Population Status and Mortality of Mountain Caribou in the Southern Purcell Mountains, British Columbia

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ABSTRACT

Population surveys and mortality monitoring for mountain caribou, an ecotype of woodland caribou (*Rangifer tarandus caribou*), were conducted in the southern Purcell Mountains of British Columbia from 1994 to 1998. Results indicated that this subpopulation was declining, with annual growth rates ranging from 0.82 to 0.88. This was a result of low calf recruitment (late-winter ratios of 0.00–0.13 calves per adult) and high adult mortality (mean annual rate = 0.27). Reasons for low recruitment were unknown, but most adult mortality was attributed to predation, particularly by cougars (*Felis concolor*). The difference in mortality rate between sexes was nonsignificant (P = 0.14), but was consistent with increasing bull:cow ratios observed during the study. The southern portion of the study area had more recent cutblocks and fires (i.e., forests ≤40 years), greater road density, and more fragmentation than the northern portion. Caribou mortality was also significantly greater in the south than the north (P = 0.03). This mortality may have been partly due to post-logging changes in the distribution of ungulates favouring edges and early-seral forests, and the predators that were attracted to these ungulates. If current trends continue, the southern Purcell caribou herd will be extirpated within a decade. To address this problem, we recommend that (1) this subpopulation be augmented with animals from other mountain caribou herds; (2) relationships between predation and patterns of forest harvesting be investigated, with harvesting either deferred in some areas or designed to minimize enhancement of other ungulates' forage; and (3) limiting predation on caribou by reducing the number of cougars and alternate prey be investigated.

Key words: caribou, cougar, *Felis concolor*, forest harvesting, mortality, population, predation, Purcell Mountains, *Rangifer tarandus caribou.*

Mountain caribou, an ecotype of woodland caribou (*Rangifer tarandus caribou)*, inhabit the high-snowfall region of southeastern British Columbia, extreme northern Idaho, and extreme northeastern Washington. This ecotype is largely defined by its late-winter diet, consisting almost entirely of arboreal lichens (Stevenson and Hatler 1985). In recent years, intensive research has focused on the population status and ecology of mountain caribou, due to concerns for long-term population viability. Populations have declined over most of the historic range, with many of the remaining subpopulations occurring at low densities in disjunct distributions (Paquet 1997), and threatened by the loss of the old forests on which they depend (Simpson et al. 1997). The provincial population is estimated at about 2,500, distributed in 13 subpopulations, of which about half are markedly below the assumed carrying capacity (Simpson et al. 1997; I. Hatter, BC Environment, unpubl. data). Furthermore, mortality rates for several subpopulations may significantly exceed recruitment (Seip 1992, Compton et al. 1995, Hamilton and Herbison 1998).

The southern Purcell Mountains (Fig. 1) support one of the smaller and more isolated mountain caribou subpopulations. At the southeastern-most and driest limit of current mountain caribou range, this subpopulation occurs with a greater suite of ungulates and predators than in other areas. These include elk (*Cervus elaphus*), moose (*Alces alces*), mountain goats (*Oreamnos americanus*), mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), cougars (*Felis concolor*), lynx (*Lynx canadensis*), bobcats (*L. rufus)*, wolves (*Canis lupus*), coyotes (*Canis latrans*), wolverines (*Gulo gulo*), black bears (*Ursus americanus*), and grizzly bears (*U. arctos*). High rates of woodland caribou mortality have been reported for areas with extensive forestry or high numbers of predators (Bergerud 1983, Seip 1992, Cumming and Beange 1993, Compton et al. 1995, Crete and Desrosier 1995, Cumming and Lavoie 1996). Because most of the southern Purcells are under commercial forestry tenure and support several potential predators,

