [2.27*thickness of rump fat (cm)].

Table 2. Reproductive status, thickness of rump fat, and estimated total body fat for female caribou in the Greater Besa-Prophet Area, 2003-2004. Animal 33A was <1.5 years old.

ID	Capture date	Progesterone (ng/ml)	Reproductive status	Thickness of rump fat (cm)	Body fat (%)
26A	10-Feb-03	4.7	Pregnant	0.3	6.4
27A	10-Feb-03	4.3	Pregnant	0.1	6.0
21B	11-Feb-03	3.7	Pregnant	0.5	6.9
25B	11-Feb-03	3.9	Pregnant	0.7	7.3
28A	11-Feb-03	7.3	Pregnant	0.4	6.7
29A	11-Feb-03	4.8	Pregnant	0.2	6.2
30A	11-Feb-03	2.7	Pregnant	0.9	7.8
31A	11-Feb-03	3.8	Pregnant	0.5	6.9
32A	12-Feb-03	5.0	Pregnant	1.3	8.7
33A	12-Feb-03	<0.2	Not pregnant	0.1	6.0
34A	12-Feb-03	5.8	Pregnant	0.5	6.9
35A	12-Feb-03	3.1	Pregnant	1.6	9.4
36A	12-Feb-03	<0.2	Not pregnant	0.1	6.0
37A	12-Feb-03	<0.2	Not pregnant	0.1	6.0
38A	13-Feb-03	n/a	Pregnant	0.4	6.7
39A	13-Feb-03	4.7	Pregnant	0.3	6.4
40A	13-Feb-03	10.9	Pregnant	0.7	7.3
41A	14-Feb-03	4.3	Pregnant	0.9	7.8
42A	14-Feb-03	6.2	Pregnant	0.2	6.2
43A	14-Feb-03	4.8	Pregnant	1.7	9.6
44A	20-Jan-04	7.2	Pregnant	0.4	6.7
45A	20-Jan-04	<0.2	Not pregnant	0.2	6.2
46A	20-Jan-04	3.8	Pregnant	0.5	6.9
47A	20-Jan-04	4.4	Pregnant	0.3	6.4
48A	20-Jan-04	7.8	Pregnant	0.9	7.8
49A	20-Jan-04	<0.2	Not pregnant	0.2	6.2
50A	20-Jan-04	5.7	Pregnant	0.4	6.7
51A	20-Jan-04	4.5	Pregnant	0.2	6.2
52A	20-Jan-04	5.6	Pregnant	0.6	7.1
53A	21-Jan-04	5.0	Pregnant	0.3	6.4
54A	21-Jan-04	4.8	Pregnant	0.5	6.9
55A	21-Jan-04	3.9	Pregnant	0.6	7.1
56A	21-Jan-04	5.4	Pregnant	0.2	6.2
57A	21-Jan-04	6.1	Pregnant	0.3	6.4
58A	21-Jan-04	12.4	Pregnant	0.3	6.4
59A	21-Jan-04	3.4	Pregnant	0.4	6.7
60A	21-Jan-04	4.8	Pregnant	0.9	7.8
61A	21-Jan-04	5.3	Pregnant	1.1	8.3
62A	21-Jan-04	5.6	Pregnant	0.4	6.7

Calving Strategies

GPS data from woodland caribou females were downloaded by plane the first week of May (2002, 2003), and subsequent flights were used to identify calving areas and the onset of parturition. There are 3 general calving areas for caribou in the Greater Besa-Prophet Area as defined by vegetation characteristics, elevation, topography, geographic location, and presence of adult female caribou and calves. These areas are the North Prophet, the Western High Country, and the Foothills (Fig. 4). Calving dates ranged from 25 May to 10 June, including observations of many non-collared woodland caribou, with peak calving occurring on 28 May ± 0.3 days (mean ± SE). A two-person capture crew, net gunner, and helicopter pilot canvassed the calving areas for calves old enough for processing (>24 hrs). We captured 50 caribou calves in 2002 and 2003 by hand or by net deployed with a net gun from the helicopter in the Foothills (n = 21), Western High Country (n = 19), and North Prophet (n = 10) calving areas.

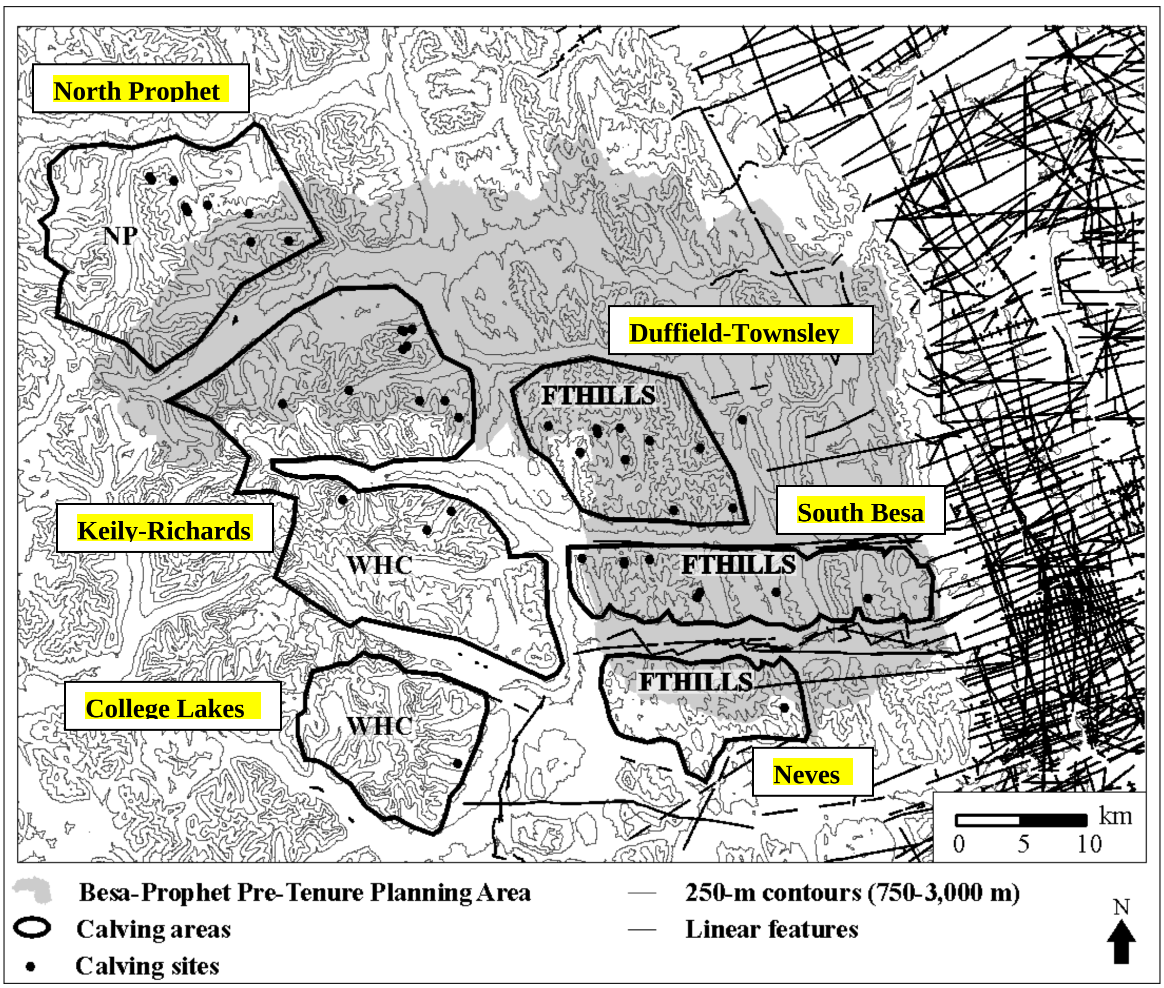


Figure 4. The Foothills (FTHILLS), North Prophet (NP), and Western High Country (WHC) calving areas, calving sites for woodland caribou, and linear features of the Greater Besa-Prophet area, northern British Columbia. The yellow-highlighted areas provide more specific geographical references for areas within the 3 general calving designations.

During processing, the crew wore clean, latex gloves for each capture to minimize scent transfer. Caribou calves were sexed, weighed with a 15-kg hand-held spring scale, aged by hoof and umbilicus condition, examined for general health (presence of diarrhea and/or injuries), and radio-collared (Fig. 5). We captured 31 females and 19 males. Age at capture for all calves ranged from 0.5 to 6 days, with the average age being 3 days. Body weights were between 6 and 19 kg, averaging 9.6 kg (Table 3), and did not differ among the Foothills, Western High Country, and North Prophet calving areas. Animals were fitted with radio-collars weighing approximately 95 g. Collar construction consisted of a weather- and impact-resistant motion-sensitive transmitter (Advanced Telemetry Systems, Isanti, MN) and leather belting with elastic (1:1.5 expansion) and surgical tubing. The pulse rate of the transmitter was scheduled to double if stationary for >2 hrs (mortality signal). The 2 lengths of surgical tubing and the elastic were designed to stretch/expand to accommodate calf growth, and then drop off in approximately 4-6 months. Average handling time per calf was ≤2 minutes, not including pursuit time (in the helicopter or on foot), which was typically <5 minutes.

We monitored the collared calves by plane (Piper Super Cub, Greg Williams Outfitting) twice daily (0700-1100 and 1800-2300), weather permitting, for 1 month post-capture, and then once weekly until the end of July. After a mortality signal was detected during a fixed-wing flight, the mortality site was accessed by helicopter as soon as possible (<16 hrs). All mortality sites were approached carefully to avoid destroying evidence as to cause of death, and for crew safety. One calf died at 6 days of age in 2002, probably from abandonment, and another calf died at 4 days of age in 2003 from accidental drowning. The remainder of mortalities (n = 17) in the first 2 months of life were predator-caused. We took photos of each mortality site and any evidence (scat, tracks) at the sites, and recovered whole or partial carcasses. We recorded cause-specific mortality based on literature review and experience.

Caribou calves were killed by numerous predators during the first 2 months. Contrary to assumptions about the predator-prey dynamics in the area, not all caribou calves that died were killed by wolves in the week immediately following birth. Rather, they were killed by bears (2), eagles (2), wolverines (5), unknown predators (for which there was not enough sign to determine cause; n = 3), and by wolves (5), distributed across time (Fig. 6). By the end of summer, 11 of 25 calves in the first year, and 6 of 25 calves in the second year had died from predation. Although to our knowledge wolverines have not been documented as the main predator of caribou calves in North America, they were the primary predator of caribou neonates less than 2 weeks of age in our study. We also recorded mortalities of 2 uncollared caribou calves, one by a wolverine and one by an eagle at approximately 1 and 2 weeks of age, respectively. Four of the 5 wolverine-caused mortalities of collared calves occurred between 9 and 15 days of age, whereas all wolf-caused mortalities occurred after calves were 18 days of age. There were no mortalities of calves less than 14 days old in the Foothills and no mortalities by wolves in the North Prophet.

Survival of caribou calves through 56 days of age was not different among the Foothills, Western High Country, and North Prophet calving areas. However, it appears that for caribou that do not move more than 1 km away from the calving site, survival rate is lower. Survival rates are approximately 2 times higher if caribou calves move than if they stay at the calving site (Fig. 7). Therefore, calving sites are important, but the ability to move to other relatively safe sites within the first 2 months of life is also important for survival of caribou calves.

Figure 5. Capture, radio-collaring, and weighing of neonatal caribou calves followed by site investigations of mortalities in the Greater Besa-Prophet Area, 2002-2003.

Table 3. Animal identification (ID), capture date, sex (male (M) and female (F)), and estimates for the date of birth (DOB), age (days), and mass (kg) of newborn caribou calves captured in the Foothills (FTHILLS), Western High Country (WHC), and North Prophet (NP) calving areas within the Greater Besa-Prophet Area, 2002-2003. * indicates animals were captured by hand; all others were captured by net deployed from a net gun in a helicopter. Specific geographical and general calving areas are shown in Figure 4.

ID	Capture date	Sex	Date of birth	Age (days)	Mass (kg)	Specific geographical area	Calving Area
C01C*	31-May-02	F	27-May-02	4.0	10.50	South Besa	FTHILLS
C02C*	31-May-02	F	29-May-02	2.0	10.00	Duffield-Townsley	FTHILLS
C03C*	31-May-02	F	29-May-02	2.0	9.50	Duffield-Townsley	FTHILLS
C04C*	1-Jun-02	M	29-May-02	2.5	8.50	Keily-Richards	WHC
C05C*	1-Jun-02	F	27-May-02	5.0	9.50	North Prophet	NP
C06C*	1-Jun-02	F	30-May-02	2.0	6.75	Keily-Richards	WHC
C07C*	2-Jun-02	F	30-May-02	3.0	8.50	Duffield-Townsley	FTHILLS
C08C*	2-Jun-02	M	1-Jun-02	0.5	7.25	Duffield-Townsley	FTHILLS
C09C*	2-Jun-02	M	28-May-02	4.5	10.75	North Prophet	NP
C10C*	2-Jun-02	M	29-May-02	4.0	9.75	North Prophet	NP
C11C*	2-Jun-02	F	1-Jun-02	0.5	6.75	Duffield-Townsley	FTHILLS
C12C*	2-Jun-02	F	1-Jun-02	1.0	6.75	South Besa	FTHILLS
C13C*	2-Jun-02	F	2-Jun-02	0.5	7.25	Duffield-Townsley	FTHILLS
C14C*	3-Jun-02	F	31-May-02	2.5	8.75	Keily-Richards	WHC
C15C	4-Jun-02	M	29-May-02	6.0	12.75	Keily-Richards	WHC
C16C	4-Jun-02	F	1-Jun-02	3.0	9.00	Keily-Richards	WHC
C17C	4-Jun-02	M	1-Jun-02	3.0	9.00	Keily-Richards	WHC
C18C	4-Jun-02	M	31-May-02	4.0	11.75	South Besa	FTHILLS
C19C	4-Jun-02	F	1-Jun-02	3.0	8.75	South Besa	FTHILLS
C20C	4-Jun-02	F	29-May-02	6.0	13.00	South Besa	FTHILLS
C21C	4-Jun-02	M	31-May-02	3.5	8.50	Keily-Richards	WHC
C22C	4-Jun-02	M	31-May-02	4.0	10.00	Keily-Richards	WHC
C23C	4-Jun-02	F	1-Jun-02	2.5	11.00	Keily-Richards	WHC
C24C	4-Jun-02	F	29-May-02	6.0	13.50	Keily-Richards	WHC
C25C	4-Jun-02	F	1-Jun-02	3.0	8.75	Keily-Richards	WHC
C26C*	28-May-03	M	27-May-03	1.0	7.25	College Lakes	WHC
C27C	28-May-03	F	25-May-03	2.5	8.75	College Lakes	WHC
C28C	28-May-03	F	25-May-03	2.5	10.50	College Lakes	WHC
C29C	28-May-03	F	25-May-03	2.5	8.00	Neves	FTHILLS
C30C	29-May-03	F	25-May-03	4.0	11.00	Duffield-Townsley	FTHILLS
C31C	29-May-03	F	25-May-03	3.5	8.50	South Besa	FTHILLS
C32C	29-May-03	M	27-May-03	1.5	8.75	South Besa	FTHILLS
C33C	29-May-03	F	25-May-03	3.5	9.75	Keily-Richards	WHC
C34C	29-May-03	M	26-May-03	2.5	9.00	Keily-Richards	WHC
C35C	29-May-03	M	26-May-03	3.0	10.25	Duffield-Townsley	FTHILLS
C36C	29-May-03	F	26-May-03	3.0	10.25	Duffield-Townsley	FTHILLS
C37C	29-May-03	M	26-May-03	3.0	13.00	Duffield-Townsley	FTHILLS

