

Cumulative Effects of Habitat Change and Backcountry Recreation on Mountain Caribou in the Central Selkirk Mountains



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Executive Summary

We used a cumulative effects analysis to examine the effects of logging and/or burning and commercial backcountry ski use on mountain caribou habitat and habitat use in the Central Selkirk Mountains.

We used forest inventory databases to infer logging and/or burning activity in caribou range during each decade 1960-2000. Skier-runs were summarized by month-year within zones defined by Canadian Mountain Holidays (CMH) for their Galena and Kootenay tenure areas. We also examined snowmobile use by interviewing users in Nakusp and Trout Lake. Areas and linear features (*i.e.*, logging roads) used by snowmobilers were mapped and classified according to estimated use.

Industrial forestry tenures cover 81% of the range of the Central Selkirks mountain caribou. Logging and/or burning disturbed >340 km² within the 6090 km² caribou range between 1960 and 2000. Caribou used these areas less than expected during the late-winter season, based on telemetry locations collected during 1992-2001. There was little or no net loss of *high* and *very high-suitability* habitat in the caribou range because lower quality habitats were recruited into higher quality habitats as forests aged from 1960 to 2000; however, this was partly an artefact of the forest age class breaks used in the suitability model.

Some snowmobiling areas were located in important caribou habitat areas, as indicated by a proposed forestry zonation strategy for mountain caribou. There was no evidence that caribou used these areas less often than expected, based on univariate tests of our limited data.

Commercial backcountry recreation tenures covered >50% of the range of the Central Selkirk mountain caribou subpopulation. Some of these areas were coincident with snowmobiling areas, and with areas that had been disturbed previously by logging and/or burning activities.

A multiple logistic regression of caribou habitat selection within CMH's Galena and Kootenay tenures suggested that caribou in early winter were found on gentler slopes and in habitats dominated by later structural stages (older forests), compared to random locations. There was also evidence that caribou use was lower in ski zones within CMH tenures in months and years when ski use was high. Caribou locations were found in areas of shallower snow than random locations during the early-winter season.

In late winter, caribou telemetry locations were found at higher elevations, on gentler slopes, in habitats dominated by later structural stages (older forests), and in ESSF proportionally more often than ESSF parkland or ICH habitats, compared to random locations. There was also evidence that caribou use was lower in ski zones within CMH tenures in months and years when ski use was high. Caribou locations were found in areas of deeper snow than random locations during the late-winter season.

Neither the early- or late-winter models with the most support included ski use, suggesting that evidence for a relationship between caribou habitat use and ski use was relatively weak. In addition, the inverse correlation between caribou use and ski use might be explained by avoidance of caribou by skiers, or the result might have been due to limitations of the source data.

This project represented one of the first attempts to address the effects of mechanized backcountry recreation (particularly heli-sking) on caribou habitat use. The results should be considered preliminary and similar hypotheses should be tested in other areas. Management actions to address habitat loss and to reduce encounters by recreationalists should continue while data from other areas are examined.

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Introduction

The Mountain Caribou Technical Advisory Committee (MCTAC; 2002) identified 3 primary threats contributing the decline of mountain caribou populations in British Columbia: 1) habitat loss and fragmentation; 2) increased human access and disturbance; and 3) alteration of predator-prey relationships.

With respect to the Central Selkirk mountain caribou subpopulation (Figure 1), recent work has focussed on halting habitat loss in high suitability caribou habitat. This has led to a landscape zonation strategy that has been agreed to in Tree Farm License (TFL) 23 (Pope & Talbot Ltd.) and has been proposed for the remaining range of the caribou subpopulation in the Arrow and Kootenay Lake forest districts (Hamilton and Wilson 2003). The zonation strategy protects areas of high-suitability caribou habitat and known use from forest harvesting while restricting harvest in other high and medium suitability caribou habitats to stand-by-stand prescriptions consistent with the retention of important habitat attributes.

Concurrently, the commercial backcountry heli-skiing and snowcat skiing industry has developed “best practices” for operating in caribou habitat. The logical next step is to examine data related to both these activities as part of an integrated analysis, and to integrate management efforts to maximize the effectiveness of actions taken to reverse the decline of mountain caribou populations.

This project focussed on integrating information related to caribou habitat and habitat use with available information on human access and disturbance during the critical early and late-winter seasons. The goal of the project was to identify areas within the range of the Central Selkirk mountain caribou subpopulation where coincident land uses might be affecting caribou interactively, and where the highest-priority conservation efforts should be directed.

Examining the effects of a number of factors on the habitat-use characteristics of mountain caribou constitutes a “cumulative effects analysis.” Under this general term fall a number of techniques, including spatial analysis using geographic information systems (GIS) and modelling (Council on Environmental Quality 1997). We used both of these techniques to:

- Investigate recent changes to caribou habitat caused by industrial forestry
- Investigate the spatial relationship between backcountry recreation and caribou habitat use
- Model the simultaneous effects of habitat and commercial heli-skiing activities on caribou habitat use within the range of the Central Selkirk mountain caribou subpopulation
- Provide management recommendations to integrate land uses in mountain caribou habitat

Methods

Study Area

The study area covered 6 090 km² and was located within the North Columbia Mountains ecoregion and the Central Columbia Mountains and Northern Kootenay Mountains ecosections (Figure 1). The area is characterized by steeply sloping mountainous terrain dominated by mature forest within the Interior Cedar-Hemlock (ICH), and Engelmann spruce-Subalpine fir (ESSF) biogeoclimatic zones. The Selkirk Wet Cold Engelmann Spruce-Subalpine Fir variant (ESSF wc4) and Selkirk Wet Mild Engelmann Spruce-Subalpine Fir variant (ESSFwm) dominate the mid to upper elevation forest zone. Mid to lower slope forests include the Interior Cedar-Hemlock moist warm variant 1 (ICHmw1), Interior Cedar-Hemlock moist warm variant 2 (ICHmw2), Interior Cedar-Hemlock moist warm variant 3 (ICHmw3) and the Interior Cedar-Hemlock wet cool variant (ICHwk1). Alpine tundra (AT) dominates upper elevations.

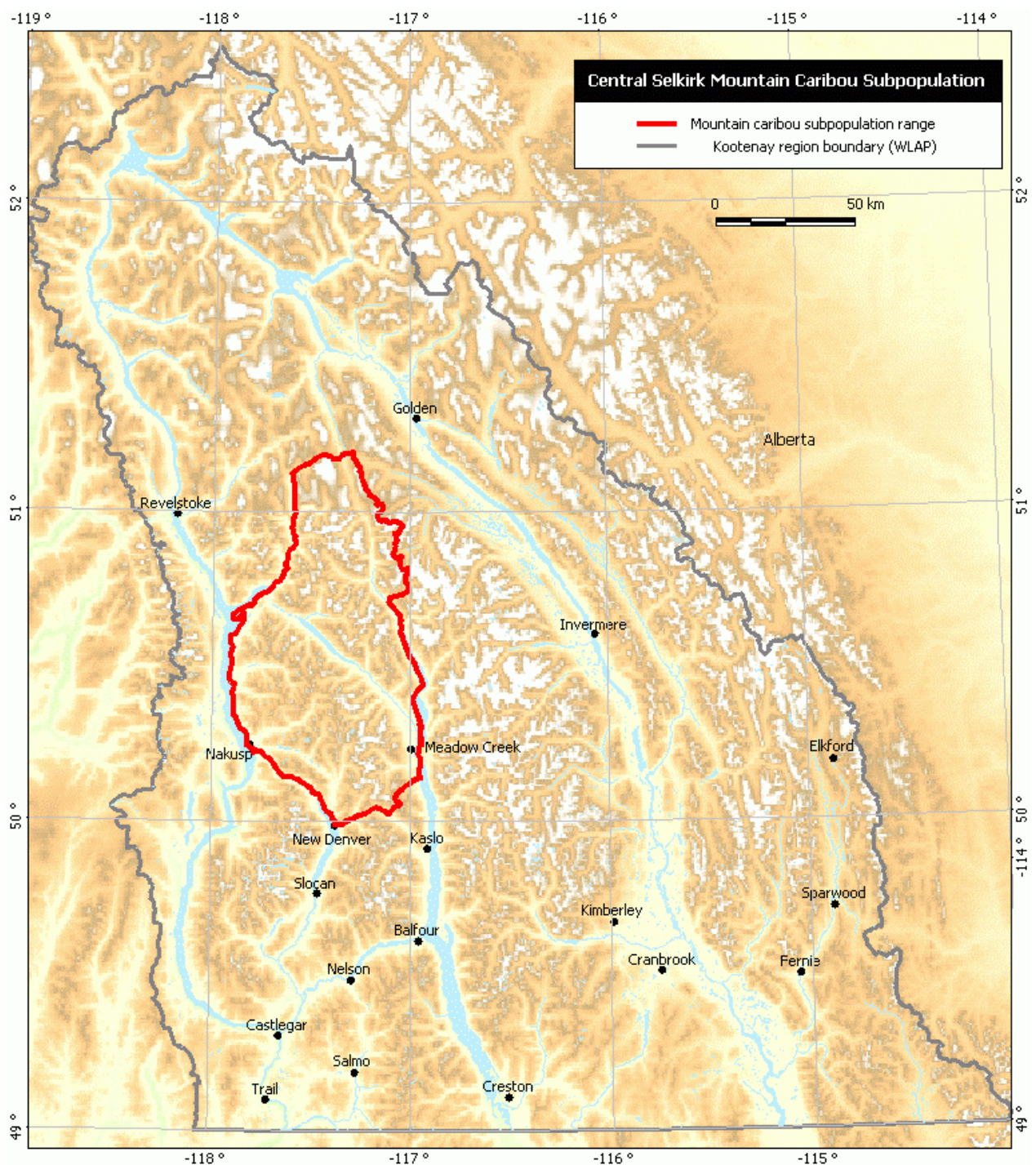


Figure 1. Range of the Central Selkirk mountain caribou subpopulation within the Kootenay region, BC.