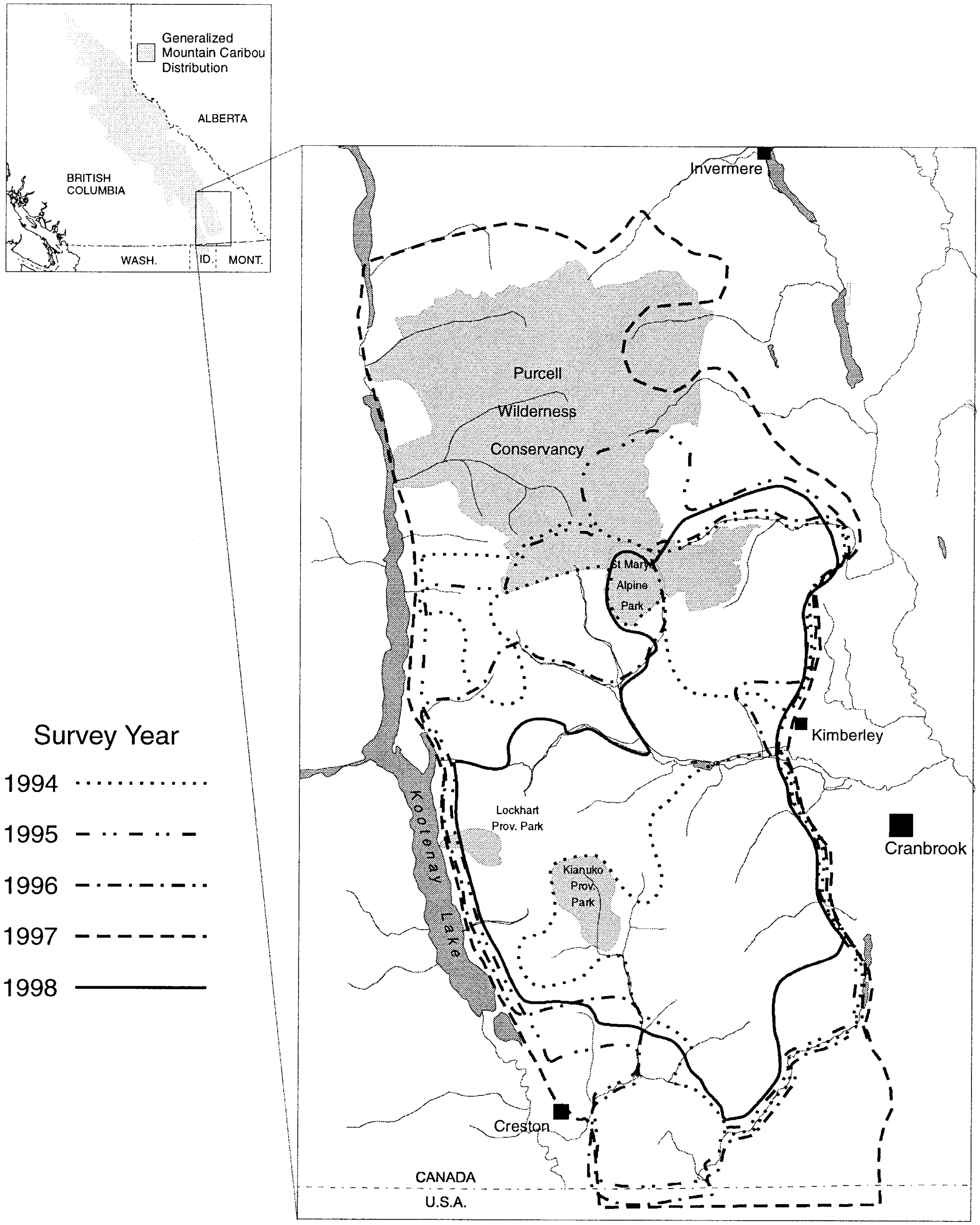

Figure. 1. Late-winter mountain caribou survey areas in the southern Purcell Mountains, British Columbia, 1994–1998.

population trends are of particular concern for this small herd. In this paper, we report results of population surveys and observed rates of mortality among radio-collared caribou. We also test for (1) gender differences in mortality rates, and (2) the potential influence of forest resource development through comparison of 2 zones with greatly differing development intensities. Management implications are discussed.