Table 3 continued

ID	Capture date	Sex	Date of birth	Age (days)	Mass (kg)	Specific geographical area	Calving Area
C38C	30-May-03	M	28-May-03	1.5	7.00	Duffield-Townsley	FTHILLS
C39C	30-May-03	F	27-May-03	2.5	8.00	North Prophet	NP
C40C	30-May-03	F	27-May-03	2.5	8.75	North Prophet	NP
C41C	30-May-03	F	27-May-03	2.5	7.50	North Prophet	NP
C42C	30-May-03	M	28-May-03	1.5	6.00	North Prophet	NP
C43C	30-May-03	F	26-May-03	3.5	9.00	North Prophet	NP
C44C	30-May-03	M	27-May-03	2.5	9.00	North Prophet	NP
C45C*	30-May-03	M	27-May-03	2.5	8.75	North Prophet	NP
C46C	31-May-03	F	27-May-03	4.0	8.75	Keily-Richards	WHC
C47C*	31-May-03	F	28-May-03	3.0	9.00	Keily-Richards	WHC
C48C	31-May-03	F	29-May-03	2.0	13.50	Keily-Richards	WHC
C49C	31-May-03	F	27-May-03	3.5	13.50	Duffield-Townsley	FTHILLS
C50C	31-May-03	M	26-May-03	6.0	19.00	South Besa	FTHILLS

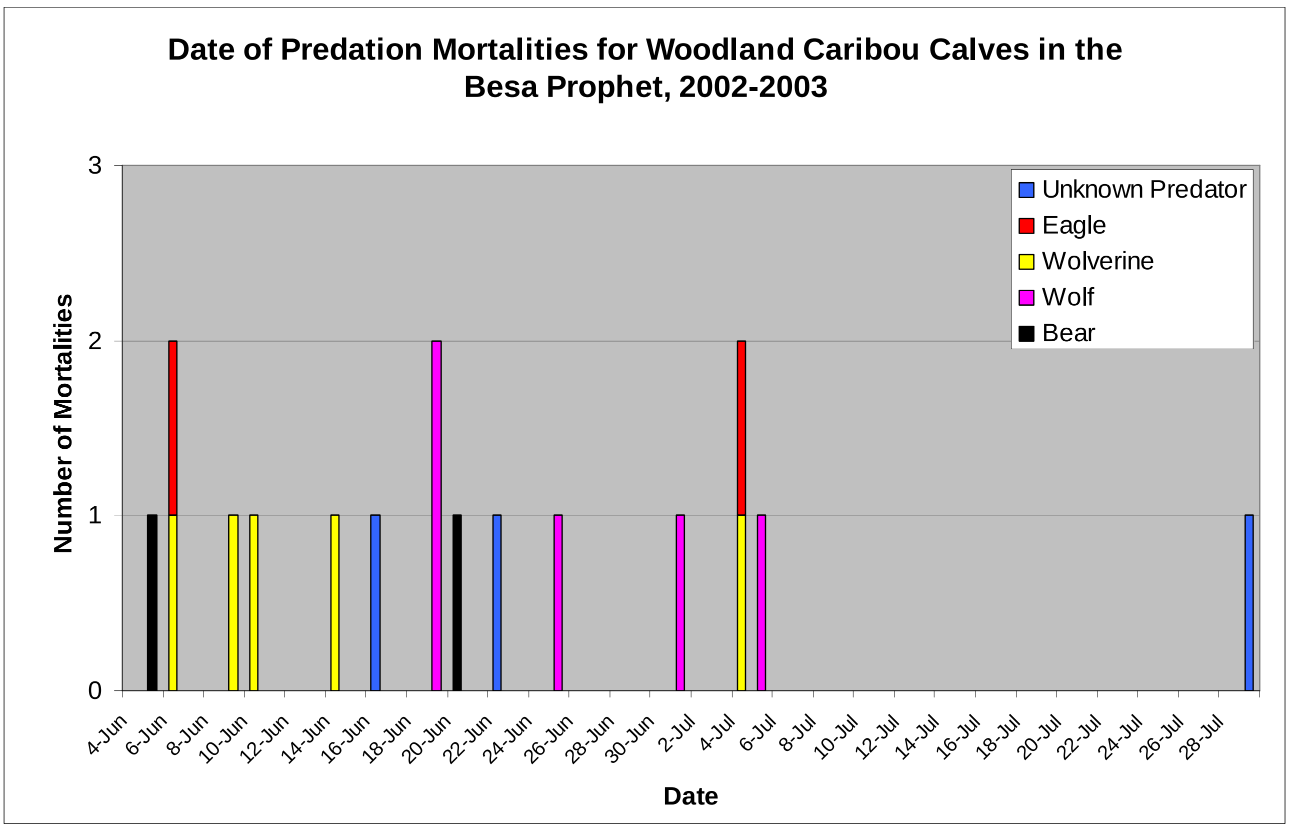


Figure 6. Timing of predation-caused mortalities of collared caribou calves in the Greater Besa-Prophet area, northern British Columbia, 2002 and 2003.

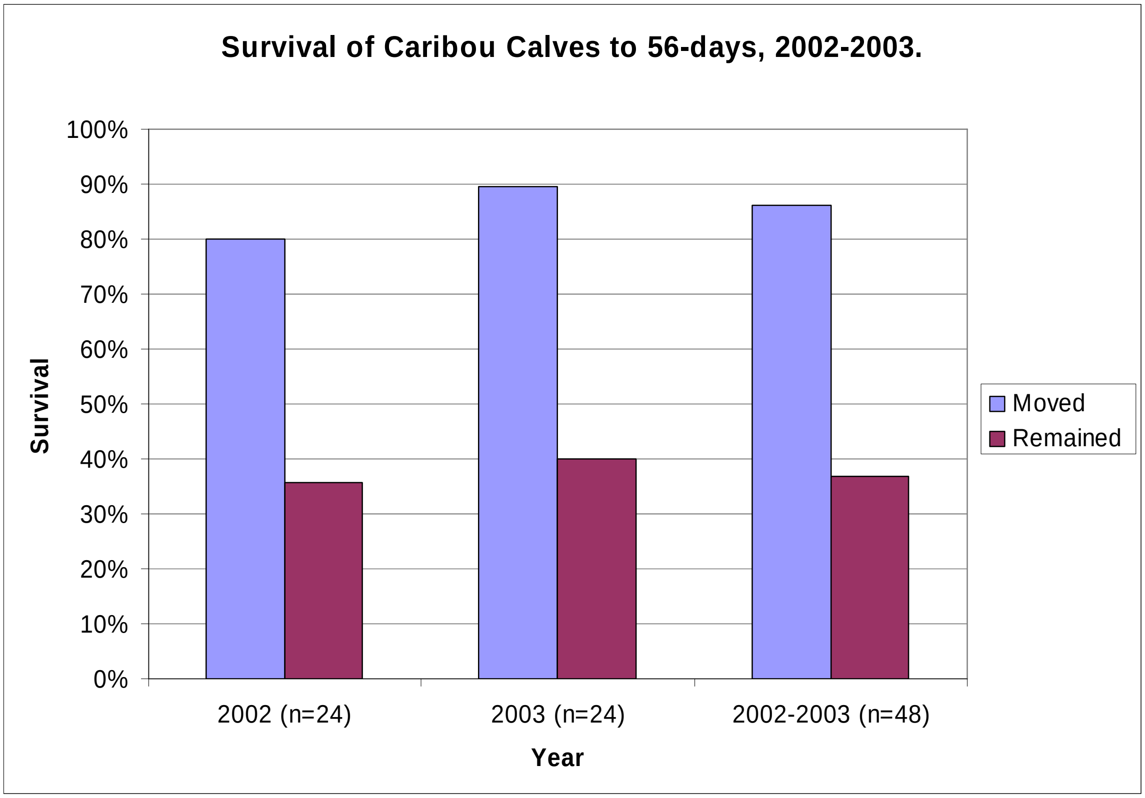


Figure 7. Survival of caribou calves that moved away from or remained at calving sites during the first 2 months of life in the Greater Besa-Prophet Area, excluding 2 neonates that died of probable abandonment and accidental drowning before 1 week of age.

Reasons for movements by caribou away from calving sites may be two-fold. The first peak in movement by cow-calf pairs occurred when calves were 2-4 weeks of age, and was probably in response to changes in vegetation. Caribou moved *towards* areas with higher vegetation biomass and quality. This period corresponds with the time of high nutritional demands for lactation (White and Luick 1984) and the time when lactating females experience their worst condition of the year (Chan-McLeod et al. 1999**).** A second peak in movement by caribou away from calving sites occurred during weeks 5-7 during the summer following an increase in caribou calf mortality. This timing coincides with the ability of wolves to leave the dens and potentially with a change in prey species in wolf diets (B. Milakovic, University of Northern British Columbia, unpublished data). Caribou may have attempted to move *away* from areas with high localized risk of predation by wolves. Caribou started to form post-calving aggregations of approximately 20-40 cows and calves in the Foothills and North Prophet calving areas in late June. Some cow-calf pairs from the Western High Country moved to these 2 areas, whereas no caribou that we monitored moved to the Western High Country. Formation of large groups of caribou can help minimize the risk of wolf predation while foraging in areas with high vegetation biomass and quality.

Small-scale characteristics of calving sites:

To analyze the characteristics of calving sites, we defined a “calving site” as where a cow-calf pair was first observed during the fixed-wing flights. Because flights were made twice daily over the area, we assumed that these sites were or were very close to the actual birthing sites. Each calving sites was recorded as a GPS location. We collected small-scale habitat information at these sites (n = 50) during the first week of July during 2002 and 2003. Using a 100-m cloth tape placed on the ground along a random bearing with the calving site as the centre point, we calculated percent intercept of trees, shrubs, and dwarf shrubs by species, and rocks/soil and cliffs (Fig. 8). At 5 stations 25 m apart along each transect, we recorded within 50 x 50-cm plots the number of individual plants for each grass and forb species to determine plant density, and estimated percent cover by each species and rocks/soil. Because lichens are important winter food items for caribou before green-up, we sampled lichen biomass by removing a 20 x 20-cm sample of soil and vegetation from a randomly chosen corner of each plot. We air-dried the biomass samples in paper bags and subsequently sorted lichens, identified them to genus, and weighed them to the nearest 0.001 g. We then compared characteristics of vegetation by functional group (% cover, density, and diversity for grasses, sedges, horsetails, and forbs measured by plots; and % cover by line intercept for trees, shrubs, and dwarf shrubs); lichens (biomass and diversity), non-vegetated cover (% cover by plots and % cover by line intercept of rocks/soil), slope (°), and elevation (m) of calving sites across calving areas.

Figure 8. Fine-scale habitat sampling of calving sites of woodland caribou in the Greater Besa-Prophet Area, northern British Columbia, 2002 and 2003.

There were no differences in vegetation characteristics of calving sites among calving areas, except that shrub cover tended to be higher at calving sites in the Foothills than the North Prophet and Western High Country (Table 4). Cover of rocks/soil was lower at calving sites in the Foothills and the Western High Country than the North Prophet, and the Foothills sites were steeper than the Western High Country. Both the Foothills and Western High Country sites were lower than the North Prophet sites.

Table 4. Small-scale characteristics of caribou calving sites (mean ± SE) among the Foothills (FTHILLS), Western High Country (WHC), and North Prophet (NP) calving areas in the Greater Besa-Prophet Area, 2002-2003. Characteristics sharing the same letter were not significantly different.

Small-Scale Characteristic	FTHILLS (n = 21)	WHC (n = 19)	NP (n = 10)	*P*
Shrub intercept (% cover)	29.6 ± 6.0[a]	15.1 ± 5.5[ab]	4.6 ± 1.8[b]	0.017[†]
Rock/soil intercept (% cover)	5.8 ± 2.7[a]	18.6 ± 6.0[a]	51 ± 10.0[b]	0.001[†]
Slope (^{o})	27.8 ± 1.6[a]	16.6 ± 1.9[b]	22.6 ± 2.7[ab]	<0.001[‡]
Elevation (m)	1767 ± 30[a]	1783 ± 38[a]	2033 ± 31[b]	<0.001[‡]
Cliff intercept (% cover)	2 ± 0.4[a]	3.8 ± 2.6[a]		0.473[†]
Dwarf shrub intercept (% cover)	22.5 ± 5.2[a]	36.4 ± 6.3[a]	19.4 ± 7.4 [a]	0.132[‡]
Tree intercept (% cover)	4.3 ± 1.7[a]	4.2 ± 3.6[a]		0.536[‡]
Herbaceous cover (% cover)	21.2 ± 2.4[a]	17.6 ± 2.6[a]	11.9 ± 3.5[a]	0.097[‡]
Herbaceous density (per m^2)	111.3 ± 23.3[a]	135.5 ± 27.9[a]	112.6 ± 34.3[a]	0.773[‡]
Grasses (% cover)	8.1 ± 2.0[a]	4.1 ± 1.3[a]	2.8 ± 1.1[a]	0.082[‡]
Sedges and horsetails (% cover)	3.2 ± 1.04[a]	6.4 ± 1.71[a]	2.3 ± 0.9[a]	0.210[†]
Forbs (% cover)	9.9 ± 1.7[a]	7.1 ± 1.3[a]	6.8 ± 1.7[a]	0.300[‡]
Lichen biomass (g/m^2)	44.4 ± 8.9[a]	28.5 ± 7.5[a]	31.2 ± 10.7[a]	0.372[‡]

[†] Nonparametric Kruskal-Wallis analysis of variance and multiple comparison of mean ranks
[‡] Parametric Analysis of variance and Tukey's honest significant difference for unequal sample sizes

<u>Large-scale characteristics of calving sites and calving areas</u>:

Because caribou use large landscapes, they respond to vegetation characteristics and predation risk over large, diverse areas. Calving sites are selected from within a calving area, which is also selected from what is available across the landscape. In addition to the small-scale characteristics of calving sites per se, we therefore quantified large-scale characteristics of the calving areas and the landscape. We quantified classes of vegetation, vegetation biomass, vegetation quality, and predation risk. We then compared 1) characteristics among the 3 calving areas and the landscape of the Greater Besa-Prophet Area, 2) characteristics of calving sites in a calving area versus random points in that calving area, and 3) characteristics of all calving sites relative to the landscape.

The habitat classification system for the Besa-Prophet area was developed using remote-sensing satellite imagery (Fig. 9) by Roberta Lay as part of her thesis at the University of Northern British Columbia (Lay 2005). Fifteen general vegetation types were classified with a 2001 Landsat Enhanced Thematic Mapper image with 25-m resolution. For analyses on caribou, we amalgamated several of these habitat classes to ensure that we had sufficient samples sizes for our analyses, resulting in 9 vegetation classes with a minimum mapping unit of 75 x 75 m: spruce, shrubs, subalpine, *Carex*, non-vegetated, pine, riparian spruce, alpine, and burned/disturbed (Table 5, Fig. 10).

Table 5. Nine general classes of vegetation used in analyses of habitat selection by caribou in the Greater Besa-Prophet Area (GBPA), northern British Columbia.

Vegetation Class	Portion of the GBPA (%)	Original 15 Classes[a]	Description[a]
Spruce	23.2	Spruce + Low-productivity Spruce	White and hybrid spruce (*Picea glauca* and *Picea glauca* x *engelmanni*)-dominated communities
Shrubs	5.8	Shrubs	Deciduous shrubs <1600 m in elevation dominated by birch (*Betula* spp.) and willow (*Salix* spp.), some cinquefoil (*Potentilla fruiticosa*)
Subalpine	9.2	Shrubs + Subalpine Spruce	Deciduous shrubs >1599 m; spruce-shrub transition zone at middle to upper elevations (white and hybrid-spruce, and dominated by birch and willow)
Carex spp.	6.0	*Carex* spp.	Wetland meadows dominated by sedges (*Carex* spp.), typically at low elevations
Non-vegetated	23.7	Rocks, Rock/Crustose Lichens, Snow/Glacier, and Water	Rock; rock habitats with black, crustose lichens; permanent snow-fields or glaciers and water bodies
Pine	4.6	Pine	Lodgepole pine (*Pinus contorta*)-dominated communities
Riparian Spruce	11.8	Riparian Spruce and Gravel Bar	Low elevation, wet areas with black (*Picea mariana*) and hybrid spruce; often with standing water in spring and summer; exposed gravel bars adjacent to rivers and creeks
Alpine	5.4	Wet and Dry Alpine	Herbaceous alpine vegetation
Burned/ Disturbed	10.2	Burned/Disturbed	Previously burned areas, grass, deciduous trees, or avalanche chutes

[a]As determined by Lay (2005) using remote-sensing satellite imagery.