Caribou Telemetry Data

The project was based on caribou location data collected during 1992-2002 during inventory projects related to the Central Selkirk mountain caribou subpopulation (Hamilton et al. 2001, Hamilton and Wilson 2002). Telemetry flights were conducted generally once per month, resulting in 449 early winter and 519 late winter telemetry locations collected from 36 VHF radio-collared mountain caribou.

Caribou capture locations were well distributed and caribou ranged widely (lifetime home ranges of males $445 \pm 83 \text{ km}^2$; females $330 \pm 47 \text{ km}^2$; Hamilton et al. 2001). Only caribou occupying the Duncan portion of the project area were monitored from 1992-1995.

Caribou Habitat and Effects of Industrial Forestry

We examined recent changes in high-suitability caribou habitat by examining the history of industrial forestry activity within the range of the Central Selkirk mountain caribou subpopulation. This involved estimating the stand stage of forest cover polygons in 1960, 1970, 1980, 1990 and 2000 based on information contained in forest inventory databases from the Arrow and Kootenay Lake Forest Districts as well as TFL 23. Because much of the information recorded in databases is estimated from photo-interpretation, this reconstruction was considered coarse.

The forest inventory database is an estimate of the state of the forest at one point in time that is subsequently updated as blocks are harvested. As a result, the age profile of blocks before a logging or natural disturbance event is unknown. We assumed that blocks prior to disturbance consisted of mature forest stands. All fires were assumed to be stand initiating, that is, “processes that largely terminate the existing forest stand and initiate secondary succession in order to produce a new stand.” (Province of BC 1995).

A number of inconsistencies were noted in the forest inventory databases that made it impossible to reconstruct the age of some forested stands. This included forest cover polygons with either missing or conflicting disturbance data. These polygons were excluded from the analysis.

The forest age information for each time period was merged with the Central Selkirk mountain caribou habitat model (Hamilton and Wilson 2003) by assigning structural stages (RIC 1998, Hamilton and Wilson 2003) according to forest age, resulting in maps estimating the suitability of caribou habitat at the end of each decade from 1960 to 2000.

Backcountry Recreation Use

Skier-runs data were summarized by month and year 1992-3 to 2001-2 for CMH’s Galena and Kootenay tenure areas. Activity within these tenures represents the majority of commercial backcountry recreation in areas of occupied caribou range. No data were available on ski-use in other tenures or by non-commercial backcountry skiers.

Snowmobiling data were collected through interviews with local users in the Nakusp and Trout Lake areas. Snowmobile use was classified as either a linear feature (*i.e.*, logging road) or area-specific, and use was categorized as either daily or weekly. A 100-m buffer was applied to linear features to estimate the area subject to disturbance by snowmobile travel. This represented a coarse estimate of snowmobile use because both area and use vary depending on a number of factors including weather, snow conditions, day of week, etc.

Assembling historical data related to snowmobile use was impractical, but evidence suggests that the sport has increased greatly in popularity over the past 15 years (sales of new snowmobiles increased 51% between 1988 and 1998; Canadian Council of Snowmobile Organizations, unpublished data). In addition, the technology associated with newer machines has greatly increased performance and the ability to access previously inaccessible terrain. Access has also increased with the continuing construction of logging roads (Kinley 2003).

Cumulative Effects Analysis

The following data were assembled for the cumulative effects analysis:

1. Telemetry point data by early (25 October-15 January) and late winter (16 January-12 May) seasons.
2. Composite (*i.e.*, pooled among all radio-collared animals) early and late winter kernel home range contours (95, 75, 50 and 25%). Kernel home ranges interpolate the density of telemetry points and

generate contours that indicate levels of habitat use. For example, the 25% contour indicates the area corresponding to densest 25% of caribou use, according to telemetry points (Worton 1989).

3. Map of commercial backcountry recreation tenures (current as of 2001, winter recreation only; data provided by BC Ministry of Sustainable Resource Management and Canadian Mountain Holidays).
4. Skier-runs by month and year by geographic “ski zones” for CMH Galena and Kootenay tenure areas.
5. Proposed zonation strategy for the range of the Central Selkirk mountain caribou subpopulation (Hamilton and Wilson 2003).
6. Areas of frequent snowmobile use.

The analysis consisted first of a series of spatial overlays to illustrate the coincidence of caribou habitat use, commercial recreation tenures, and areas frequented by snowmobiles. We also examined the distribution of telemetry locations with respect to individual factors with chi-square tests.

Second, we conducted a statistical analysis to examine the relationship of landscape factors simultaneously on the habitat-use characteristics of mountain caribou. We used a multiple logistic regression analysis to model the relationship between the binary dependent variable (caribou telemetry locations and an equal number of random locations within the composite 95% home range contour of all telemetry locations) and a number of independent factors:

1. Ski-use: number of skier-runs by month-year and ski zone (standardized) within CMH’s Galena and Kootenay tenure areas (Figure 2).
2. Snowmobile use: coded as high, low or nil use. This variable was examined with univariate statistics but was dropped from the cumulative effects analysis because data were insufficient to relate snowmobile use to caribou movements with confidence.
3. Terrain: elevation, aspect and slope. Elevation and slope were standardized and aspect was coded as 3 dummy variables relative to north.
4. Habitat: forest type and structural stage. Forests were classified as Engelmann spruce subalpine fir parkland (ESSFp; high elevation alpine transition), ESSF and interior cedar-hemlock (ICH; Meidinger and Pojar 1991). Forest types were coded as dummy variables relative to ICH. Structural stage was used to indicate the history of disturbance of the forest.
5. Snow: mean monthly snow depths recorded at snow monitoring stations located near tree-line in the Galena and Kootenay tenures (Appendix I). This was used as a broad index of within- and between- year trends in snow depths, which is known to influence the habitat use characteristics of caribou (Hamilton et al. 2002, Hamilton and Wilson 2003).

Analyses were stratified by early and late winter seasons of caribou use. Overlays and univariate statistics examined all data within the Central Selkirk caribou range. The regression analysis was restricted to the boundaries of CMH’s Galena and Kootenay tenure areas because accurate skier-use data were available only for these areas.

The most parsimonious models were selected among biologically plausible alternatives based on the information-theoretic approach, using the adjusted Akaike’s Information Criterion for small samples (AICc; Burnham and Anderson 1998). Models <2 AICc from the top model were considered to have support. The sign associated with coefficients for each factor was used to indicate selection or avoidance.