STUDY AREA

The study area covered about 6,000 km^2 near the south end of the Purcell Mountains, at elevations ranging from 530 to 2,850 m. It fell within the Columbia Mountains and Highlands ecoregion of the Southern Interior Mountains ecoprovince (Luttmerding et al. 1990). Moisture increases from east to west, and from lower to higher elevations. The Alpine Tundra biogeoclimatic zone (AT) occurs above about 1,950 m in the west and 2,100 m in the east, the Engelmann Spruce– Subalpine Fir (ESSF) zone lies at roughly 1,550–1,950 m in the west and 1,600–2,100 m in the east, the Interior Cedar–Hemlock (ICH) exists below about 1,550 m in the west, and the Montane Spruce (MS) occurs below about 1,600 m in the east (Braumandl and Curran 1992). Climax forests are typically Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) in the ESSF, western redcedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) in the ICH, and hybrid white spruce (*Picea glauca* x *engelmannii*) in the MS. Fire-successional stands of lodgepole pine (*Pinus contorta*) are common at all elevations below the AT, Douglas-fir (*Pseudotsuga menziesii*) occurs on some warmer aspects of the ICH and MS, and whitebark pine (*Pinus albicaulis*) and alpine larch (*Larix lyalli*) are common at the ESSF/AT transition. The study area contained 2 distinct zones of caribou activity, separated by the east–west trending St. Mary River Valley (Apps and Kinley 1997). Forestry development varied from nonexistent to intensive.

METHODS

Population Surveys

Adult caribou were captured in March and April of 1993, 1994, and 1997 using a net-gun fired from a helicopter, and were fitted with very high frequency (VHF) or global positioning system (GPS) collars equipped with mortality sensors. Capture efforts were geographically proportional to numbers of animals censused across the known distribution of the southern Purcell population, and samples varied from 8 to 23 animals. Schedules for aerial telemetry monitoring varied among seasons and years, ranging from twice-weekly to monthly. Caribou were surveyed in March or April of 1994 to 1998, with methods consistent with current standards (Resources Inventory Committee 1997). Within the survey area (Fig. 1), all ridges >1,800 m were examined for caribou. A pilot and 3 observers, using a Cessna 182 aircraft, flew along each side of the ridges at the elevation of the forest/subalpine parkland boundary (about 1,800–2,000 m). All caribou tracks were recorded on 1:125,000-scale topographic maps. Upon completion of these fixed-wing flights, each track location was visited with a Bell Jet Ranger II helicopter to search for caribou. The helicopter was equipped with a scanning telemetry receiver to aid in determining whether radio-collared caribou were in the groups observed, and to locate collared caribou that had not otherwise been found.

Of caribou clearly observed from the helicopter, the number of animals, age class (calf versus adult), and gender were recorded. Occasionally, fresh tracks were located but the caribou associated with them were not observed. In such cases, a minimum number of caribou were attributed to the tracks, and were included in the survey results. This estimate was applied only if tracks appeared to have been made the day of the survey, if no tracks could be found exiting the immediate area, and if tracks were separated by more than about 5 km from other areas where caribou were observed. The ratio of the total number of radio-collared caribou known to be present to the number of radio-collared caribou located without using the telemetry equipment was used as a sightability index. The number of caribou observed (collared plus uncollared, and animals plus track-only observations) was multiplied by this index to yield the estimated population size.

When "track-only" observations were included in the survey, all radio-collar frequencies were scanned to ensure that the tracks had not been made by a radio-collared caribou that had not been seen. Caribou located only with the aid of telemetry were included in the data used to calculate age and sex ratios, but were not included in the sum of animals observed. The annual rate of population change (λ) was calculated as the quotient of the estimated populations for that year and the previous year.

Mortality Rates

Upon detection of mortality during monitoring flights, carcasses were located on the ground and causal evidence was collected. This evidence included signs of sickness or starvation, predator tracks, method of kill, carcass disarticulation and caching, and presence of scat. In 2 cases, intact carcasses were removed for necropsy. A cause of death and associated confidence rating was then assigned. In this paper, data on cause of death include only mortalities for which the cause was known or considered almost certain. Annual mortality rates (q) among radio-collared caribou having known fates were calculated on a 1 May to 30 April year. A chi-square test compared differences between males and females, and between the 2 caribou activity areas ($\alpha = 0.05$). Annual survival rates, l, were calculated as $l = 1 - q$.