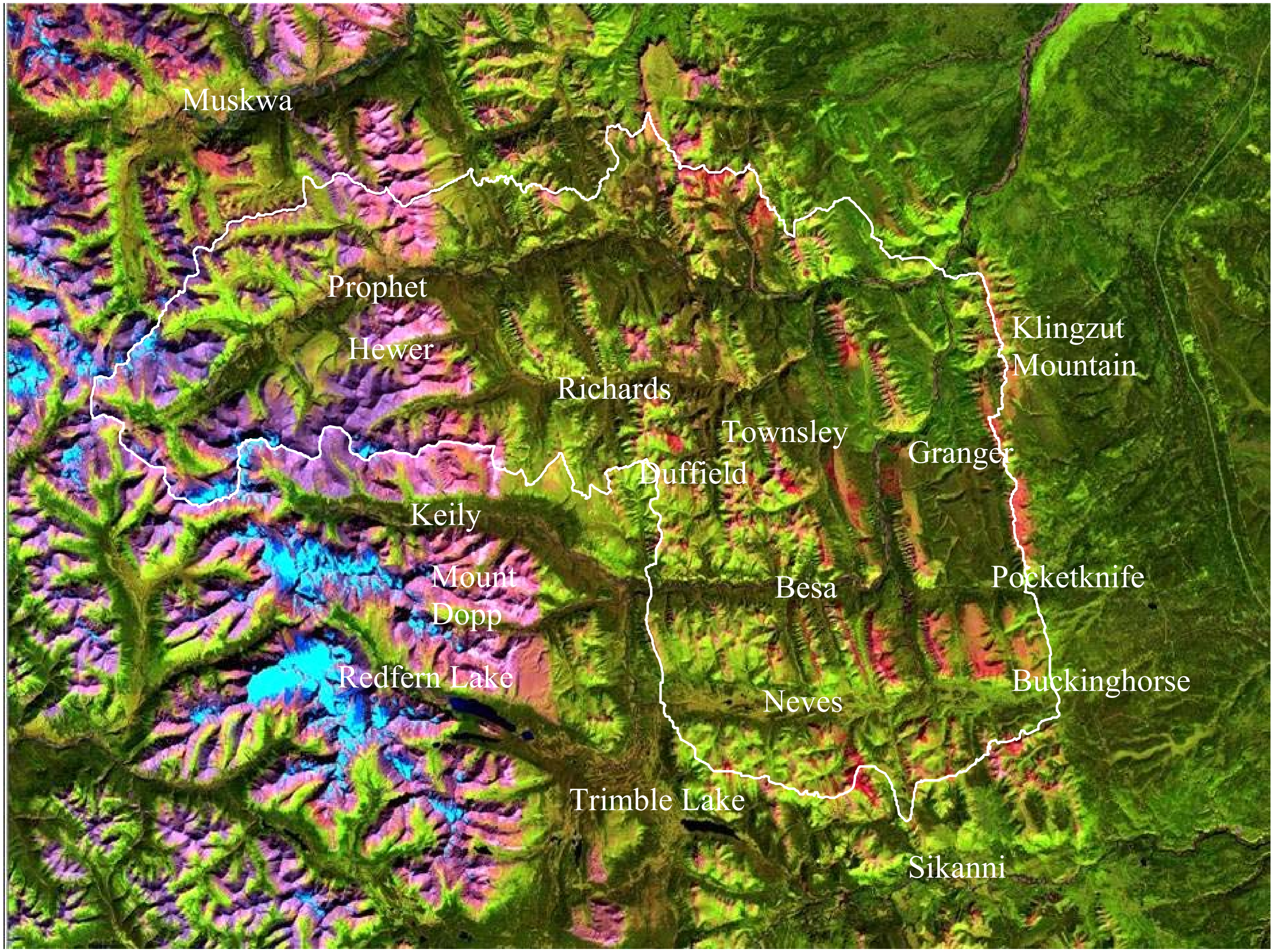


Figure 9. Remote-sensing satellite image of the Besa-Prophet study area including outline of the Besa-Prophet Pre-tenure Planning Area and notable drainages and landscape features.

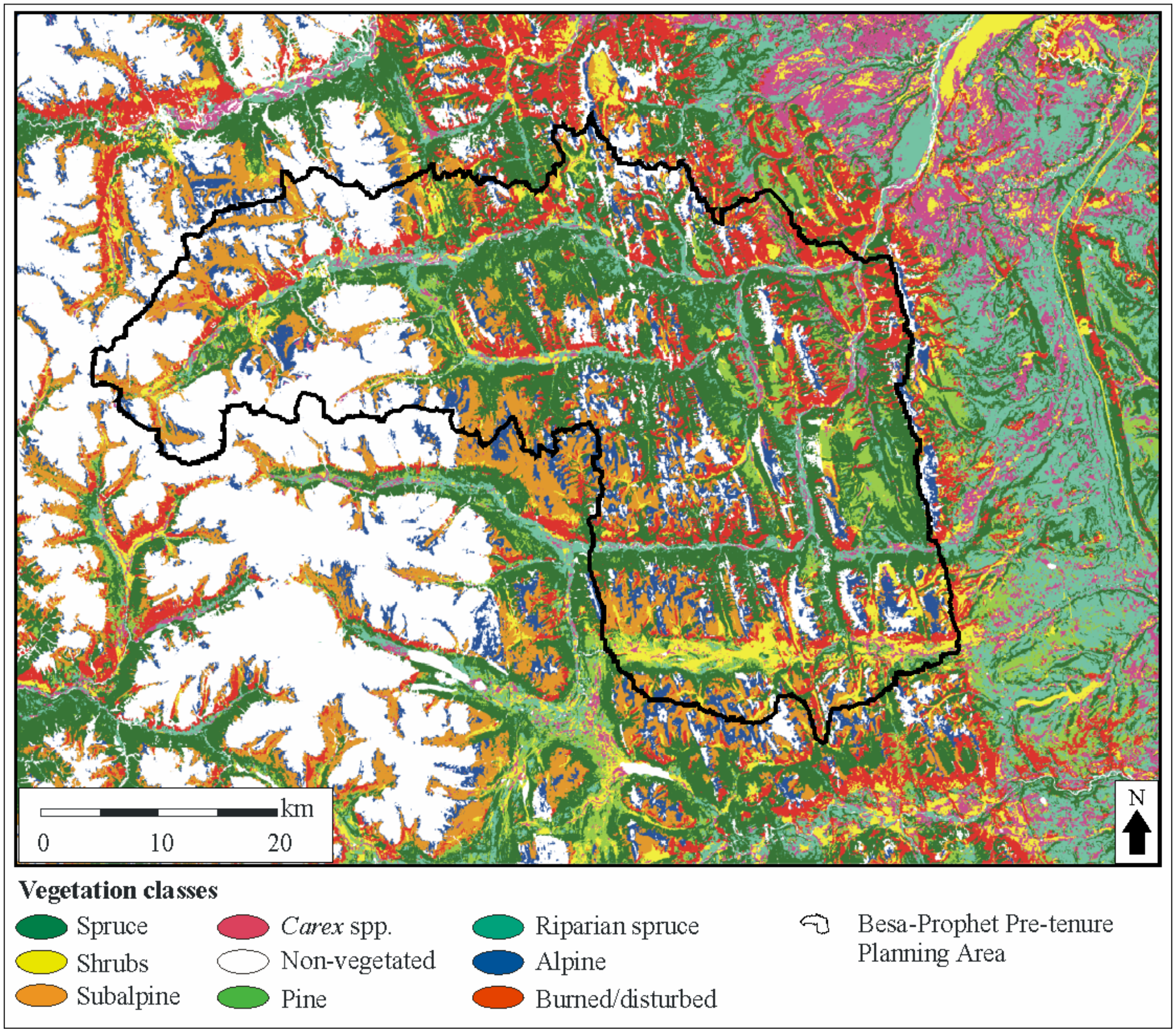
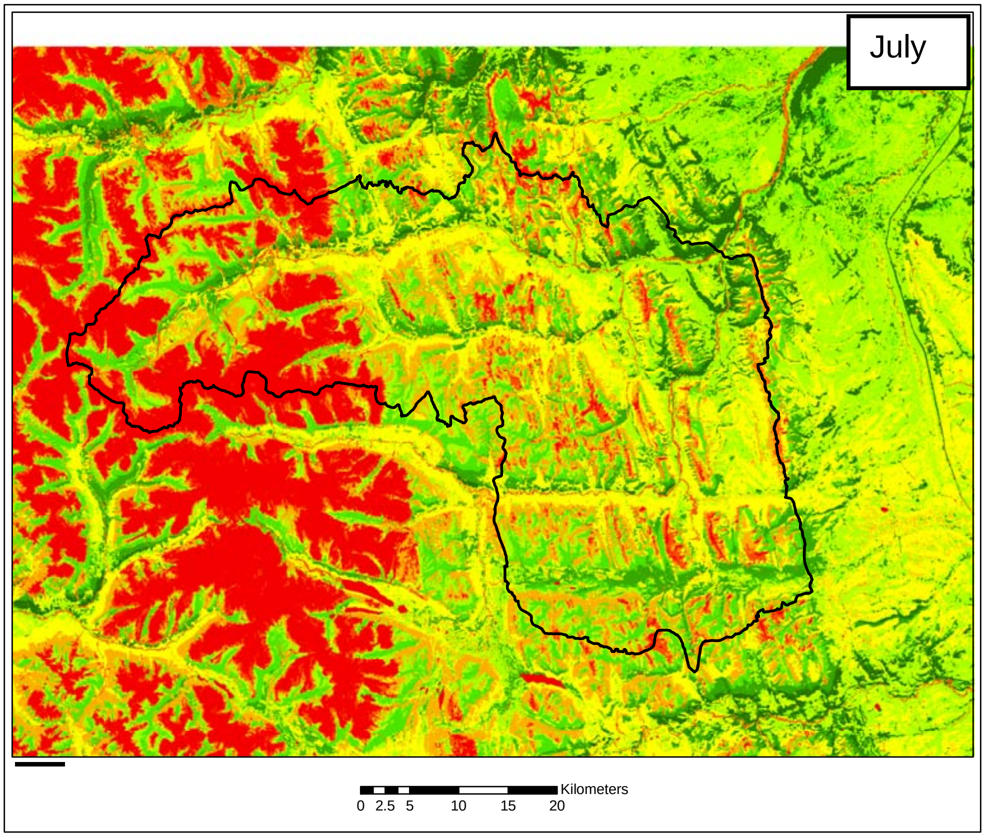


Figure 10. Nine vegetation classes, as defined using a vegetation classification from a 15 August 2001 Landsat Enhanced Thematic Mapper image of the Greater Besa-Prophet area, northern British Columbia.

During the spring/summer months, we extracted NDVI (Normalized Difference Vegetation Index) values from the 2001 remote-sensing images (Landsat 5 Thematic Mapper and Landsat 7 ETM; Lay 2005). NDVI is related to leaf area and plant biomass. For all community types, plant biomass increased from June to July and August, and then declined in September (Fig. 11, from R. Lay unpublished data). Shrubs, burned slopes, and subalpine areas were highest in plant biomass; gravel bars were lowest. We mapped this index of relative biomass across the entire study area (e.g., the darkest green areas along south-facing slopes had the greatest biomass in July, whereas the lowest biomass (reddest areas) was on rocky areas and glaciers in Fig. 11). We also determined the rate of change in green-ness for each vegetation community from the change in NDVI between months (Fig. 12). Highest rates of change were between June and July for shrubs, burned and disturbed areas, and subalpine areas, and much less change occurred on gravel bars and riparian areas. Change was relatively stable from July to August, and was negative from August to September as plants declined in green-ness. We used this information as an index of forage quality (highest rates of green-up are likely the most digestible, best quality forage), and mapped quality across the study area (e.g., the darkest green areas had the highest relative quality between June and July in Fig. 12).

To define predation risk to caribou, we used resource selection functions (RSFs) to quantify the combination of variables that grizzly bears and wolves were choosing or avoiding in the Greater Besa-Prophet Area. These models determine the likelihood of an area being highly selected by an animal or group of animals and provide a broad-scale perspective of general patterns on the landscape (Boyce and McDonald 1999; Manly et al. 2002). They also accommodate any type of habitat variables (categorical and continuous) and easily incorporate spatial data acquired from Geographical Information Systems (GIS) or remote sensing (Boyce and McDonald 1999).

We developed RSF models for the calving and summer seasons using logistic regression from GPS locations of 15 collared female grizzly bears and 22 gray wolves from 5 packs that were being monitored in a concurrent study (B. Milakovic, University of Northern British Columbia, PhD dissertation in progress). Grizzly bears and wolves were assumed to be the most significant large mammal predators in the Muskwa-Kechika Management Area (Bergerud and Elliott 1998). The models included slope, aspect, elevation, vegetation class, fragmentation (an index of vegetation diversity) and distance to linear features. Linear features included roads, trails, and seismic lines (see Fig. 4). For each GPS location used by a predator, we selected 5 random locations from individual bear and wolf pack ranges, as defined by a 100 % minimum convex polygon, to determine what predators were selecting from the area around them. In areas where data for wolf packs or bears were not available, we used a global model that combined data from all bears or wolves to rank risk in those few parts of the landscape. Resource selection function (RSF) values from the predator-risk models are relative values that rank habitats based on a variety of topographical and vegetation features. Because RSF values are relative to each data set (e.g., pack, season, and year) and species (i.e., bear and wolf), we standardized and normalized values to define risk across packs and species within each season. Where pack boundaries of wolves overlapped, we assigned the lowest risk value to each GIS pixel because there generally tends to be less pack vigilance along boundary areas (Mech 1994). We then generated a risk surface that defined which areas have the highest selection values for bears or wolves in each season (as in Gustine 2005a).