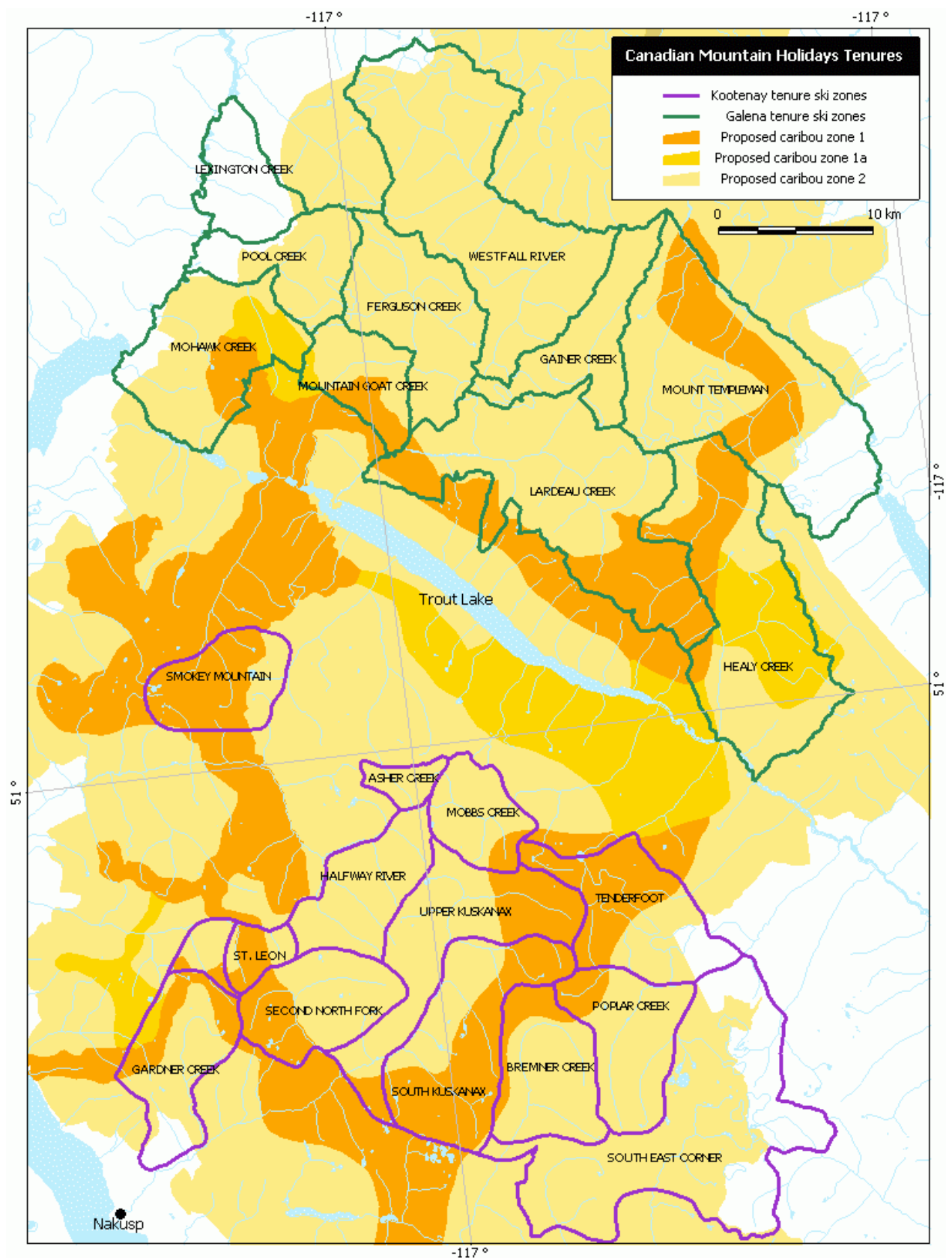


Figure 2. Canadian Mountain Holidays commercial recreation tenures and associated ski zones for which skier-runs were available for month-years while mountain caribou in the Central Selkirk mountains were radio-collared.

Results

Caribou Habitat and Effects of Industrial Forestry

Logging and/or fire resulted in disturbance to $>340 \text{ km}^2$ (8.4%) of forested habitat within the range of the Central Selkirk mountain caribou subpopulation 1960-2000 (Figure 3). The rate of loss accelerated in each decade until 1990 and then declined relative to the 1980-1990 period. The highest rates of logging and/or burning over the entire study area were associated with the highest rates of habitat loss within the proposed Zone 1 and Zone 1a areas (Figure 4). Relatively large areas were logged or burned in southern portions of the proposed caribou Zone 1 and within Old Seral Patches in the Duncan River valley (Figure 5).

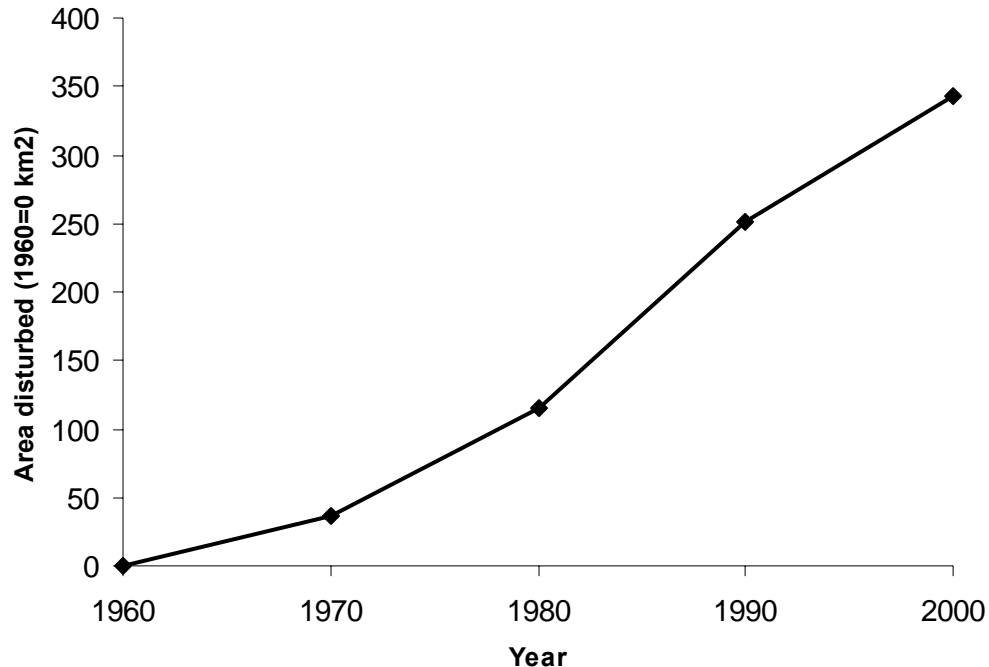


Figure 3. Cumulative area disturbed by logging and/or fire within the range of the Central Selkirk mountain caribou subpopulation, 1960-2000.

With respect to caribou habitat suitability, logging and/or fire disturbance impacts resulted in a negligible aspatial effect (Figure 6), based on the caribou habitat suitability model. These impacts were relatively small in comparison to the overall range of the caribou subpopulation in the Central Selkirks, and declines in habitat suitability were balanced by recruitment of high-suitability habitat as the forests aged during the period from 1960 to 2000. Among early winter habitats, 231 km^2 that were classified as *very low-moderate* habitats in 1960 were recruited into *high-very high* suitability categories by 2000. The same was true of 61 km^2 of late winter habitats.

Backcountry Recreation Use

The number of skier-runs in CMH's Galena and Kootenay tenures areas was 85% higher in 2001-2 than in 1992-3 (Figure 7). The spatial distribution of skier-runs differed by month and year but the highest use was generally concentrated near their lodges; that is, in the western portion of the Galena tenure and southwestern portion of the Kootenay tenure.

We identified 344 km of trails and 324 km^2 of areas frequented by snowmobilers on either a daily or weekly basis (

Table 1).

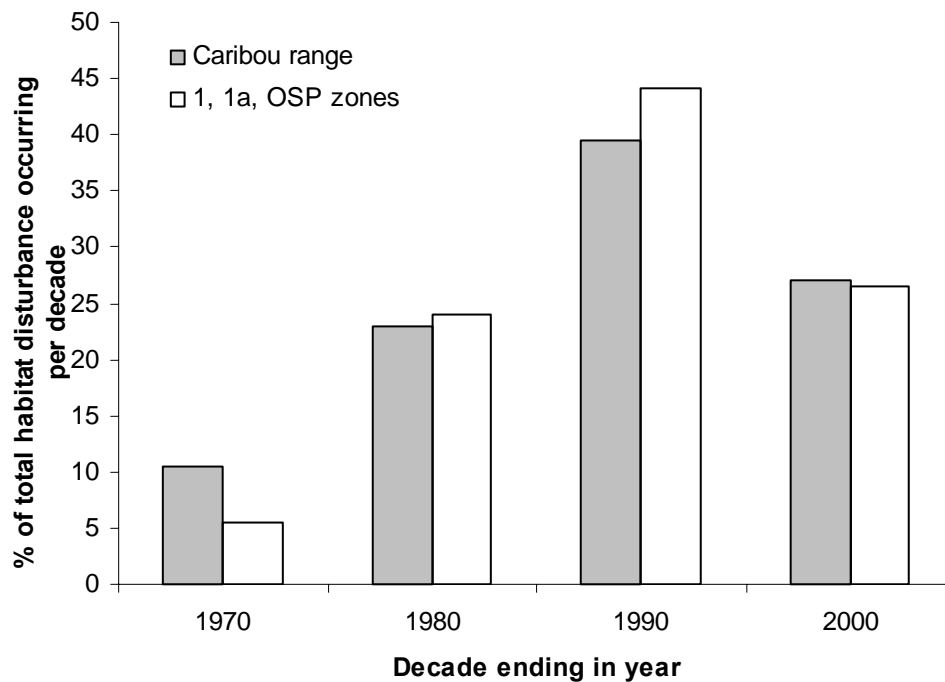


Figure 4. Decade in which habitat was disturbed, within the range of the Central Selkirk mountain caribou subpopulation and within proposed caribou zones 1, 1a and Old seral patches.