Habitat Fragmentation

Habitat conditions related to forestry development in the 2 caribou activity zones were quantified using a geographic information system (GIS). The 2 zones were objectively defined by assessing the adaptive kernel utilization distribution (UD) (Worton 1989) of existing telemetry and GPS collar data (T. Kinley, unpubl. data), with all locations temporally independent by ≥1 week. The minimum UD contour (97%) that encompassed all mortality locations was used to define the boundary of each zone. Forest inventory (B.C. Ministry of Forests 1995) and Terrain Resource Information Mapping (B.C. Ministry of Environment, Lands and Parks 1992) data were then used to determine the proportional occurrence of several attributes in each zone. These attributes included recent human-caused and natural disturbances (forests ≤40 years old), and road density (km/km^2). On a Boolean map of disturbed habitats (forests ≤40 years vs. those >40 years), the average centre versus neighbours (CVN) fragmentation index (Murphy 1985) was also determined. This index is based on the number of 1-ha cells different from the centre cell in a 7 x 7 moving matrix.

RESULTS

The estimated population declined from a high of 78 in 1995 to a low of 47 in 1998 (Table 1), which equates to rates of population change of 0.82–0.88 (mean λ = 0.85, standard deviation [SD] = 0.03). Calf recruitment varied annually from 0.00 to 0.13 calves/adult (Table 2), with a mean of 0.05 (SD = 0.06). Sex ratios varied from slightly more females between 1994 and 1996, to far more males in 1997 and 1998 (Table 2). Mortality occurred almost entirely in summer and fall, mostly due to cougars and other predators (Table 3). The difference in mortality rate between sexes (Table 4) was nonsignificant (χ^2_{OBS} = 2.20, df = 1, P = 0.14). Mortality was greater in the southern zone (χ^2_{OBS} = 3.67, df = 1, P = 0.03). Compared with the northern zone, the south was associated with a greater road density, a higher proportion of disturbed habitats, and a higher level of fragmentation (Table 5).

Table 1. Annual mountain caribou population and growth rates (λ), southern Purcell Mountains, British Columbia, 1994–1998.

Year	No. of observed	Collars present/ Collars observed	Population estimate	λ
1994	74	1.00	74[a]	--[b]
1995	78	1.00	78	--[b]
1996	56	1.14	64	0.82
1997	37	1.50	56	0.88
1998	27	1.75	47	0.84

[a] Incomplete census.
[b] Not possible to calculate λ because previous year's data unavailable or incomplete.

DISCUSSION

Survey areas shifted slightly each year from 1994 through 1998. These changes are unlikely to have caused a difference in results between years from 1995 to 1998 because caribou were not detected outside of the smallest survey area in any of these years. However, the 1994 survey omitted some areas in which a minor percentage of the caribou were observed in later years; therefore, the 1994 population estimate may be low.

We expected the adult survivorship rate, *l,* would be lower than the rate of change in the population, λ, because λ included calf recruitment. However, the difference between the two (0.12) was not consistent with the mean calf:adult ratio of 0.05. While a portion of the population was not directly observed, the number of calves in it was unlikely sufficient to account for this discrepancy. Similarly, immigration or misclassification were unlikely to have made up the difference. Two more realistic possibilities are (1) that sightability was higher than estimated during the latter part of the study, resulting in erroneously high population estimates in later years, or (2) the mortality rate among collared caribou was higher than among uncollared caribou.

Overall, our results suggest that the population was decreasing rapidly, due to both low calf recruitment and high adult mortality. An extension of the current λ value results in

Table 2. Late-winter mountain caribou sex and calf ratios based on uncorrected census data, southern Purcell Mountains, British Columbia, 1994–1998.

Year	Bulls	Cows	Unclassified adults	Total adults[a]	Calves	Bulls/Cow	Calves/Adult
1994	17	20	32	69	5	0.85	0.09
1995	27	39	11	77	1	0.69	0.01
1996	18	29	2	49	2	0.62	0.04
1997	21	11	8	32	4	1.91	0.13
1998	15	2	1	18	0	7.50	0.00

[a] Numbers do not match those of Table 1, because "track-only" observations are deleted in Table 2, and some animals seen and classified immediately after or before the survey are included in Table 2.