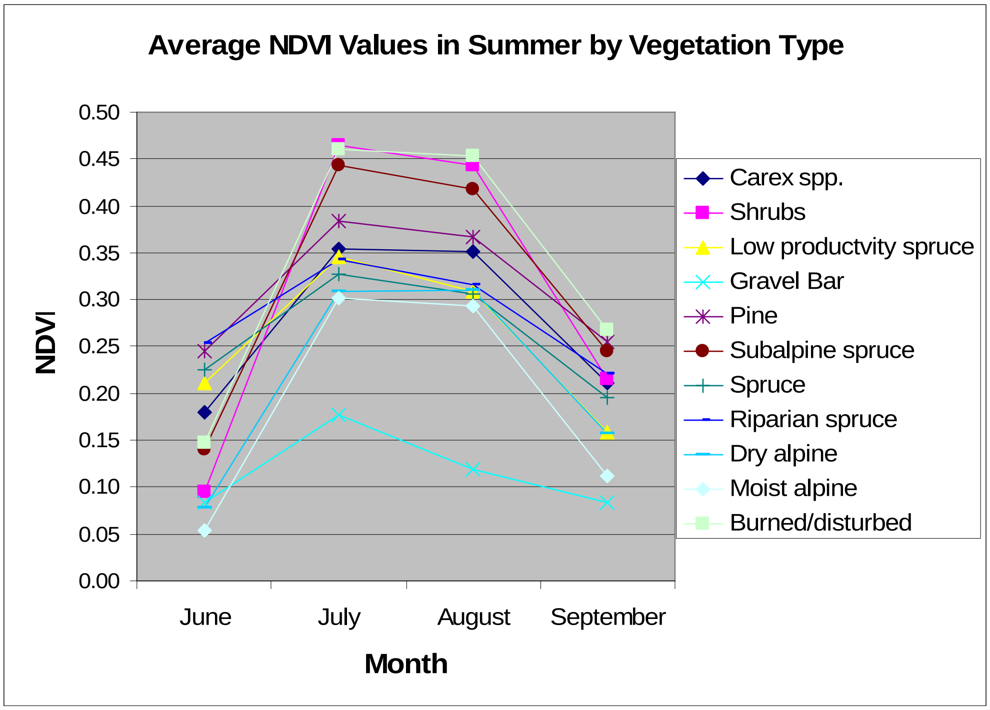
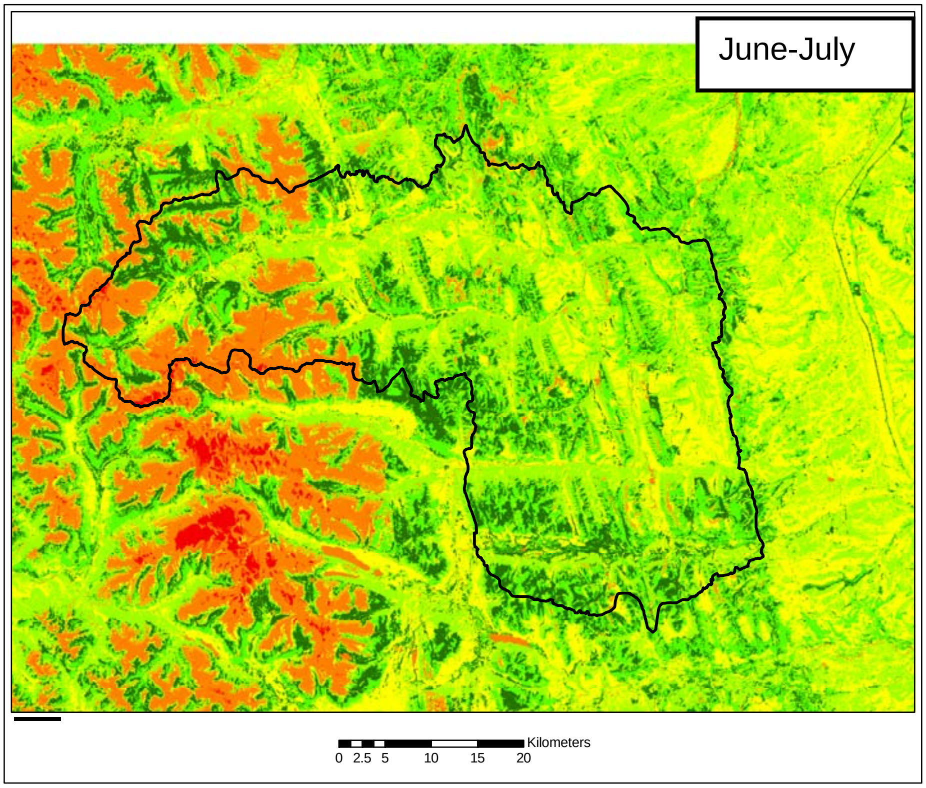


Figure 11. Relative forage biomass, as indexed by Normalized Difference Vegetation Index (NDVI), across the Greater Besa-Prophet Area, northern British Columbia in July, and for comparison among vegetation classes from June through September.



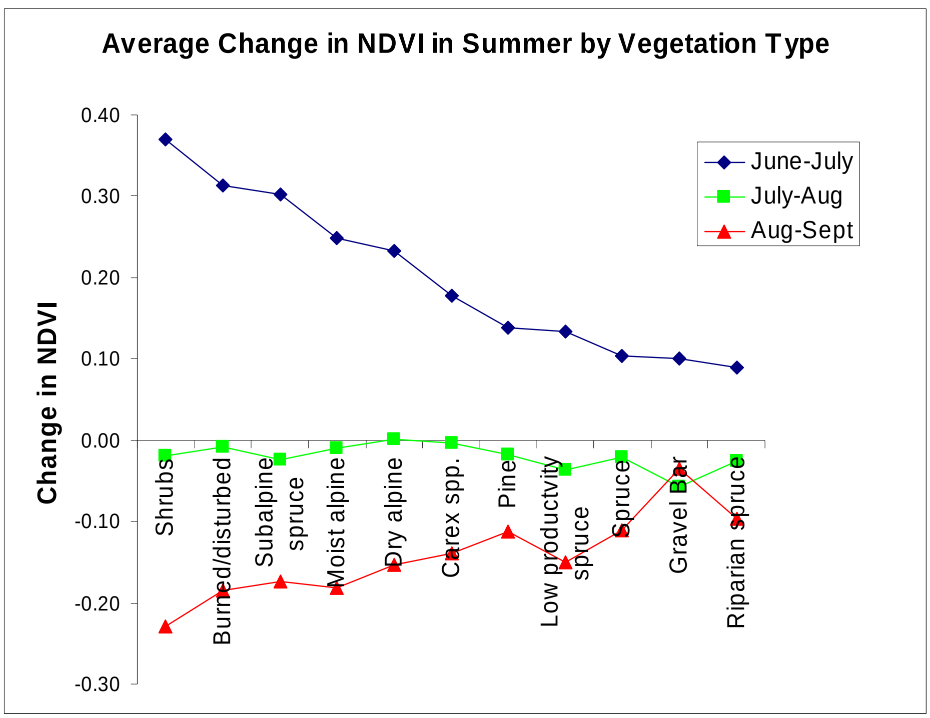


Figure 12. Relative forage quality, as indexed by change in NDVI, across the Greater Besa-Prophet Area, northern British Columbia in June-July, and for comparison among vegetation classes from June to September.

The predation-risk surfaces represent the relative selection value for a predator in each 25 x 25-m pixel across the study area. We assumed that the risk of predation to caribou from wolves and grizzly bears was directly related to selection values from the RSFs of those species. Figure 13 is an example of grizzly bear risk in spring (e.g., the red areas across the study area had the highest bear risk). We also determined the distance to high-risk habitats for each of the selected locations in the calving areas and across the landscape. We defined a high-risk habitat as where a caribou had a much higher than random chance of being in an area with high selection value to a predator (RSF >0.75, or the habitats in the top 25th percentile value within a season and year; normalized, median values for a layer varied from 0.47-0.54).

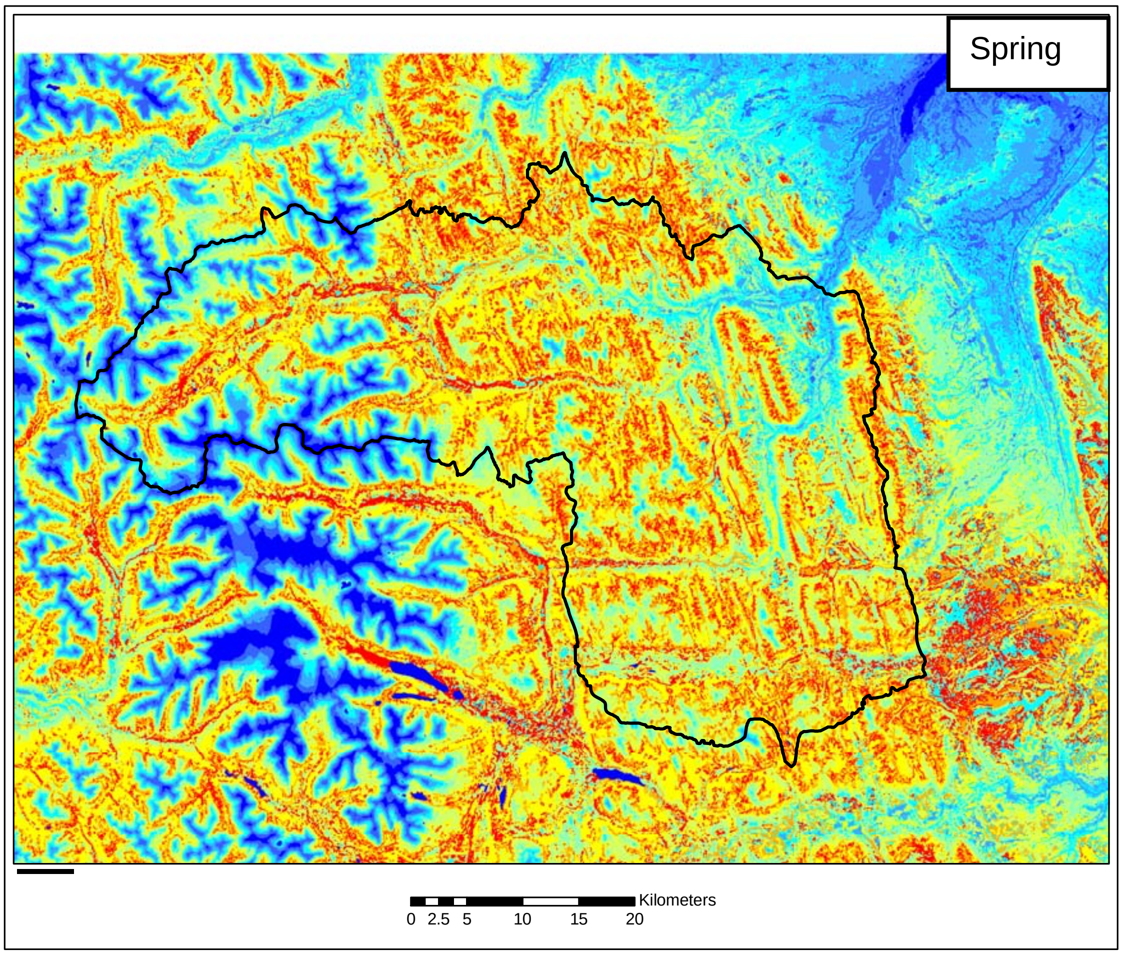


Figure 13. Relative predation risk from grizzly bears in spring across the Greater Besa-Prophet Area, northern British Columbia.

We compared the calving sites that caribou used with random points from calving areas and the landscape. We set the number of random points within each calving area to be 10 times the number of radio-collared calves within an area that were monitored relative to survival from predation (i.e., this did not include the 2 early abandonment and accidental mortalities). We therefore used the following sample sizes for calving areas: $n_{\text{Foothills}}$ = 200, $n_{\text{Western High Country}}$ = 180, and $n_{\text{North Prophet}}$ = 100), which turned out to be directly proportional to sizes of the calving areas. We set the number of random points on the landscape to be equal to the total number of data points across the calving areas (n = 480). Topography, vegetation characteristics, and predation risk varied among calving areas in both the calving and summer seasons (Table 6).

Topography: All calving areas were steeper and higher than the overall landscape of the Greater Besa-Prophet Area. The Foothills was lower in elevation (~1,600 m) than the other 2 calving areas (~1,870 m).

Vegetation Biomass: Caribou always avoided high vegetation biomass during calving. The calving areas had lower biomass and were farther from areas of high biomass than were randomly available on the landscape (Table 6). The Foothills had the highest vegetation biomass and was the closest to areas of high biomass (~400 m) of the 3 calving areas. During the calving season, the calving sites in all calving areas were also farther from areas of high biomass than were available to them in the calving areas, but by summer the biomass at all calving sites was lower than the landscape in general.

Vegetation Quality: The contribution of vegetation quality to the selection of calving areas and calving sites was variable. The Foothills was higher in quality and closer to areas of high quality than the other calving areas and the landscape, whereas the Western High Country was lower in vegetation quality than the landscape (Table 6). In all of the calving areas, caribou used calving sites that were higher in vegetation quality and closer to areas of high quality than found on the landscape.

Predation Risk: Caribou calved in areas with grizzly bear risk that was no different or higher than available on the landscape in 2 of the 3 calving areas (Table 6). The Foothills was the riskiest area to calve and remain during the summer, as grizzly bear risk was higher, and random locations within this area were closer to areas of high grizzly bear risk in both seasons. The North Prophet had lower grizzly bear risk than the landscape and was farthest from areas of high grizzly bear risk during calving. In both calving areas, however, caribou minimized their risk to predation by choosing calving sites that were lower in risk than the calving area around them. Therefore, minimizing grizzly bear risk was important in the selection of calving sites within calving areas, but not at the scale of the calving area per se.

Wolf risk, in contrast, was generally important in the selection of calving areas by caribou, but not in selecting calving sites within those areas. Although the Foothills had higher wolf risk and was closer to areas of high wolf risk than other calving areas, the other 2 calving areas had lower wolf risk than what was found on the landscape, and all calving areas were farther than random to areas of high wolf risk during the calving season (Table 6). Within each of the calving areas, wolf risk significantly increased and the distance to areas of high wolf risk decreased from calving to summer. Caribou appeared to cope with the increase in wolf risk from calving to summer in part by moving away from calving sites and forming large post-calving aggregations.

Table 6. Large-scale characteristics of predation risk from grizzly bears and wolves, and vegetation biomass and quality (mean ± SE) at calving sites and random points within the Foothills (FTHILLS), Western High Country (WHC), and North Prophet (NP) calving areas in the Greater Besa-Prophet Area (GBPA), 2002-2003. Characteristics of calving sites marked with an asterisk (*) indicate significant differences (P < 0.05) from random points within that calving area. Characteristics of random points sharing the same letter were not significantly different among calving areas.

Season	Variable	FTHILLS	WHC	NP	GBPA
Calving Sites					
Calving	Bear risk	0.57±0.021*	0.54±0.022	0.38±0.025*	0.52±0.017
	Distance to areas of high bear risk (m)	277±38.1*	425±68.9	920±175.9	466±58.0
	Wolf risk	0.41±0.024	0.45±0.026*	0.27±0.029	0.39±0.018*
	Distance to areas of high wolf risk (m)	793±82.4	1304±222.7	2532±369.2	1347±149.2*
	Biomass (NDVI)	0.04±0.015*	0.07±0.017*	0.001±0.011	0.04±0.10*
	Distance to areas of high biomass (m)	494±56.2*	504.1±109.3	1113±91.2*	627±61.7*
Summer	Bear risk	0.61±0.039	0.52±0.053	0.29±0.028	0.51±0.031
	Distance to areas of high bear risk (m)	109±23.3	208±69.2*	440±66.9	215±35.3
	Wolf risk	0.49±0.033	0.54±0.046*	0.34±0.033	0.48±0.025
	Distance to areas of high wolf risk (m)	304±60.5	284±72.4	536±56.3	345±40.8
	Biomass (NDVI)	0.34±0.014	0.28±0.033*	0.14±0.040	0.28±0.019*
	Distance to areas of high biomass (m)	139±24.7	242±66.5	508±58.5	254±35.3
Calving to Summer	Quality (change in NDVI)	0.79±0.026	0.60±0.062*	0.42±0.104	0.64±0.039*
	Distance to areas of high quality (m)	13±9.2*	116±57.1*	100±36.2	69±23.6*
	Slope (^{o})	28±1.6	17±1.9*	23±2.7	22±1.3
	Elevation (m)	1767±29.6*	1783±38.3	2033±30.6*	1828±24.9*

Table 6. Continued.