Cumulative Effects Analysis

Of all telemetry locations recorded within the range of the Central Selkirk mountain caribou subpopulation, 7.1% of early winter and 3.8% of late winter locations were in areas within the caribou range disturbed by logging and/or burning between 1960 and 2000. Use by caribou of these areas was not significantly less than expected during early winter but was so during late winter (early winter: $\chi^2 = 0.6$, $P > 0.9$; late winter: $\chi^2 = 8.9$, $P < 0.003$).

Industrial forestry tenures cover 81% of the total range (6 090 km²) of the Central Selkirk subpopulation. The largest tenures include TFL 23 (Pope & Talbot Ltd.; 1,815 km² overlap with the caribou range) and Slocan Forest Products Limited (1,598 km²). Other significant tenure holders include Meadow Creek Cedar Company (843 km²) and BC Timber Sales (592 km²). Fifty-three percent of early winter and 45% of late-winter telemetry locations were located within TFL 23.

Commercial backcountry recreation tenures covered 52% of the total range of the Central Selkirk mountain caribou subpopulation (Figure 8, Figure 9). One hundred twenty-two (27%) early winter telemetry locations and 250 (48%) late winter locations were located within commercial recreation tenures.

Snowmobiling areas that received daily use were located along Silvercup Ridge above Trout Lake, within the 75% and 95% early and late winter home range contours of mountain caribou, and also within the commercial backcountry recreation tenures of CMH (Galena) and Great Northern Snow-cat Skiing (Figure 8, Figure 9).

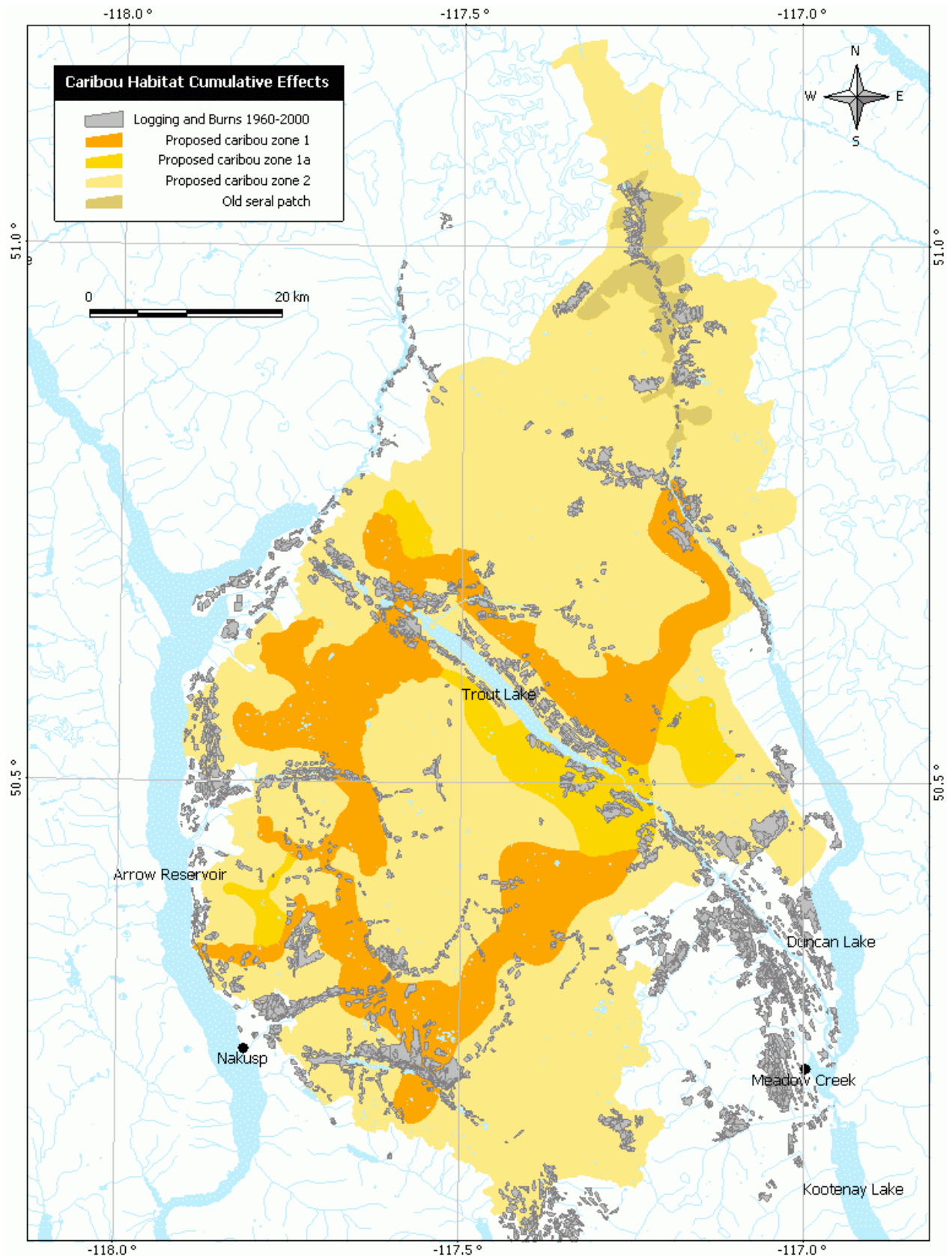


Figure 5. Logging and fire history 1960-2000 within proposed caribou zones, based on the forest inventory database.

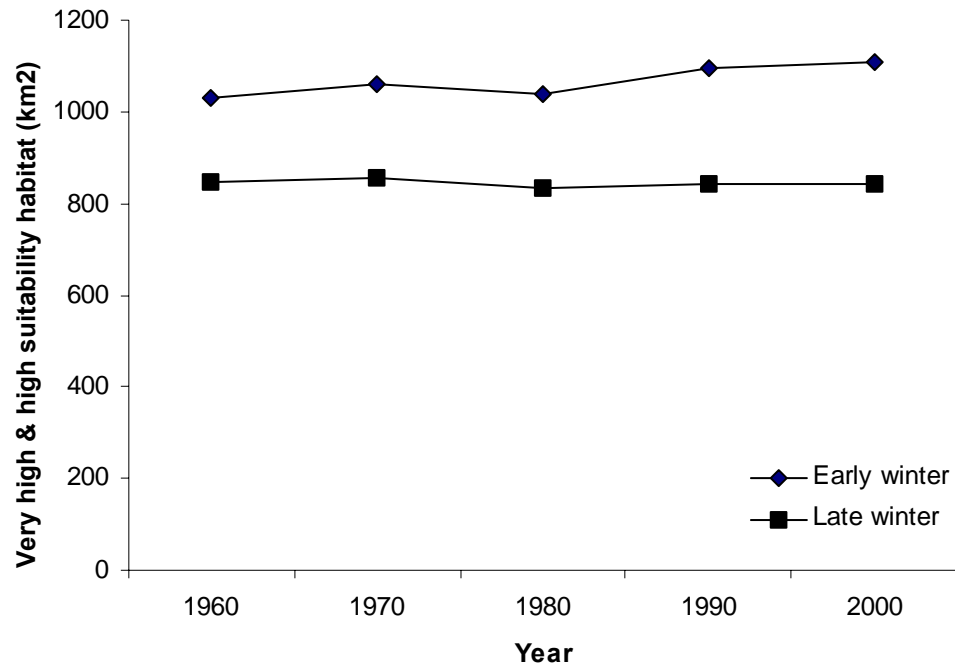


Figure 6. Area of very high and high-suitability habitat for mountain caribou within the range of the Central Selkirk subpopulation, 1960-2000.