Table 3. Sources of mortality among radio-collared mountain caribou, southern Purcell Mountains, British Columbia, 1993–1997.

Cause	Jan–May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Cougar predation	0	1	0	3	0	2	0	0	6
Bear predation	0	0	0	1	0	1	0	0	2
Wolverine predation	0	0	0	0	0	0	0	1	1
Vehicle collision	0	0	0	0	0	0	1	0	1
Illegal shooting	0	0	0	0	1	0	0	0	1
Fall in snow well	0	1	0	0	0	0	0	0	1
Unknown	0	1	0	2	0	0	0	0	3
Total	0	3	0	6	1	3	1	1	15

a population estimate of <10 animals in 10 years. This calculation does not account for the aging of the current population, the apparently decreasing proportion of females, the potential inability to find mates at low population densities, or inbreeding depression. Thus, a continuation of the current trend would almost certainly cause extirpation within a decade. No substantial data were available to interpret calf mortality causes, but adult mortality appeared to be largely due to predation, with cougars accounting for half of the known-cause mortalities. Almost all deaths occurred from June through October, peaking in August. High summer mortality corresponds with the results of several other populations of this ecotype in which predation was a leading cause of mortality (Seip 1992, Compton et al. 1995). This result is also consistent with data from 2 caribou that had emigrated to the Purcells from Idaho prior to the start of this study. The exact date of death was not known for these 2 animals, but was between May and July of 1991. Similarly, 2 caribou immigrating to the Purcells from Washington in summer 1996 died that season (J. Almack, Wash. Dep. Fish. and Wildl., pers. comm.).

The high mortality rates observed in this study may be attributable to several causes. Forest harvesting continually increases road density, area of regenerating cutblocks, and levels of habitat fragmentation, all of which were especially pronounced in the southern part of the study area. These effects may have changed the distribution of ungulates showing affinity to edges or early-seral stands (elk, deer, and moose), allowing them to shift into landscapes that, under a natural disturbance regime, would have been dominated by nearly contiguous tracts of old-growth forest and consequently of less value to those species. Thus, cougars and other predators may have expanded into landscapes where they would otherwise not be expected in response to a change in prey distribution. Simultaneously, caribou may have been forced into smaller habitat patches, with their movements being more predictable, thus increasing predator efficiency. A shift in cougar distribution may have been exacerbated by increased cougar populations. Although no firm cougar population estimates were available, the

Table 4. Annual mortality (q) of adult mountain caribou, southern Purcell Mountains, British Columbia, 1993–1998.

Year	Deaths 1 May to 30 April[a]					q
	Male	Female	North	South	Total	
1993/94	0/2	5/7	0/0	5/9	5/9	0.56
1994/95	1/5	2/9	0/3	3/11	3/14	0.21
1995/96	0/3	1/7	0/3	1/7	1/10	0.10
1996/97	0/2	2/6	1/3	1/5	2/8	0.25
1997/98	2/8	2/7	0/5	4/10	4/15	0.27
Mean	0.15	0.33	0.07	0.33	0.27	0.27

[a] Includes collars malfunctioning after the normal "mortality season" indicated by Table 3.

Table 5. Fragmentation measures in areas used by mountain caribou, southern Purcell Mountains, British Columbia.

Area	Forest ≥ 20 years (%)	Forest 21–40 years (%)	Total forest ≥ 40 years (%)	Road density (km/km^2)	Fragmentation Index (CVN)[a]
North of St. Mary River	1	6	7	0.1	3.2
South of St. Mary River	13	10	23	1.0	8.1

[a] CVN = centre versus neighbours.

Ministry of Environment, Lands and Parks managed cougar harvest on the assumption that cougar numbers increased substantially in southeastern British Columbia through the 1990s, with regulations liberalized in the mid- and late 1990s. Furthermore, a high density of open roads may have increased the vulnerability of caribou to illegal harvest, vehicle collisions, and displacement. Although the influence of forestry development on mortality rate is hypothetical, the much higher rate of mortality observed in the more heavily developed portion of the study area is strongly suggestive; this mechanism has been proposed for another ecotype of woodland caribou by Cumming and Lavoie (1996). Simpson et al. (1994) noted that mountain caribou are abundant only in areas with 60% old-growth habitat. This finding might not always be related to habitat-mediated predation, but is at least consistent with the hypothesis.