Season	Variable	FTHILLS	WHC	NP	GBPA
Random Points					
Calving	Bear risk	0.63±0.008[a]	0.49±0.014[bc]	0.47±0.016[c]	0.52±0.008[b]
	Distance to areas of high bear risk (m)	175±12.2[a]	475±36.1[b]	874±71.1[c†]	1193±120.8[b†]
	Wolf risk	0.46±0.008[a]	0.35±0.011[b]	0.34±0.014[b]	0.49±0.009[a]
	Distance to areas of high wolf risk (m)	838±37.4[a]	1567±85.1[b]	1910±124.6[b]	739±41.6[c]
	Biomass (NDVI)	0.10±0.006[a]	0.03±0.006[b]	0.03±0.007[b]	0.14±0.005[c]
	Distance to areas of high biomass (m)	386±27.0[a]	666±39.0[b]	754±52.5[b]	292±20.2[c]
Summer	Bear risk	0.61±0.012[a]	0.43±0.017[b]	0.46±0.025[b]	0.53±0.009[c]
	Distance to areas of high bear risk (m)	130±10.6[a]	463±35.4[b]	386±42.8[b]	447±33.4[b]
	Wolf risk	0.53±0.012[a]	0.41±0.018[b]	0.43±0.022[bc]	0.51±0.011[ac]
	Distance to areas of high wolf risk (m)	300±18.9[a]	536±37.2[b]	591±58.9[b]	391±23.8[a]
	Biomass (NDVI)	0.34±0.007[a]	0.16±0.014[b]	0.20±0.019[b]	0.31±0.008[a]
	Distance to areas of high biomass (m)	123±10.3[a]	457±35.5[b]	420.9±45.2[b]	273±18.2[c]
Calving to Summer	Quality (change in NDVI)	0.67±0.016[a]	0.34±0.028[b]	0.43±0.039[bc]	0.47±0.014[c]
	Distance to areas of high quality (m)	65±8.4[a]	276±25.9[b]	173±28.9[c]	222±14[bc]
	Slope (°)	25±0.7[a]	26±0.9[a]	25±1.0[a]	19±0.6[b]
	Elevation (m)	1611±14.0[a]	1857±18.2[b]	1881±24.8[b]	1456±18.6[c]

Calving caribou may have used topography to minimize predation risk. In the risky Foothills area, caribou chose calving sites higher in elevation than what was available, whereas the caribou in areas with lower predation risk showed no selection for the higher elevations. By avoiding areas with high biomass, caribou also reduced risk of predation during calving because vegetation biomass was positively correlated with predation risk. Despite the spatial variation in predation risk and vegetation among the calving areas, survival of caribou calves and cause-specific mortality did not differ among areas. The calving strategies involved trade-offs between predation risk and forage value, but there appeared to be no proximate benefit(s) of calving in one area over another in terms of higher birth mass (as estimated from mass at capture (a) and age in days (x), where y = a-0.571x; Parker 1989) or increased survival through summer.

The persistence of the 3 types of calving areas (Fig. 4) may be important because caribou calf production in an area is likely to vary with changing environmental (e.g., timing of late spring snows) and ecological conditions (e.g., changes in ungulate and predator densities). During calving, calving areas should be free of anthropogenic disturbance that may alter distributions of parturient female caribou, other ungulates, and/or their predators.

The following characterizes the 3 general types of calving areas in the Greater Besa-Prophet Area:

1) The North Prophet at 1,200-2,400 m is characterized by wide valleys with almost no forest cover. There are large areas of subalpine and alpine vegetation, and access to steep, rocky terrain. Permanent snowfields and talus-scree fields are common at high elevations. Caribou choose sites to calve that are characterized by elevations >2,000 m in rock or alpine habitats. There are typically no trees; low (<5 %) shrub cover, a low diversity and ground cover of herbaceous vegetation; high (~50 %) rock or bare ground cover; and a high diversity of lichens. The North Prophet offers benefits of both abundant and productive alpine-subalpine vegetation that may green up relatively early, as well as access to steep terrain that serves as escape cover for caribou with young. Caribou select calving sites that are low in grizzly bear risk and that increase separation from areas of high vegetation biomass.

2) The Western High Country, in the areas of Keily and upper Richards Creeks as well as College Lakes, is characterized by rugged and steep mountains from 1,400-2,500 m elevation. Rock, permanent snowfields, and glaciers dominate the area, but there is some vegetative cover in the form of spruce-lined river bottoms, and subalpine and alpine habitats in the north- and south-facing hanging valleys. Caribou choose specific calving sites between 1,700-1,850 m in spruce, subalpine, alpine, rock, or *Carex* habitats. The sites typically have low (~5 %) tree cover; moderate to low (~15 %) shrub cover; high (~37 %) dwarf shrub cover with low to moderate ground herbaceous cover; moderate (~20 %) rock/bare ground cover; and a moderate diversity of lichens. Generally the Western High Country provides areas lower in the risk of predation, but also lower in forage biomass and quality.

3) The Foothills includes Duffield Townsley, South Besa, and Neves areas. The Foothills is on the eastern front of the Rocky Mountains, with elevations ranging from 1,000-2,000 m, and is defined by timbered valleys and steep, vegetated mountains. Spruce-lined valleys transition into shrubby subalpine and alpine habitats with little non-vegetated cover and no

permanent snowfields. Caribou select calving sites that are typically between 1,650 and 1,800 m in spruce, subalpine, or alpine habitats. There is low (~5 %) tree cover; high (~35 %) shrub cover; variable dwarf shrub cover; a high diversity and ground cover of herbaceous vegetation; low (~10 %) rock/bare ground cover; and a low diversity of ground lichens. The Foothills generally provides large areas of productive alpine and subalpine vegetation that green up earlier than the other calving areas, although there is relatively high wolf and bear risk.

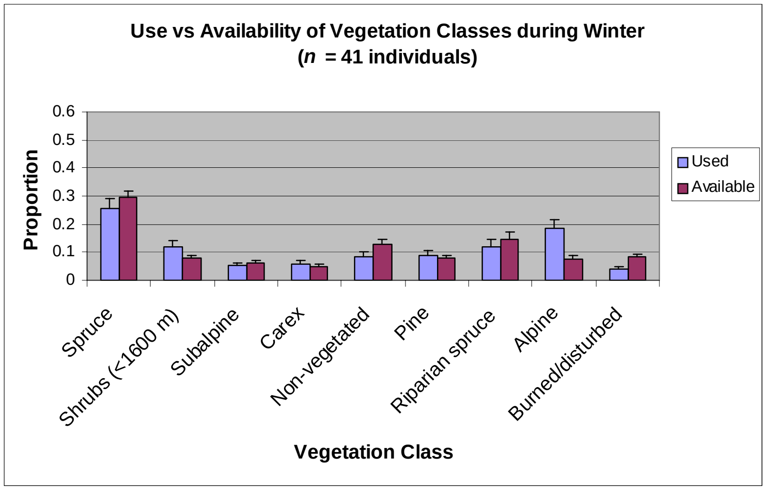
Both the Foothills and North Prophet calving areas are also important summer (15 June-15 August) range for woodland caribou, and should be recognized in addition to their importance as calving areas. Because of its relatively easier access, the Foothills area is most susceptible to anthropogenic activity. Caribou cow-calf pairs should have choices in routes to this area to form post-calving aggregations that are important to calf survival. Any disturbance during either times of movement to the calving area or during formation of post-calving aggregations may have direct (increased predation) or indirect consequences (displacement to lower quality summer range) to calf survival and population productivity.

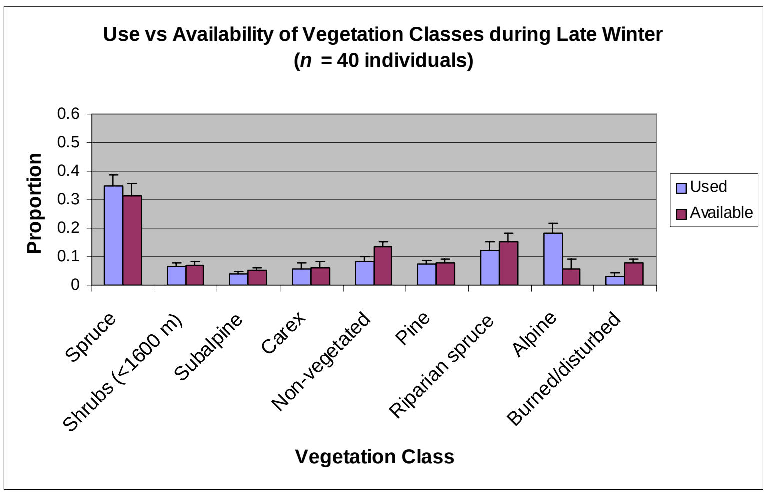
General Habitat Use and Availability

We used the GPS data from radio-collared individuals to describe the habitat associations of woodland caribou on a seasonal basis in the Greater Besa-Prophet Area. We visually compared use to availability of different vegetation classes, but then determined selection for combinations of variables because habitat use occurs in response to multiple variables and not to vegetation class alone.

To index available resources for individual caribou, we took all movement rates from the 6-hr GPS fixes and determined the 95th percentile rate with its corresponding distance travelled. Our reasoning was that 95 % of the time, an animal typically moves within this movement potential. The remaining 5 % includes faster rates (longer distances travelled during the 6-hr GPS time frame) and much rarer events, and could be evoked by more non-typical conditions. We then assumed that for each location used by caribou, resources were accessible within the 95th percentile distance in any direction. Therefore, from a circle with this potential movement radius around each use point, we randomly selected 5 points as what was available to the animal (see Gustine 2005a for more details). We averaged the proportions of vegetation classes that were used and available by each individual to reduce effects of uneven sample sizes among individuals.

The spruce vegetation class, which covers almost a quarter of the Greater Besa-Prophet Area (Table 5), was used most by caribou during winter, late winter, and pre-calving (Fig. 14). Use of this class increased from 26 % of GPS locations in winter to 41 % during pre-calving. This reflects the movements by caribou towards calving areas. During calving, 85 % of use locations were in alpine, subalpine, and non-vegetated areas (Fig. 15). Female caribou continued to use the alpine and subalpine classes most (>60 % of locations) from summer through breeding. Caribou avoided burned and disturbed areas during all seasons; highest use (7 % of use locations) occurred during pre-calving, presumably during the movements to calving areas.





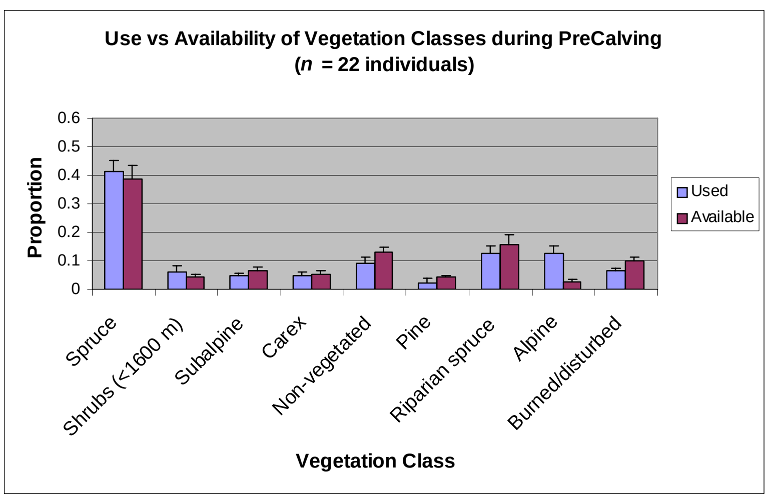


Figure 14. Proportional use versus availability (+ SE) of vegetation classes by woodland caribou in the Greater Besa-Prophet Area of British Columbia from winter through pre-calving seasons, 2002-2004. Standard errors were determined from averages for each individual by season as defined in Table 1.

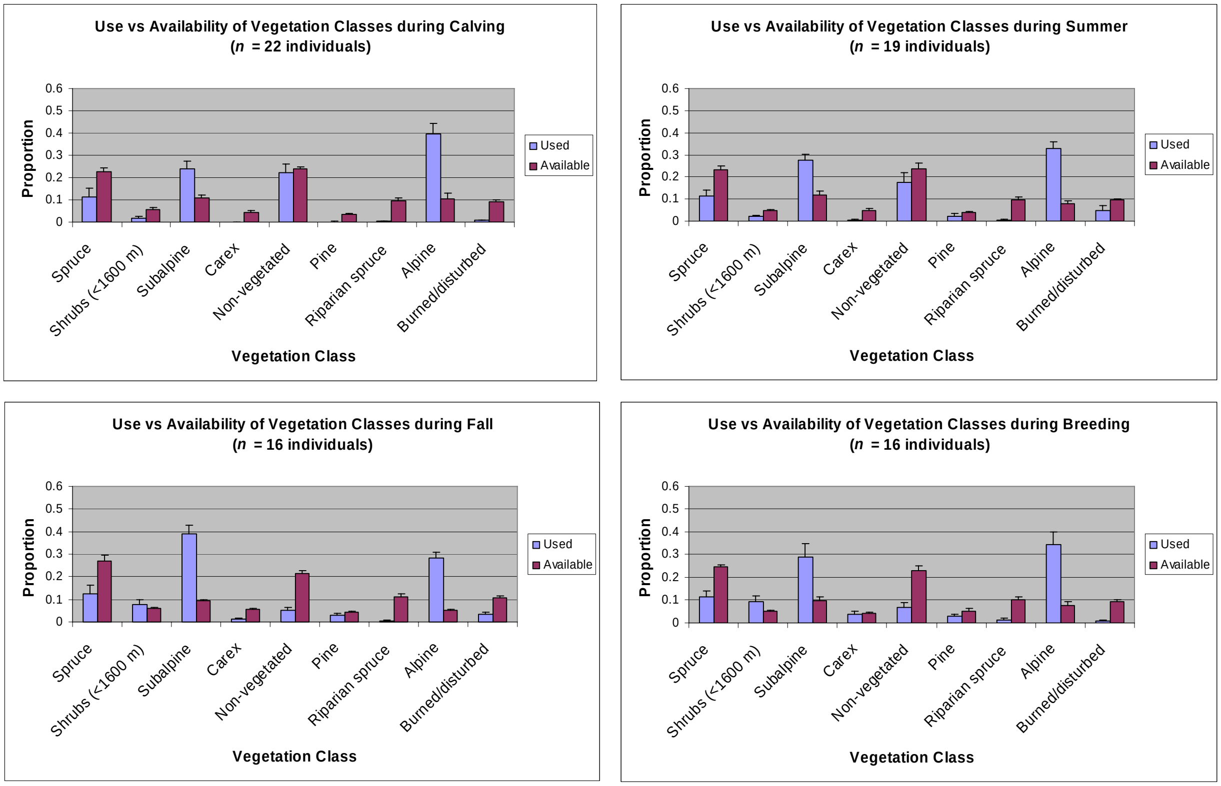


Figure 15. Proportional use versus availability (+ SE) of vegetation classes by woodland caribou in the Greater Besa-Prophet Area or northern British Columbia from calving through breeding seasons, 2002-2004. Standard errors were determined from averages for each individual by season as defined in Table 1.

Winter Habitat Selection

Because of malfunctioning GPS collars, we were only able to define selection for caribou in the Greater Besa-Prophet Area over the winter seasons. We used the GPS data from female caribou collared in November-December 2001 to describe habitat selection during winter (November through February) and late winter (March-April). Eleven of 25 GPS collars functioned as programmed from date of capture to 30 April 2002. Because >90 % of the locations for one animal was east of the Greater Besa-Prophet Area, we used data for 10 individuals (8 pregnant, 2 non-pregnant) in our analyses. Fix rates were high (91.3 ± 2.1 %, mean ± SE), resulting in 3,254 locations (552 for non-pregnant animals) from winter and 2,123 locations (452 for non-pregnant animals) from late winter for analysis.

To quantify habitats and ecological parameters important to female caribou during the winter and late-winter seasons, we quantified broad-scale selection using RSF models. Our objectives were:

1) to identify the relative importance of the energetic cost of movement, the risk of wolf predation, and the distance to areas of high risk for pregnant and non-pregnant animals at a relatively small spatial scale defined by their seasonal movement; and

2) to compare the importance of predation risk between the scale of seasonal movements and the relatively large seasonal home range.

Our selection models typically included vegetation class (Table 5), elevation, slope, aspect, and the index of predation risk from wolves (as defined under Calving Strategies). Aspect was categorized into north (316° - 45°), east (46° - 135°), south (136° - 225°), west (226° - 315°), and no aspect (NAS). Pixels with slopes of <1° were assigned to the NAS category. We used the change in elevation and the distance between used as well as available points to model the energetic cost of movement (using equations from Fancy and White 1987).

All analyses were based on use (GPS locations of 10 collared caribou) and availability. We defined availability at 2 scales. Seasonal movement was an individual caribou's potential for movement within each of the 2 winter seasons (as described under General Habitat Use and Availability). Seasonal movements were variable among individuals depending on month (as in Fig. 2). Consequently, we assumed that resources available to the animal were potentially accessible (available) over a larger area in winter (November-February) than in late winter (March-April). We defined a seasonal range as the home range, using a 100 % minimum convex polygon (MCP) of an individual caribou for that season, and buffering it by the movement potential distance. We selected 5 random availability points per use point within each MCP for each individual caribou. Details of all models and results are provided in Gustine (2005a).