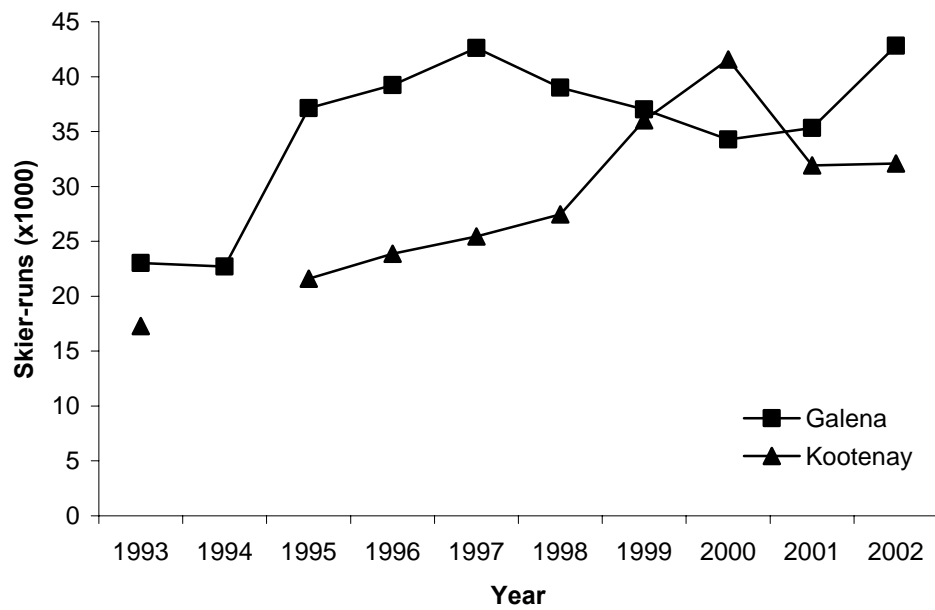


Figure 7. Skier-runs recorded within Canadian Mountain Holidays' Galena and Kootenay tenures, 1992-3 to 2001-2.

Table 1. Trails (roads), areas, and frequency of use by snowmobilers within the range of the Central Selkirk mountain caribou subpopulation, based on user interviews.

Feature	Size	Frequency of Use	Notes
Area	191 km ²	Daily	96 km ² commonly used after 31 March
	133 km ²	Weekly	
Trails	104 km	Daily	
	240 km	Weekly	

Snowmobiling areas that received daily use were also located within Zone 1 areas, according to the proposed caribou habitat zonation strategy (Figure 10). Significant portions of CMH Galena (21%), CMH Kootenay (24%) and Great Northern Snow-cat Skiing (50%) tenures are located within Zone 1 habitat areas. There was no evidence that fewer telemetry locations than expected were located within snowmobiling areas; in fact, more telemetry locations were found within snowmobiling areas than expected (early winter: $\chi^2 = 17.0$, $P < 0.001$; late winter: $\chi^2 = 20.3$, $P < 0.001$).

Modelling caribou habitat use (based on telemetry versus random locations) against terrain, habitat, skier-use and snow factors results in similar models for both early and late-winter seasons (Table 2). The most parsimonious model for early winter included slope and structural stage; however, the model that included ski-use was almost equally well supported (based on Akaike weights). The model that included slope, structural stage and snow depth was also supported (<2 AICc from the top model). In early winter, caribou telemetry locations were found on gentler slopes and in habitats dominated by later structural stages (older forests), compared to random locations. There was also evidence that caribou use of ski zones within CMH tenures was lower in months and years when ski use was high. The relationship with snow depth suggested that caribou locations were found in areas of shallower snow than random locations during the early-winter season.

Logistic regression equations (standardized continuous variables) for the supported models for early winter were:

$$\text{Logit}(Y) = -1.99 - 0.98(\text{slope}) + 0.37(\text{structural stage})$$

$$\text{Logit}(Y) = -2.12 - 1.01(\text{slope}) + 0.38(\text{structural stage}) - 0.38(\text{ski use})$$

$$\text{Logit}(Y) = -2.38 - 1.04(\text{slope}) + 0.40(\text{structural stage}) - 0.33(\text{snow depth})$$

where Y was the dichotomous dependent variable *location* (telemetry or random).

The most parsimonious model for late winter included elevation, slope, structural stage and habitat type (ESSFp and ESSF relative to ICH). However, models that also included ski-use and/or snow depth were also supported (<2 AICc from the top model). In late winter, caribou telemetry locations were found at higher elevations, on gentler slopes, in habitats dominated by later structural stages (older forests), and in ESSF more often than ESSFp or ICH, compared to random locations. There was also evidence that caribou use of ski zones within CMH tenures was lower in month and years when ski use was high. The relationship with snow depth suggested that caribou locations were found in areas of deeper snow than random locations during the late-winter season.

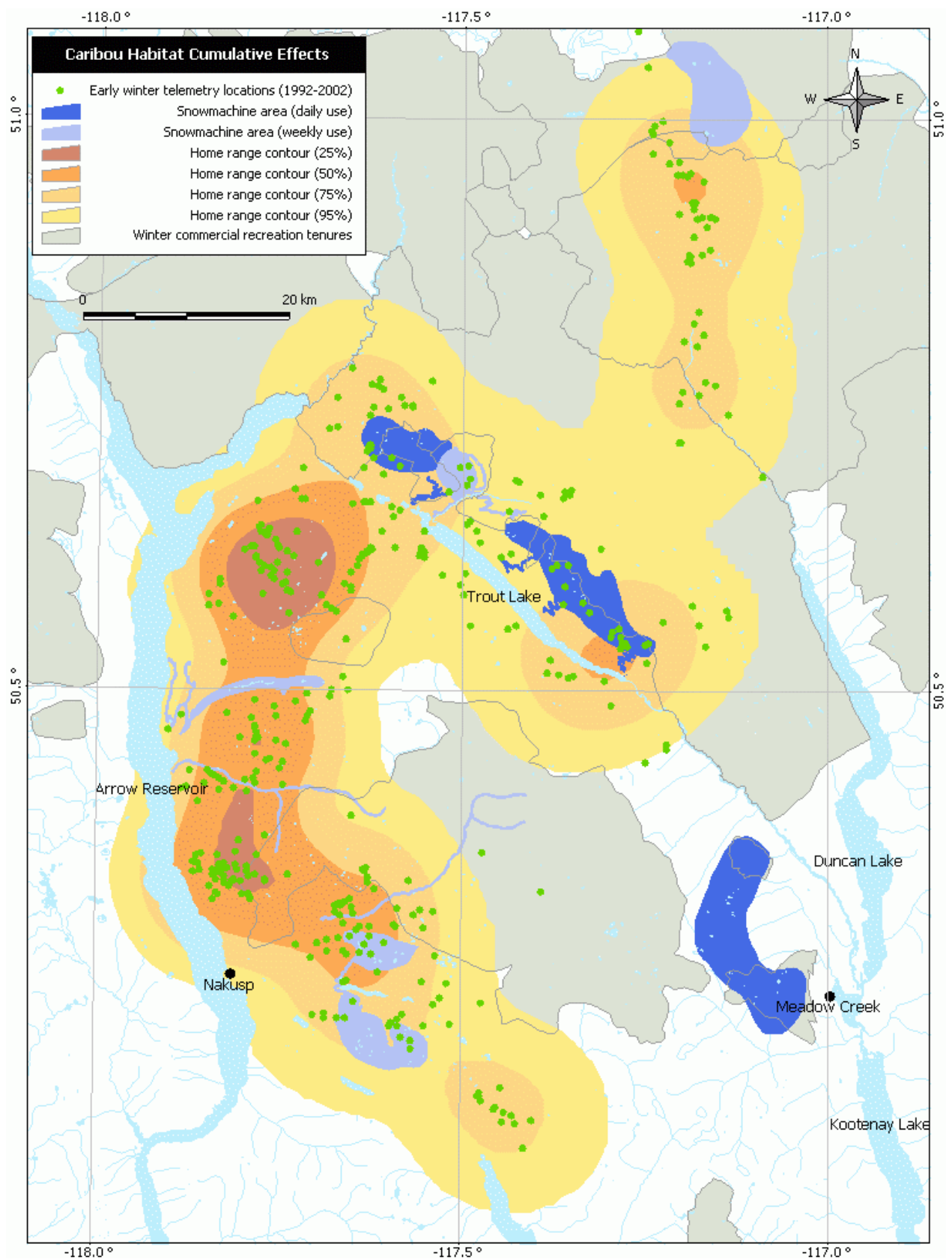


Figure 8. Mountain caribou telemetry locations from early winter (25 October-15 January), home range contours, snowmobiling areas and backcountry recreation tenures.