Research may have contributed to the high mortality in the southern Purcells. For example, collared caribou may have been more obvious to predators either because of the radio-collars or the circling aircraft, or may have suffered long-term effects of capture myopathy. However, the number of dead collared animals could not account for the rate of population decrease; therefore, this explanation appears to only partially account for the observed pattern, if at all.

Trends in sex ratios are unclear. Although nonsignificant, the difference in mortality rates between males and females suggests that mortality may have been higher among females. Such a difference would be more consistent with the apparent shift in sex ratios from the first 3 years of surveys to the last 2 years. On the other hand, the degree of the apparent shift in population sex ratios was far greater than any observed mortality differences. Furthermore, small sampling errors in observations of mortality rates or in the true sex ratios among unclassified adults would have resulted in large differences in calculated proportions. A final confounding factor is that males and females might have been unequally sighted during the surveys. The 1997 survey occurred in a year of exceptionally heavy snowfall, while the 1998 census was so late that the snowpack did not support their weight. In both cases, cows and calves, having shorter legs, may have been more inclined to move downslope to the shelter of the forest where they would have been less visible to observers in aircraft. In both years, all of those collared caribou that were not observed in the census were females, which supports this possibility. Coincidentally, censuses in the nearby central Selkirk Mountains population indicated a decreasing proportion of females from 1997 to 1998 (Hamilton and Herbison 1998). This indication of a decrease in the proportion of females in the southern Purcells among such a small population warrants further investigation.

MANAGEMENT IMPLICATIONS

The data indicate that: (1) the southern Purcell caribou population declined; (2) female numbers in particular appeared to decline; (3) very high adult mortality contributed to this; (4) cougars and other predators appeared to be the major source of mortality; (5) mortality was higher in the area with greater forestry development; and (6) a continuation of the observed trend would result in extirpation within a decade.

Based on these conclusions, the following management actions are recommended:

1. Translocate mountain caribou from other subpopulations to the southern Purcells. If the Purcell herd is not augmented soon, its probability of extirpation is very high. The short-term goals of translocation would be to (a) allow the augmented population to "ride out" this potentially short-term peak in mortality rate, (b) provide more time to determine reasons for the high mortality, and (c) make the herd less susceptible to the random occurrences that influence small populations. Translocation met with little success in the southern Selkirks in past years (Compton et al. 1995), but in the most recent augmentation there, survivorship was much higher (J. Almack, Wash. Dep. Fish and Wildl., pers. comm.). Preliminary data indicate that the mortality rate in the Purcells was much lower in 1998–99 than previously (T. Kinley, unpubl. data). Furthermore, the southern Purcells offer a large area of unoccupied suitable habitat (Apps and Kinley 1997), much within provincial parks. Although the success of augmentation is unknown, we submit that the potential to reestablish a self-sustaining caribou subpopulation in the southern Purcells is worth the risk of removing relatively few animals from source subpopulations.
2. Immediately address the potential link between forestry development and mortality. Data in this paper are consistent with a pattern of high mortality in areas of heavy forest harvesting. Current research into connections between habitat fragmentation, alternate prey species, and mortality in the Selkirk Mountains should be strongly supported. Until this link is better understood, forestry development should be deferred across large areas of caribou habitat. Failing this, new forestry prescriptions should aim to minimize habitat enhancement for other ungulates.
3. Institute more detailed tracking of cougar population levels; then, if necessary, further reduce local populations of cougars and alternate prey through changes to hunting regulations. This recommendation must be approached cautiously, as it is unclear whether observed kills were caused by one or many cougars, whether a moderate increase in the harvest of adult male cougars would decrease the cougar population, or whether moderate reductions in the numbers of other ungulates sharing caribou range

would markedly influence the attraction of cougars to those areas. Such steps will only be worthwhile if a long-term commitment is made to research and to address the potential link between habitat alteration and mortality.

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