At the scale of seasonal movement, caribou generally did not appear to respond to the components of risk. Wolf risk and distance to areas of high wolf risk explained very little towards habitat selection by caribou in winter at this scale. Rather, most caribou strongly minimized the energetic costs of movement. Non-pregnant individuals ($n = 2$) showed a stronger avoidance of high-cost movements than most pregnant animals. In the late winter, our models suggested that non-pregnant caribou continued to strongly minimize their cost of movement, whereas the importance of minimizing the cost of movement varied for pregnant animals. Our data from the ultrasound measurements of rump fat on radio-collared caribou indicated that the non-pregnant caribou had less fat than pregnant individuals (Table 2). Females in poorer condition may attempt to minimize energetic costs earlier in winter than animals with higher fat reserves.

At the scale of seasonal range, there appear to be 2 strategies used by caribou wintering in the Greater Besa-Prophet Area: an Eastern and a Mountain strategy. For all female caribou, spacing out from areas of high wolf risk was important in both winter seasons. With few exceptions, increasing the distance to high-risk areas contributed substantial information to explaining habitat selection by caribou. Elevation also was important in habitat selection for all individual caribou in both winter seasons. Caribou that resided in the east showed similar patterns in the selection of elevations, as this area has relatively little topographic relief (approximately 700-1,100 m). Selection for these lower elevations is similar to some caribou in the Tweedsmuir-Entiako herd of western British Columbia, as individuals in that herd wintered in either lower (~1,000 m) or upper (~1,600 m) elevations (Cichowski 1993). In contrast, within mountainous areas in the Greater Besa-Prophet Area, some individuals chose moderate (1,200-1,400 m) and others higher elevations (1,400-1,600 m and 1,500-1,800 m). All animals selected against steep slopes. These attributes in the Mountain model appear similar to caribou near Takla Lake (Poole et al. 2000) and to the Tweedsmuir-Entiako, Itcha-Ilgachuz, and Rainbow herds (Cichowski 1993).

There was less variation in the selection of vegetation classes among caribou than other parameters at the scale of seasonal range. In addition to selection strategies regarding elevation and increasing their distance from areas of high wolf risk, caribou generally selected for sedge (*Carex* spp.) meadows and riparian spruce and spruce stands, and avoided the shrub and subalpine shrub classes in winter. Caribou in the east selected for *Carex* spp. and avoided the non-vegetated and alpine areas, not surprisingly because of the relatively flat boreal forest landscape. Caribou in the mountains showed strong selection for *Carex* spp. at higher elevations and avoidance of subalpine shrub areas as well (Fig. 16). Selection for these vegetation types was similar to other research conducted on the northern ecotype of woodland caribou (spruce, Poole et al. 2000; riparian spruce and *Carex* spp., Johnson 2000). Selection against the subalpine shrubs and burned-disturbed classes occurred in both seasons, which was likely in response to predation risk because wolf packs consistently selected these vegetation classes in the Greater Besa-Prophet Area (Gustine 2005a). Burns may negatively effect population productivity either directly (i.e., loss of forage; Seip 1990) or indirectly (e.g., increases in moose populations and wolves; Bergerud and Elliott 1986, Seip 1991). The avoidance of pine stands by caribou in the Greater Besa-Prophet Area was in contrast to other research on woodland caribou in winter (e.g., Cichowski 1993, Johnson 2000) and is probably explained at least in part by the lack of mature, lichen-producing pine stands in our study area.

To generate mapped surfaces showing areas of relatively high selection value for caribou, the coefficients for the variables within each seasonal model were multiplied by their appropriate input layers and summed. We used the maximum RSF value (scaled from 0 to 1) for each pixel from among the individual models. For example, if 3 caribou models overlapped a single pixel, and RSFs for caribou A, B, and C were equal to 0.25, 0.50, and 0.75 respectively, the highest value (0.75) was assigned to that pixel. We then divided RSF values into 5 quantiles (i.e., 20th, 40th, 60th, 80th, and 100th percentile values) representing low to high selection value to female caribou occupying a pixel. For areas where we had no estimates of use for individuals, data were filled in using estimates of selection from either the East or Mountain selection models. For all caribou, selection for late winter habitats was within areas selected during winter, and therefore one map was generated to portray areas important to female caribou over winter (Fig. 17). These areas, however, were not the only areas selected by wintering caribou in the Greater Besa-Prophet Area because observations, telemetry data from 1998-2000 (R. Woods, Ministry of Environment, Fort St John, unpublished data), and Zimmerman et al. (2002) indicated that animals also were wintering near Hewer Creek, and Mounts Dopp and Trimble (Fig. 9). Hence, Figure 17 represents known areas of importance to caribou in winter, but only for some radio-collared individuals in our study.

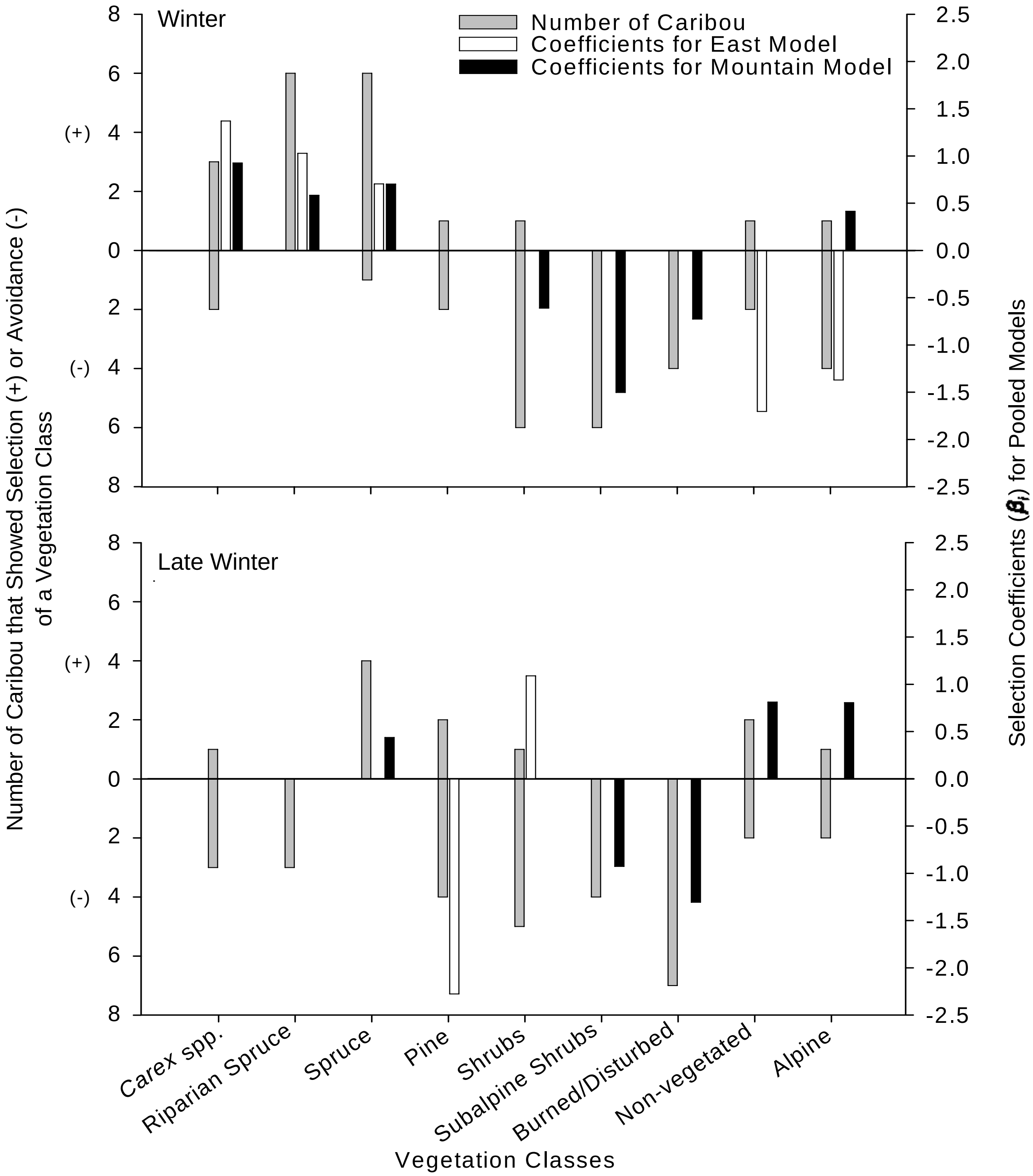


Figure 16. Number of GPS-collared caribou that selected or avoided a vegetation class (left axes) and the strength of significant ($P < 0.050$) coefficients of selection for the pooled models of animals living in the eastern (East, n = 2) and mountainous (Mountain, n = 8) portions of the Greater Besa-Prophet Area during winter (November-February) and late winter (March-April), 2001-2002.

Besa-Prophet Caribou

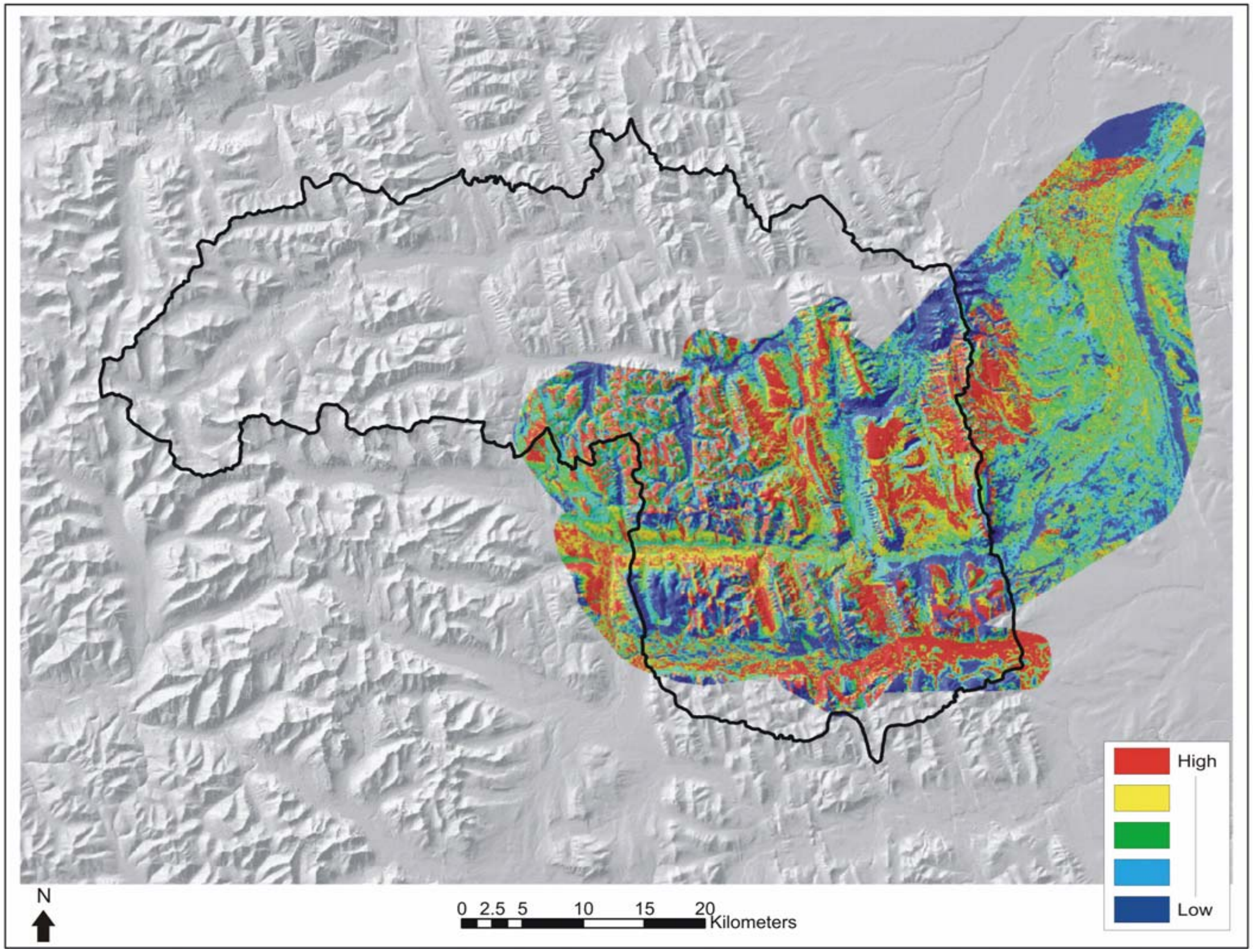


Figure 17. Areas selected by GPS-collared female woodland caribou in winter and late winter in the Greater Besa-Prophet Area, 2001-2002.

Habitat Use in Relation to Pre-tenure Plans

We compared the GPS use locations of the radio-collared caribou in this study with the habitat suitability index (HSI) model developed by British Columbia Ministry of Environment staff (Rod Backmeyer, Fort St John) for caribou from November through March. The HSI model was based primarily on literature review and local accounts of high-use areas, and was developed to help rank the Besa-Prophet landscape using classes from 1 (high value) to 6 (low value) during pre-tenure planning processes. The Besa-Prophet Pre-tenure Plan incorporates a roll-up map from the HSI modelling efforts for several species, but did not incorporate specific information for caribou because of the lack of quantifiable data. The roll-up map categorizes habitats into pre-tenure zones, as defined by physical and topographical features (Table 7). We present our findings relative to both the Plan and the preliminary suitability (HSI) models.

Table 7. Biophysical zones with wildlife value and management requirements in the pre-tenure planning areas of the Muskwa-Kechika Management Area (British Columbia Ministry of Sustainable Resource Management 2004).