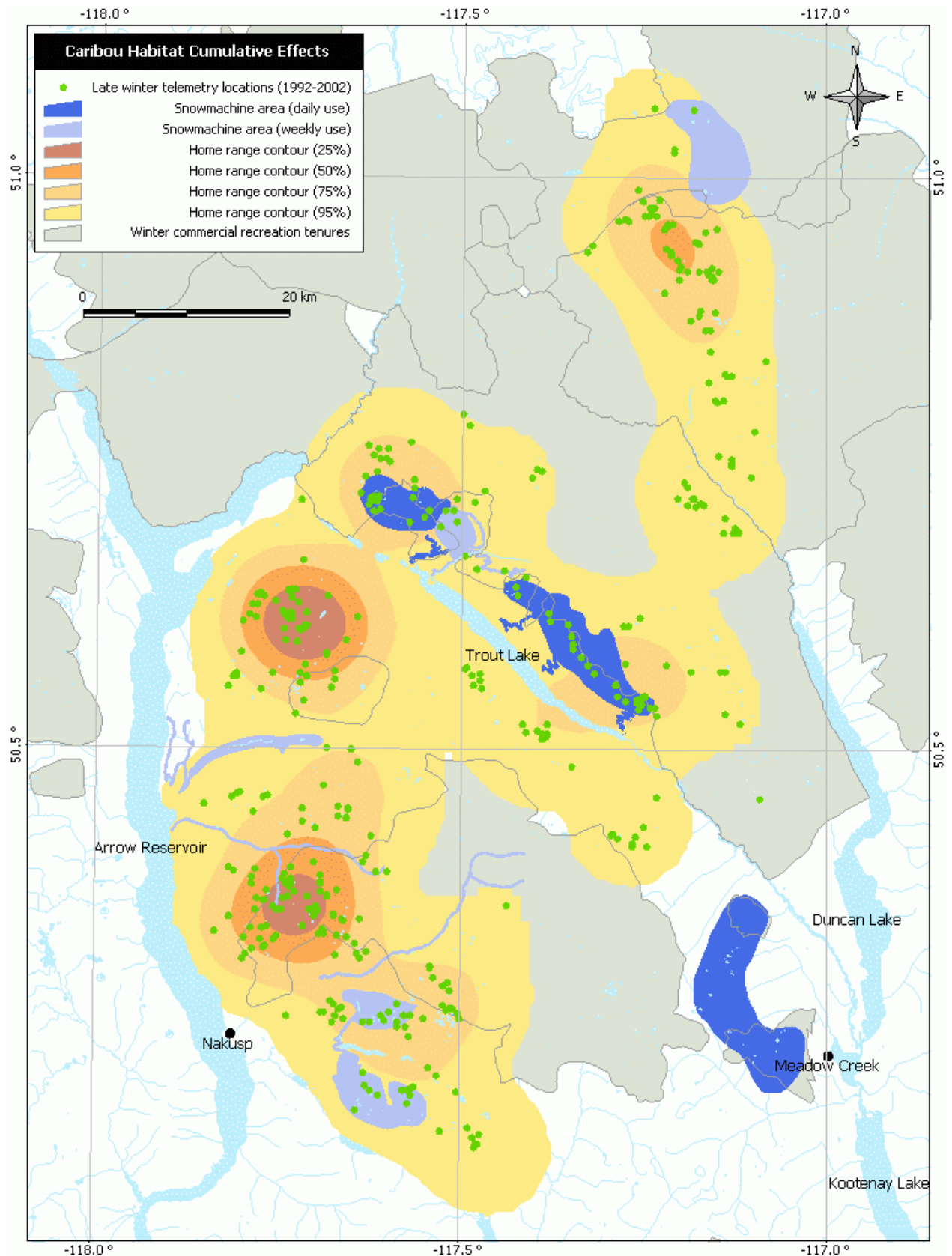


Figure 9. Mountain caribou telemetry locations from late winter (16 January- 12 May), home range contours, snowmobiling areas and backcountry recreation tenures.

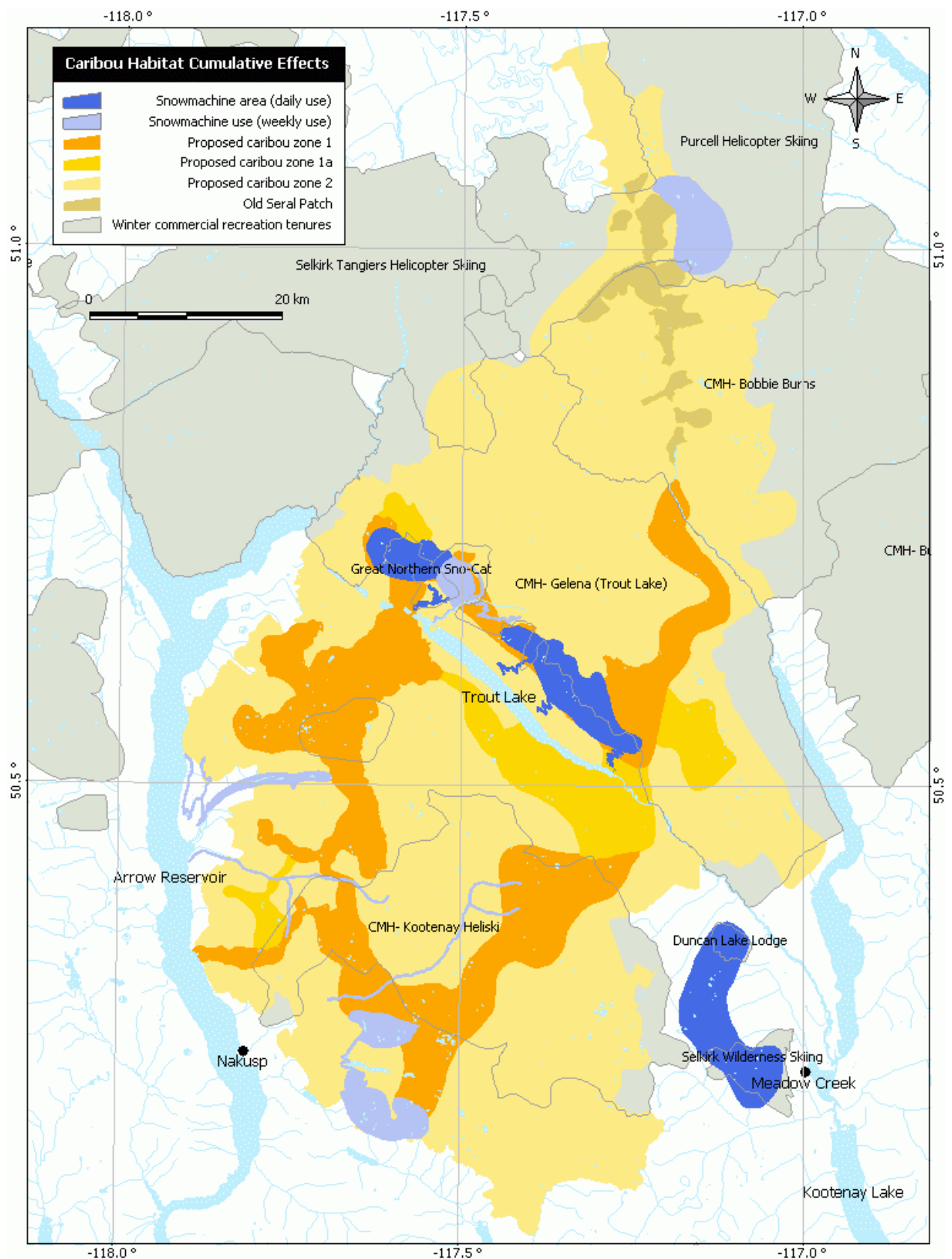


Figure 10. Proposed caribou habitat zonation strategy in relation to commercial recreation tenures and snowmobiling areas.

Table 2. Results of modelling caribou habitat selection as a function of terrain, habitat, ski-use and snow depth. Top models were selected on the basis of AICc (Burnham and Anderson 1998). Sign indicate selection (+) or avoidance (-) of factors based on differences between caribou telemetry locations and random locations within CMH's Galena and Kootenay tenures.

Early winter models	Log-likelihood	k	AICc	ΔAICc	Akaike weight
Slope (-), structural stage (+)	-44.94	3	96.18	0.00	0.31
Slope (-), structural stage (+), ski use (-)	-43.89	4	96.29	0.11	0.30
Slope (-), structural stage (+), snow depth (-)	-44.51	4	97.54	1.35	0.16
Slope (-), structural stage (+), ski use (-), snow depth (-)	-43.73	5	98.22	2.04	0.11
Elevation (+), slope (-), structural stage (+), ski use (-), snow depth (-)	-42.59	6	98.27	2.08	0.11
Elevation (+), slope (-), structural stage (+), ski use (-), snow depth (-)	-78.44	2	153.01	16.11	0.00
Elevation (+), slope (-), structural stage (+), ski use (-), snow depth (-), ESSFp relative to ICH (+), ESSF relative to ICH (+)	-42.34	8	102.59	6.41	0.01
Global model (all variables)	-42.22	11	110.11	13.82	0.00
Late winter models	Log-likelihood	k	AICc	ΔAICc	Akaike weight
Elevation (+), slope (-), structural stage (+), ESSFp relative to ICH (-), ESSF relative to ICH (+)	-90.25	6	193.00	0.00	0.32
Elevation (+), slope (-), structural stage (+), ESSFp relative to ICH (-), ESSF relative to ICH (+), ski use (-)	-89.43	7	193.53	0.53	0.24
Elevation (+), slope (-), structural stage (+), ESSFp relative to ICH (-), ESSF relative to ICH (+), snow depth (+)	-89.56	7	193.79	0.78	0.21
Elevation (+), slope (-), structural stage (+), ESSFp relative to ICH (-), ESSF relative to ICH (+), ski use (-), snow depth (+)	-88.75	8	194.35	1.35	0.16
Global model (all variables)	-86.27	11	196.14	3.14	0.07
Elevation (+), slope (-), structural stage (+), ski use (-), snow depth (+)	-95.73	6	203.95	10.94	0.00