Code	Pre-tenure Biophysical Zone	Description
LEW	Wetlands – Low Elevation	Concentrated in valley bottoms and lowland areas. Consists of seasonal and year-round moisture saturated soils; watercourses and coniferous/deciduous forest patches can be dispersed throughout the wetland. Contains summer and critical winter habitat for moose, critical caribou habitat and high fisheries values. Various other wildlife species such as raptors, birds, rodents, furbearers, amphibians and reptiles inhabit this zone. High fisheries values are also found within this zone. The wetland zone is important for maintaining water quality and quantity.
HEW	Wetlands – High Elevation	Located in mid to high elevation valley bottoms. Consists of seasonal and year-round moisture saturated soils. Minimal if any coniferous forest within or adjacent to this zone. Contains summer moose habitat, critical caribou winter habitat and year-round furbearer habitat.
MOS	Mosaic	Contains a mixture of forested and open habitats interspersed with wetlands, meadows, and forested lowlands and hills. The zone provides a mixture of foraging and security cover for ungulates. It contains critical winter habitat for moose and caribou; as well the older forested stands provide habitat for furbearer species.
IS	Incised Stream	Consists of steep-sloped stream-banks with flat upland areas. Important values include riparian habitat, fish, wildlife movement corridor and water quality and quantity. A mixture of ungulate security and foraging cover primarily on the uplands with a minor component on the steep slopes. Critical moose and elk winter habitat on the upland region.
MWA	Warm Aspect Forest (moderate <45% slope)	Consists of both extensive tracks of coniferous tree species and open forested habitat on south-west aspect slopes of gentle to moderate sloped terrain and contains areas of old growth. Depending on the pre-tenure plan area, this zone can provide critical winter elk habitat depending on snow depths. Older forest stands are important year round habitat for a variety of furbearers, while younger willow stands provide critical winter moose habitat. Spring grizzly bear habitat is found on steeper slopes that experience early snowmelt.
CAF	Cool Aspect Forest (<45% slope)	Consists of wet and cool forests that occur on gentle to moderately sloped terrain. Some forest stands may be interspersed with smaller

		interconnected wetland complexes. Older forested stands contain critical winter caribou habitat and important year round habitat for a variety of furbearer species, while shrub areas provide critical moose habitat. Pockets of permafrost are found on north slopes in this habitat type. This zone is a wildlife movement corridor.
SWA	Steep Slope Warm Aspect (>45% slope)	Consists of open and forested habitat on steep, southwest facing slopes. A variety of terrain features and habitat types are found in this zone including: alpine meadows, old growth forested stands, parkland, young forests, cliffs, rock outcrops and talus slopes. Furbearers are found in this zone. Steeper slopes are primarily open and provide critical winter Stone's sheep habitat and important year round goat habitat. This zone also provides elk and moose winter habitat and birthing and rearing areas for Stone's sheep, mountain goat and caribou. Higher zone elevations have lower biological productivity.
SCA	Steep Slope Cool Aspect (>45% slope)	Consists of open and forested habitat on steep, northeast facing slopes, with pockets of permafrost found on north slopes. A variety of terrain features and habitat types are found in this zone including: alpine meadows, old growth forested stands, parkland, young forests, cliffs, rock outcrops and talus slopes. This zone is primarily mountainous terrain, highly visible throughout the plan area. Critical winter Stone's sheep habitat borders a large portion of this zone. Steep slopes offer security habitat for caribou, elk and moose. This zone is important as a wildlife movement corridor, for grizzly bear denning and furbearer habitat. Higher zone elevations have lower biological productivity.
HEP	High Elevation Plateau	Consists of high elevation plateaus, often surrounded by steep open and treed terrain. The plateaus are primarily open and consist of vegetation types that are particularly sensitive to disturbance due to low biological productivity, shallow soils and low moisture and nutrient conditions. Isolated pockets of coniferous forest are found on some plateaus. These areas are prone to strong winter winds and provide critical winter caribou habitat especially during winters of high snowfall.
FFP	Forested Floodplain	Low elevation zone and adjacent to the River Zone. Forested Floodplain zone width is variable, dependent on valley bottom topography. Forest cover is dominated by conifers. May contain stable side/back water channels. Provides foraging, security and thermal cover for a diverse range of wildlife, including: elk, moose, bear, and a variety of furbearers, raptors and songbirds.
RFP	Major River Floodplain	A low elevation zone characterized by braided streams bordered by a multi-layered forest canopy and understory. Waterflow varies throughout the year with peak flows generally occurring late spring and early summer. Year to year, the active water channel can change location within the floodplain. The zone provides foraging, security and thermal cover for a diverse range of wildlife, including: elk, moose, bear, furbearers, raptors, and songbirds. High fisheries values exist in this zone.
G	Glacier	Consists of areas that have year-round accumulations of ice and snow that exclude the establishment of any vegetation. During summer months, various ungulate species may use accessible portions of glaciers to mitigate high ambient temperatures and/or to seek a reprieve from blood sucking insects.
R	River	Stream flow varies throughout the year with peak flows generally occurring late spring and early summer. Year to year, the active channel can change location within this zone. High fisheries values exist in this zone. May contain forested islands.
RB	River Breaks	Consists of actively eroding unstable steep-sloped banks of various heights and lengths bordering watercourses.

More than a third of the GPS locations recorded for caribou from November through March were in steep slope cool aspect (SCA) zones (Table 8, Fig. 18). Caribou also used steep slope warm aspects (SWA), moderate slope warm aspects (MWA), and cool aspect forest (CAF) almost equally for another 47 % of our observations.

Table 8. Pre-tenure biophysical zones and final habitat suitability (FS) classes as a percentage of the Besa-Prophet Pre-tenure Planning Area (excluding the Upper Prophet) compared to locations used by GPS-collared female caribou from November through March.

Pre-tenure Zone	% of Area	# GPS Locations	% Use
CAF	17.31	628	13.53
HEP	3.94	429	9.24
HEW	0.87	0	0.00
IS	1.71	52	1.12
LEW	3.46	72	1.55
MOS	0.84	82	1.77
MWA	11.64	708	15.25
RFP	1.65	33	0.71
SCA	31.92	1787	38.50
SWA	26.67	851	18.33
		n = 4642	
FS Class	**% of Area**	**# GPS Locations**	**% Use**
1	2.40	78	1.70
2	13.47	821	17.93
3	19.51	1011	22.08
4	23.88	1239	27.06
5	19.15	967	21.12
6	21.58	463	10.11
		n = 4579	

In the Neves Planning Unit (Besa-Prophet Pre-tenure Plan Phase I, British Columbia Ministry of Sustainable Resource Management 2002), caribou tended to frequent the cool aspect forests (CAF) next to the Neves Valley, grading up into the steeper slopes with cool aspect (SCA) (Fig. 18). These findings were similar to our observations of animals wintering along the upper Besa River. As noted in the Plan, the forested stands of the CAF contain critical winter caribou habitat. The Pocketknife and Lower Besa Planning Units (Fig. 9) were also used extensively by caribou from November through March because of the adjacency of the steep cool and warm aspects (SCA, SWA) with high elevation plateaus (HEP) and extensive stands of moderate slope warm aspect forests (MWA) next to steep slopes (SWA) (Fig. 18). Although MWA zones were noted to provide critical winter elk habitat in the Plan, the specific importance to wintering caribou was not recorded, and we recommend that this be noted in updates to the Plan, particularly relative to access west of Klingzut Mountain. We were unable to assess caribou use of the Lower Prophet Planning Unit because we did not have functioning GPS collars in this area.

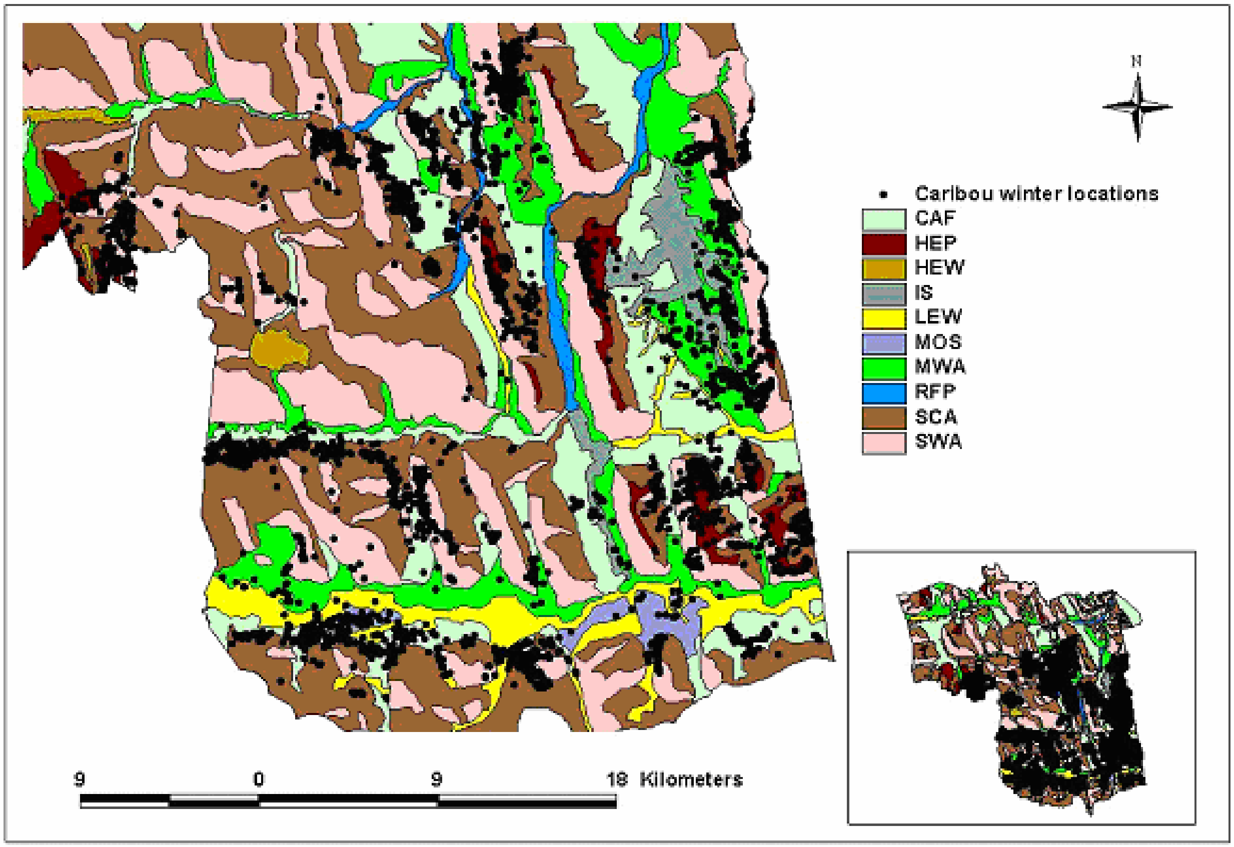
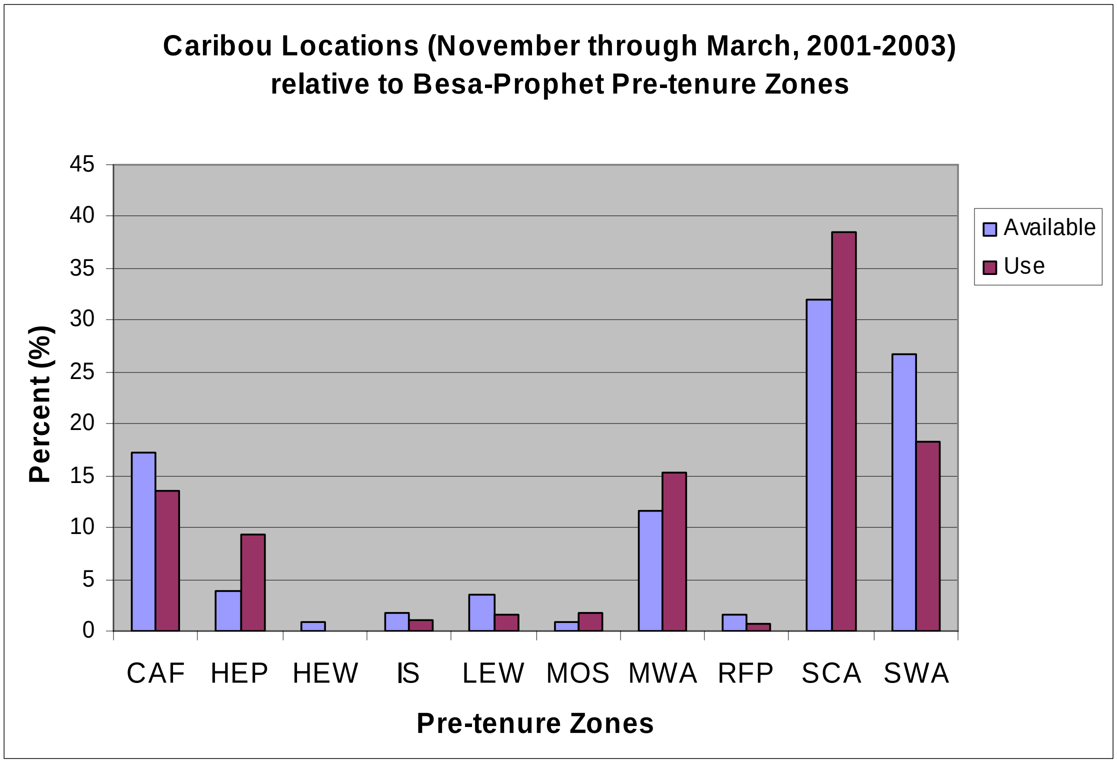


Figure 18. Winter GPS locations of radio-collared female caribou in the Besa-Prophet area in relation to zones designated in the Besa-Prophet Pre-tenure Plan.

Slight differences in sample sizes occurred between our GPS use locations relative to the pre-tenure biophysical zones and to habitat suitability classes because of small differences in the boundaries of different map files. Caribou tended to use habitat suitability classes 2 through 5 slightly more than available on the landscape, but there was no clear tendency for animals to select the most ‘suitable’ areas, as modelled by Ministry of Environment (Table 8, Fig. 19). This may reflect inadequacies with the HSI model, or possible trade-offs between food quality and predation risk.

For example, many of the locations used by caribou in the southern Besa-Prophet area were not in highest suitability classes (e.g., close-up view along Besa River, Fig. 20). Many of the animals used areas estimated to have only moderate quality, and very few animals used the predicted high quality classes. Fifty percent of all GPS locations in the Besa-Prophet Pre-tenure Planning Area (excluding the Upper Prophet) were in those medium quality (3 and 4) classes (Fig. 19). This probably emphasizes the importance of using selection models to define more than just topographical factors that influence habitat selection (see section on Winter Habitat Selection).



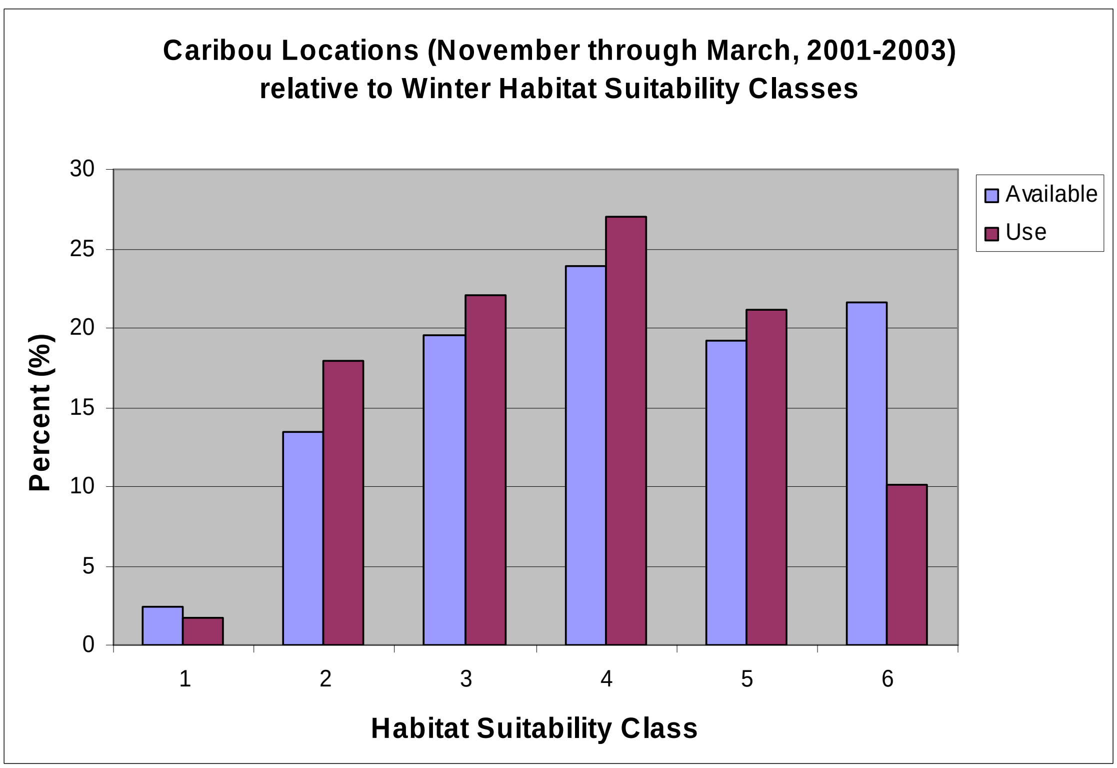
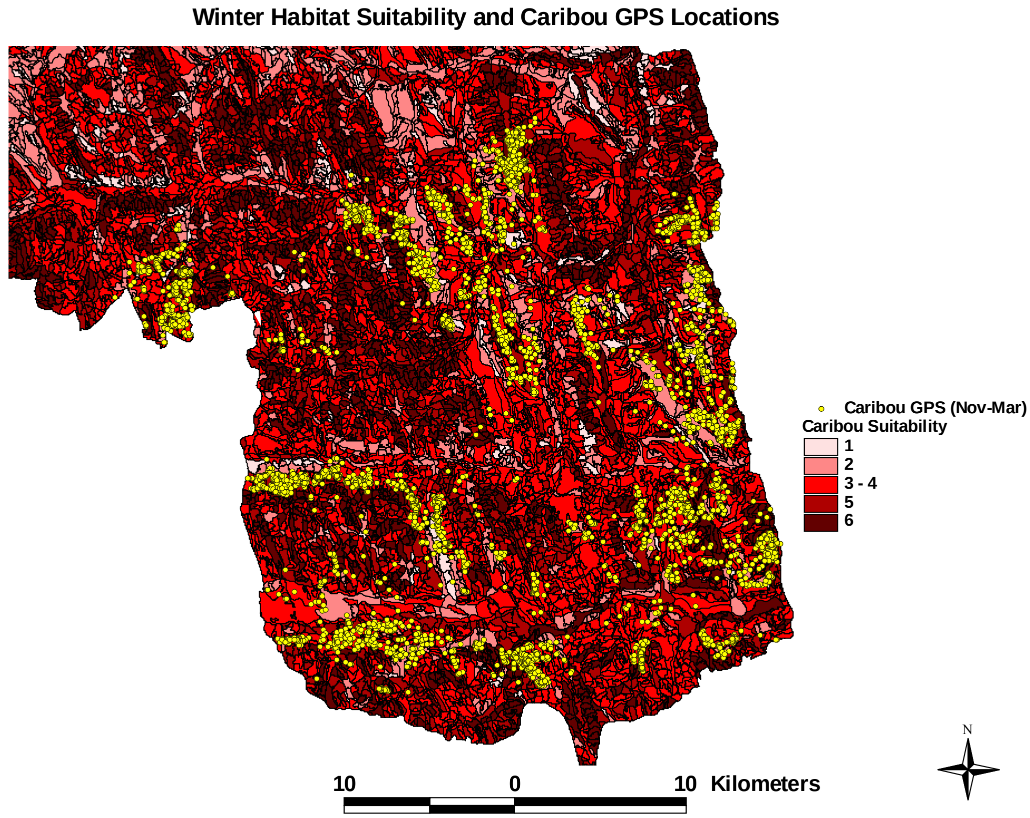


Figure 19. GPS locations of radio-collared female caribou (November through March) in relation to pre-tenure zones designated in the Besa-Prophet Pre-tenure Plan and availability of winter habitat suitability classes (British Columbia Ministry of Environment, Fort St John, BC).



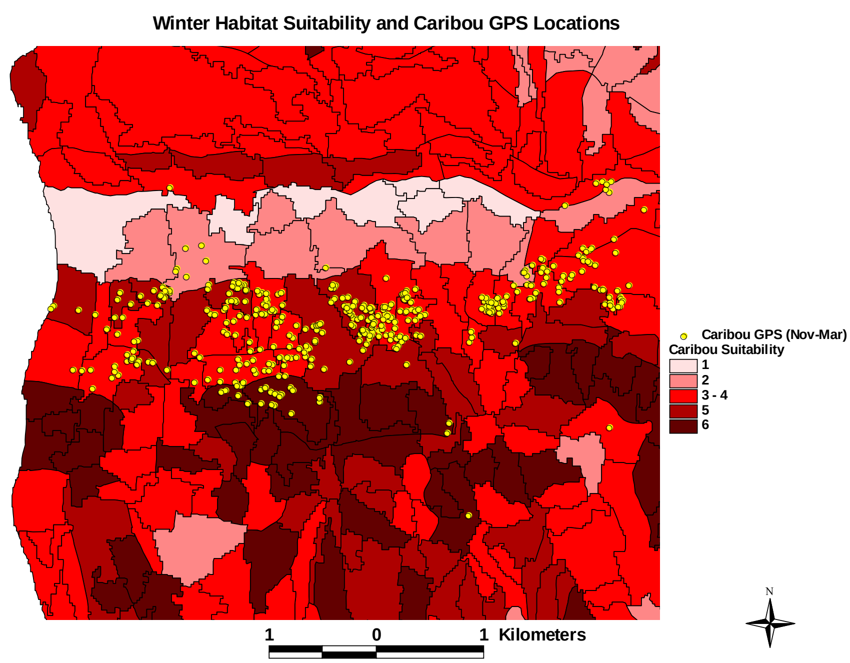


Figure 20. GPS locations of radio-collared female caribou from November through March in the southern Besa-Prophet area and specifically along the Besa River in relation to winter habitat suitability classes (Ministry of Environment, Fort St John, BC).

At the request of the Muskwa-Kechika Advisory Board, we provided information to the Besa-Prophet Pre-tenure Planning Committee on core use areas of wintering caribou. Figure 21 is a general overview of the areas used by caribou over winter in relation to the calving areas presented in Figure 4. Because caribou move across large areas, we included 3 periods of use within the entire winter: November-February (winter), March-April (late winter), and May (encompassing the pre-calving season). The map shows the core areas where animal locations from all 3 periods of use overlap (in purple), where 2 periods overlap (in light blue), and where there are animal locations for only one period of use (in dark blue). It is important to note that the most consistently used areas in purple straddle Klingzut Mountain and encompass industrial lease areas. These coloured use areas for wintering caribou are shown relative to the locations of major spring calving areas. The colour scheme for winter use does not suggest that dark blue areas (used for only one period within the winter) are unimportant. In fact, all of the areas may be necessary to successfully reach particular calving areas. East of the Muskwa-Kechika Management Area boundary, there are numerous linear features (roads and seismic lines, Fig. 21). For caribou, which are often negatively affected by industrial development, the Greater Besa-Prophet Area to the west without anthropogenic development is critical. This map shows known use areas, but is very conservative because it is based on locations obtained only from relatively few wintering radio-collared individuals.

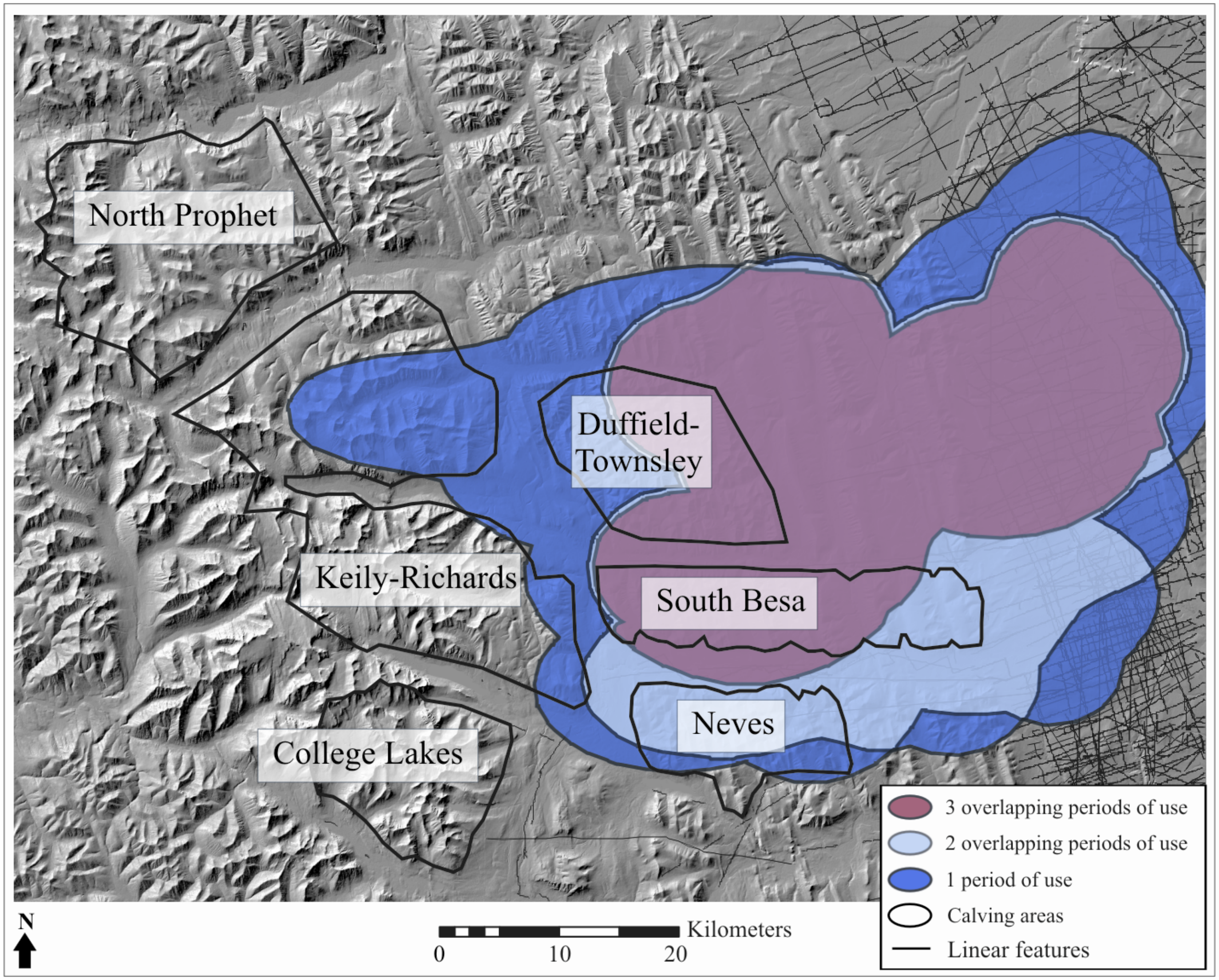


Figure 21. Core wintering (Nov-May) and calving areas for female caribou in the Besa-Prophet area, 2002-2003.

MANAGEMENT RECOMMENDATIONS

Rarely is there the opportunity to quantify the ecological relationships within relatively undisturbed ecosystems and to obtain baseline control data that can be used subsequently to monitor impacts. The general trend in many ecological studies has been to examine a system that has already been impacted to some extent by human activity and then attempt to make inferences about how the system has changed. In our study, the potential to make important contributions towards maintaining predator-prey ecosystems is significant, especially because there has been relatively little human interference in the Besa-Prophet region to date. Our data from the Greater Besa-Prophet Area provide inputs to a management and conservation framework that is based on observed, natural ecosystem function. We believe that planning processes should include knowledge of ecosystem-level processes, and that the challenge will be to compile and use data obtained at different scales (e.g., in-depth biological knowledge obtained from relatively small scales in studies such as ours, conservation area designs at larger scales, and cumulative impact frameworks). Sustainable management strategies for natural resources and effective planning processes in the Besa-Prophet region must include details from studies such as this research on caribou to best operationalize activity on the ground while still maintaining ecological integrity.

It is important that caribou have ‘choices’ for calving and wintering areas on the landscape. With fewer choices, caribou may become more predictable in time and space for their main predators and have difficulty meeting their nutritional requirements, with possible consequences to survival, reproduction, and, ultimately, population persistence. Of the 3 calving areas in the Greater Besa-Prophet Area, the Foothills is most susceptible to anthropogenic alteration and activity because of easier access and current lack of protection. Portions of the Western High Country and North Prophet calving areas fall within either Redfern-Keily or Northern Rocky Mountains Provincial Parks. Currently, each of the caving areas is far from the linear disturbances associated with roads and industry outside of the Muswka-Kechika Management Area. Caribou cow-calf pairs should continue to be ensured choices of non-disturbed routes from calving areas to summer range within the Foothills so that they can form post-calving aggregations. Any disturbance during times of movement or the formation of post-calving aggregations may have direct (increased predation) or indirect (displacement to lower quality summer range) consequences to calf survival. Caribou are especially sensitive to anthropogenic disturbances during the post-calving period (Johnson et al. 2005). Management or industrial activities that alter the distribution of caribou or their main predators during calving and summer should be avoided until they can be evaluated for possible long-term effects on population productivity.

During winter, we determined that there were 2 general patterns of selection for elevations, slopes, and vegetation classes among caribou in the Greater Besa-Prophet Area. These patterns distinguished caribou that resided in the eastern region from those in the more mountainous region. Although these wintering areas are relatively free of anthropogenic disturbance compared to that outside of the Muswka-Kechika Management Area, there is encroachment of linear corridors particularly into the eastern wintering areas of caribou. Assuming the average width for linear corridors that can be observed from aerial photography or satellite imagery is 5 m, there were ~6,000 ha of the Greater Besa-Prophet Area covered by linear features as of December 2003 (Fig. 4). With the development of linear corridors, there is often increased recreational use of all-terrain vehicles and snowmobiles. Linear developments and seismic activity during the winter months in Alberta have been linked to increased predation from wolves that use the corridors to increase encounter rates with prey (James 1999, James and Stuart-Smith 2000). Increasing the cumulative effects of higher energetic costs from increased movement (Murphy and Curatolo 1987), reduced foraging times (Bradshaw et al. 1997), increased risk of predation (James and Stuart-Smith 2000), and loss of functional habitat resulting from anthropogenic disturbance (Dyer et al. 2001, Weclaw and Hudson 2004) is likely to decrease productivity of caribou population in the Greater Besa-Prophet Area. Therefore, as proposals for seismic developments increase, all efforts should be made to minimize the effects of access, especially in the mountainous regions of the Greater Besa-Prophet Area. These cautions are necessary if caribou are to remain in perpetuity in the Greater Besa-Prophet Area, and to avoid the declines in caribou populations that have resulted as a consequence of industrial development in other areas (Dzuz 2001; McLoughlin et al. 2003, Weclaw and Hudson 2004).

We recommend the following to incorporate this research into management decision-making and to follow up with projects that expand on our research findings in the Besa-Prophet:

1) Update the current Besa-Prophet Pre-tenure Plan. The Plan (British Columbia Ministry of Sustainable Resource Management 2004) allows for adaptive management and inclusion of new information. Caribou, as a large-ranging species for which there was little quantified information, were not included in the Plan and now that data are available, the Plan should call attention to critical and important areas for this species of concern. Inclusion of an appendix that provides recommended or suggested ways to minimize impacts on caribou would be helpful to commercial and recreational users of the area. This could be accommodated by adding an appendix of information as was provided for each of the Planning Units in the original Besa-Prophet Pre-tenure Plan Phase I (British Columbia Ministry of Sustainable Resource Management 2002).
2) Monitor movement routes of caribou between wintering and calving sites over multiple years. Determine if animals routinely use similar migration corridors and the same calving area each year.
3) Initiate a study on the ecology of wolverines. We assumed that the primary predators of caribou were grizzly bears and wolves, and underestimated the influence of wolverines on caribou calf survival.
4) Define consequences of range burning. If prescribed burns are enabling increases in elk populations in the Besa-Prophet, there is the potential that with this expanding prey base, wolf numbers will also increase. If so, it is likely that wolves will expand into broader areas and encounter caribou more frequently, potentially playing a more significant role in the population dynamics of caribou.

Additional details of all methodologies, analyses, and results can be found in Dave Gustine's Master of Science thesis at the University of Northern British Columbia:

Gustine, D. D. 2005. Plasticity in selection strategies of woodland caribou (*Rangifer tarandus caribou*) during winter and calving. M.Sc. Natural Resources and Environmental Studies (Biology), University of Northern British Columbia. 197 pp.

The following scientific articles also have been published:

Gustine, D.D., K.L. Parker, R.J. Lay, M.P. Gillingham, and D.C. Heard. 2006. Calf survival of woodland caribou in a multi-predator ecosystem. Wildlife Monographs 165: 1-32.

Gustine, D.D., K.L. Parker, R.J. Lay, M.P. Gillingham, and D.C. Heard. 2006. Interpreting resource selection at different scales for woodland caribou in winter. Journal of Wildlife Management 70: 1601-1614.

Gustine, D.D., K.L. Parker, and D.C. Heard. 2007. Using ultrasound measurements of rump fat to assess nutritional condition of woodland caribou in northern British Columbia, Canada. *In press*. Rangifer.

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Figure 22. Authors Dave Gustine and Kathy Parker, University of Northern British Columbia.

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