Logistic regression equations (standardized continuous variables) for the supported models for late winter were:

$$\text{Logit}(Y) = -1.97 + 1.63(\text{elevation}) - 0.85(\text{slope}) + 0.20(\text{structural stage}) - 0.48(\text{ESSFp relative to ICH}) + 1.23(\text{ESSF relative to ICH})$$

$$\text{Logit}(Y) = -1.72 + 1.68(\text{elevation}) - 0.84(\text{slope}) + 0.20(\text{structural stage}) - 0.81(\text{ESSFp relative to ICH}) + 1.00(\text{ESSF relative to ICH}) - 0.26(\text{ski use})$$

$$\text{Logit}(Y) = -2.10 + 1.62(\text{elevation}) - 0.85(\text{slope}) + 0.21(\text{structural stage}) - 0.49(\text{ESSFp relative to ICH}) + 1.22(\text{ESSF relative to ICH}) + 0.25(\text{snow depth})$$

$$\text{Logit}(Y) = -1.81 + 1.67(\text{elevation}) - 0.85(\text{slope}) + 0.21(\text{structural stage}) - 0.85(\text{ESSFp relative to ICH}) + 0.96(\text{ESSF relative to ICH}) - 0.26(\text{ski use}) + 0.25(\text{snow depth})$$

Ski use and snow depth were in supported models for both seasons, but were not in the top models. This suggested relatively weak relationships with these variables.

Discussion

Caribou Habitat and Effects of Industrial Forestry

Traditional forest practices are generally considered incompatible with the habitat requirements of mountain caribou (Stevenson et al. 2001), and industrial forestry tenures cover most of the current range of the Central Selkirks mountain caribou population. Forestry removes large, old, lichen-bearing trees and replaces them with even-aged younger stands that have little value for caribou, particularly in winter when caribou subsist on arboreal lichens (Rominger and Oldemeyer 1990, Rominger et al. 1996). Forest harvesting also results in a flush of woody browse, which provides habitat for deer, elk and moose. The proximity of these alternative prey to caribou in managed landscapes is hypothesized to increase mortality on caribou, whose primary anti-predator strategy is to occupy large areas at low densities in areas infrequently visited by predators (Kinley 2002). Industrial forestry also results in a proliferation of roads, particularly into remote areas. Roads become conduits for increased human access and the likelihood that caribou will be displaced from preferred habitats (Stevenson et al. 2001). These direct effects on caribou habitat and indirect effects on demography (via alternative prey and risk of predation) represent the greatest risk to mountain caribou of all factors examined.

We found evidence in univariate tests of the distribution of telemetry points that during late winter caribou avoided areas that had been disturbed by logging and/or fire during 1960-2000. We found no similar evidence for early winter, for reasons that are unclear. However, the multivariate modelling suggested that caribou in both seasons select areas with older structural attributes, based on structural stage.

Historically, forestry activity has been concentrated on the most accessible timber in valley bottoms and at lower elevations; however, harvesting in higher-elevation ESSF habitats is increasing (Stevenson et al. 2001). These higher elevation areas support habitats that are occupied by mountain caribou in both winter and late summer/fall seasons, and also provide high elevation travel corridors and links to seasonal habitats within the range and distribution of the Central Selkirk subpopulation (Hamilton et al. 2001).

The loss of *high* and *very high-suitability habitat* to forestry and fire was not apparent when applying historic structural stages to the mountain caribou habitat model (Hamilton and Wilson 2003). The proportion of *high* and *very high-suitability* habitat on the landscape was stable 1960-2000 because the loss of habitat due to logging or burns was balanced by the recruitment of younger forest stands (generally *low* or *moderate* habitat suitability) into mature and old forest stands (generally *high* and *very high* suitability). However, this recruitment was probably over-estimated because of the structure of the habitat capability-suitability models (RIC 1999), which assigned habitat ratings to ecosystem units related to forest structural stages (*i.e.*, range of forest age classes). For example, many 80 year-old forest stands were rated *low* in suitability because they were considered to lack mature/old characteristics important to caribou (*i.e.*, arboreal lichen production), but at 81 years of age these same stands were rated *high* because the stand age that defined a structural stage threshold included stands from 81-120 years of age (*i.e.*, capable of lichen production). Because of the forest age structure identified in the project area (Timber Forest Inventory Consultants Ltd. 2003), there were a large number of stands <80 years in 1960 that were >80 years old by 2000. In addition, the analysis was aspatial, so any potential effects of fragmentation caused by the specific locations of cutblocks and fires were not evident. Therefore, there may have been some net loss of habitat quality over the analysis period.

A general drawback of an historical analysis of forestry and fire disturbances is the inaccuracy of the forest inventory database. Most stand-age and time-of-disturbance data are photo-interpreted and can be considered only estimates.

The Proposed Zonation Strategy

In 2002, a landscape unit planning strategy linking higher level plan direction with operational practices specific to mountain caribou was developed, approved and implemented for TFL 23. The strategy consists

of a district-level agreement involving three levels of zoning for caribou. Zone 1 is a large contiguous corridor of interconnected areas of high habitat suitability and known high levels of use by caribou. Zone 1a areas support medium to high habitat suitability and known caribou use and are deferred from forest harvesting for a minimum period of five years – pending assessment of innovative forest practices and monitoring of caribou use of managed stands in Zone 2. Forest harvesting is permitted in Zone 2 but field assessments are required for any proposed harvesting activity. The field assessment results and a set of stand-level harvesting and silviculture guidelines are used to identify innovative forest practices and strategies focused on stand-level management of forest habitat elements and attributes important to caribou. The caribou population is monitored through annual censuses and field reconnaissance surveys to assess the effectiveness of the strategy. The TFL 23 caribou strategy was recently extended to encompass the remainder of the range of known caribou habitat in the Central Selkirks (Hamilton and Wilson 2003); however, implementation is pending government approval.

In terms of our retrospective analysis of landscape disturbances in relation to the landscape unit planning zonation strategy for caribou, some Zone 1 areas (*i.e.*, the southern portion of Zone 1 and the Duncan River) included relatively large logged or burned areas. The rate of logging and/or burning in Zone 1 was highest during decades when the most logging occurred in the overall study area (1980-1990 in particular). The rate of habitat disturbance due to forestry and fire declined during 1990-2000 throughout the caribou range and in the proposed Zone 1 and 1a areas, although it was still higher than during 1960-1970 and 1970-1980 periods.

The success of the zonation and management strategy for mountain caribou habitat will depend on other landscape users respecting the intent of the strategy. The most immediate concern is the heavy snowmobiling use on Silvercup Ridge. This area has been identified in the past as a concern (*e.g.*, Simpson and Terry 2000) but use of the area remains unregulated and the extent and duration of use appears to be on the increase. Early-winter habitat below the ridge and travel corridor habitat at the north end of Trout Lake has been compromised by logging and habitat fragmentation, likely affecting the ability of this area to support caribou. The ridge also falls within CMH's Galena tenure and is close to its lodge.

Backcountry Recreation Use

There are growing concerns about the impact of backcountry recreation activities on the winter habitat use and survival of mountain caribou (Simpson and Terry 2000). Risks associated with backcountry recreation are likely related to short- and medium-term displacement from preferred habitats. Unlike industrial forestry, most backcountry recreation activities do not result in long-term changes to habitat suitability. The impacts of backcountry recreation are indirect, more difficult to measure, and likely less severe than the direct habitat loss and associated indirect effects of industrial forestry.

Impacts related to heli-skiing are assumed to be related to helicopter disturbance and displacement of caribou from preferred habitats. Helicopter activity is not distributed equally throughout tenure areas but is concentrated in certain corridors leading to frequently used ski runs. The size of the actual ski runs is very small in comparison to the overall size of the tenure. The Province of BC has developed guidelines to mitigate possible impacts of commercial backcountry recreation on wildlife, and CMH and the heli-skiing and snowcat industry has committed to a series of "best practices" for operations in mountain caribou habitat. These include recording sightings of mountain caribou (and other wildlife) and the animals' response to encounters; immediately leaving the area when caribou are encountered, and avoiding skiing and flight activities in areas known to be occupied by caribou. The goal of CMH's best practices is to minimize mountain caribou encounters and reactions in their daily operations. The adequacy of such guidelines is not known and is difficult and expensive to test (Wilson and Shackleton 2001).

High-suitability late-winter habitat for caribou is not considered ideal ski terrain because late-winter habitat is generally located on gentle slopes (Simpson and Terry 2000, Hamilton et al. 2001), but these areas can be used as helicopter drop-off points. Helicopter traffic related to CMH activities is concentrated

in valleys but flights over high-suitability caribou habitat occur on approaches to drop-off and pick-up areas and traverses between valleys.

Research on the effects of helicopter activity on caribou is limited. Research from other wild ungulates provides strong evidence for short-term behavioural impacts, evidence of habitat displacement in some instances, and few studies demonstrating long-term demographic consequences (review in Wilson and Shackleton 2001). There is also anecdotal evidence of research-related impacts. Net-gunning and radio-collaring might sensitize caribou to future helicopter disturbance, compounding the effects of otherwise less-intrusive overflights by commercial backcountry recreation operators (Kinley 2003).

There is no research available on the effects of snowcat skiing operations on mountain caribou. Impacts might be lower because operations are more restricted spatially. However, these localized impacts could be greater than those related to operations that use helicopters because of the higher frequencies of activity, reduced use by caribou, and associated packing of trails that could serve as travel corridors for predators into high elevation areas (Simpson and Terry 2000). Human use related to high-elevation tourist resorts in Norway has been shown to displace wild reindeer (Nellemann et al. 2001).

Snowmobiling is assumed to have the greatest potential impact of all backcountry recreation activities on mountain caribou because snowmobile users select habitats that are similar to those used by caribou in late winter (Simpson and Terry 2000). There are high-use snowmobiling areas located within the proposed caribou Zone 1 along Silvercup Ridge, north of Trout Lake. Snowmobile use has also been recently observed in Zones 1, 1a and 2 in the upper St. Leon and upper Kuskanax areas, not previously known to be traditional snowmachine use areas. Snowmobiling is a difficult backcountry activity to both measure and manage because it generally involves private users on Crown land rather than commercial, or legally licensed, operators.

Again, research is limited on the effects of snowmobiling on mountain caribou. Simpson (1987) found that short-term behavioural responses depended on a number of variables, including frequency, noise, speed, visibility and terrain. Kinley (2003) assembled data from mountain caribou herds throughout southern BC and found evidence of changes in range use with recent increases in snowmobiling activity. Reimers et al. (2003) found that snowmobiles provoked responses in reindeer at greater distances than did skiers, although animals did not flee as far. Snowmobile activity has been shown to alter range use of white-tailed deer (Dorrance et al. 1975, Eckstein et al. 1979).

Cumulative Effects Analysis

The multivariate model suggested that the most important variables determining the distribution of caribou telemetry locations versus random locations within CMH's Galena and Kootenay tenures were terrain variables such as elevation and slope, and other variables related to habitat: structural stage and EESF/ESSFp forest types relative to ICH.

These results are consistent with previous work in the Central Selkirk Mountains (Hamilton et al. 2001) and elsewhere (Stevenson et al. 2001). The most parsimonious model for the early-winter season identified only slope and structural stage as important variables. During early winter in the Central Selkirks, mountain caribou use low-elevation forest but also use higher elevations as snow conditions allow. A model that included ski use in addition to slope and structural stage was supported by the data almost as much as the top model (according to Akaike weights). This equivocal result can be interpreted as weak support for the hypothesis that caribou avoided ski zones during early winter in years when ski use was high.

Support for early winter models that included snow depth was weaker still. The relationship with snow depth was negative, suggesting that animals avoided areas with deeper snow. This is consistent with our understanding of caribou biology; caribou avoid deep snow in the early winter because it is unconsolidated and restricts movement. The model results for ski use and snow depth might reflect the

selection behaviour of skiers as well as caribou, at the spatial scale of ski zones: CMH selects deep, unconsolidated snow for skiing while caribou in the early winter avoid such areas. Zones dominated by lower elevations might be used more in low snow years by caribou and less by skiers. In addition, CMH actively avoids skiing in areas where caribou are known to be.

In late winter, mountain caribou remain consistently at higher elevations (Hamilton et al. 2001). This was reflected in the most parsimonious model that suggested that caribou telemetry locations were found at higher elevations, on gentler slopes, in habitats dominated by later structural stages (older forests), and in ESSF more often than ESSFp or ICH, compared to random locations. Again, ski use was included in a supported model (<2 AICc from the top model). However, the result was weaker than for early winter (according to Akaike weights). A model including a positive relationship with snow depth was also included in the model. Unlike the early-winter season, an avoidance of deep snow is an unlikely response by skiers, but heavy-snow years might also be related to poor visibility, which would tend to concentrate skiing in small areas close to lodges.

Our results are consistent with a hypothesis of changes in range use by caribou in response to high levels of commercial backcountry skiing activity. However, we caution that the analysis is based on broad-scale data and the relationships were not strong. It also remains possible that ski use was correlated with an unknown variable that caribou responded to that was not included in our analysis.

It should also be noted that the ski use and snow depth values associated with each telemetry location were the only variables in the analysis that were averaged by ski zone and month-year, due to limitations of the source data. More precise ski use and snow depths for each location would likely alter the relationships suggested by the supported models.

More detailed, run-by-run ski use data are available in hard copy and could be used to increase the resolution of the analysis. However, these data are generally beyond the resolution of our caribou habitat use data, which are based on periodic relocations (generally every 2 weeks) from fixed wing aircraft flying in good weather. Finer-scale analyses will require more detailed data on caribou movements, such as those collected by GPS collars.

This project represented one of the first attempts to address the effects of mechanized backcountry recreation (particularly heli-skiing) on caribou habitat use. Data on snowmobiling were limited to spatial distribution and rough measures of use. More detailed data regarding the location, timing and intensity of snowmobile activities are required to develop an adequate test of effects in the Central Selkirk Mountains.

Management Recommendations

We provide the following recommendations arising from this work:

- In examining the supply of wildlife habitat based on RISC-standard wildlife habitat models, seasonal habitat ratings should be interpolated to better reflect the suitability of aging forest stands.
- A similar analysis should be conducted in additional areas used by different tenure holders, including cat-skiing operations. This would help support or refute the results of this analysis.
- Agreements should be negotiated with all land users (heli-ski, cat-ski, recreational snowmachiners) to ensure that the proposed caribou zonation strategy for forestry is not compromised.
- More detailed research regarding fine-scale behavioural and range use responses of caribou to skiing and mechanized backcountry activities should be encouraged. Important data include:
 - Run-by-run ski use and detailed flight paths within commercial backcountry tenures
 - Location and intensity of non-commercial backcountry recreation activities

- Detailed data describing habitat use and behavioural responses of caribou collected at spatial and temporal scales similar to available skier-use data.

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Appendix I. Snow Station Data

The following table summarizes snow data collected by CMH during their operations in the Galena and Kootenay tenures.

Year	Month	Stations reporting	n	Mean snow depth (cm)	SE
1996	Dec	2	6	188.3	7.9
1997	Jan	2	8	291.9	10.1
1997	Feb	2	8	325.6	9.5
1997	Mar	2	4	420.0	48.8
1997	Nov	1	1	140.0	0.0
1997	Dec	3	13	179.4	10.2
1998	Jan	5	25	269.7	5.2
1998	Feb	5	15	286.1	8.2
1998	Mar	5	15	287.0	4.7
1998	Dec	4	13	245.1	12.6
1999	Jan	6	35	344.5	7.9
1999	Feb	5	33	437.3	7.4
1999	Mar	6	14	456.9	11.2
1999	Dec	5	16	237.6	7.9
2000	Jan	5	38	294.3	6.0
2000	Feb	6	25	303.1	5.6
2000	Mar	5	24	345.9	7.1
2000	Apr	3	3	363.3	28.5
2000	Dec	3	3	133.0	7.5
2001	Jan	6	18	138.4	4.3
2001	Feb	6	23	188.5	3.4
2001	Mar	6	23	214.6	4.5
2001	Apr	2	3	216.0	14.5
2001	Nov	2	3	144.0	16.3
2001	Dec	2	8	228.8	12.1
2002	Jan	5	31	252.2	9.6
2002	Feb	5	20	321.0	7.4
2002	Mar	5	17	391.4	5.9
2002	Apr	5	6	406.7	14.6
2002	Dec	3	12	116.4	12.7
2003	Jan	6	28	198.1	4.4
2003	Feb	5	18	229.8	4.1
2003	Mar	5	18	314.9	11.2
2003	Apr	4	4	352.5	17.0