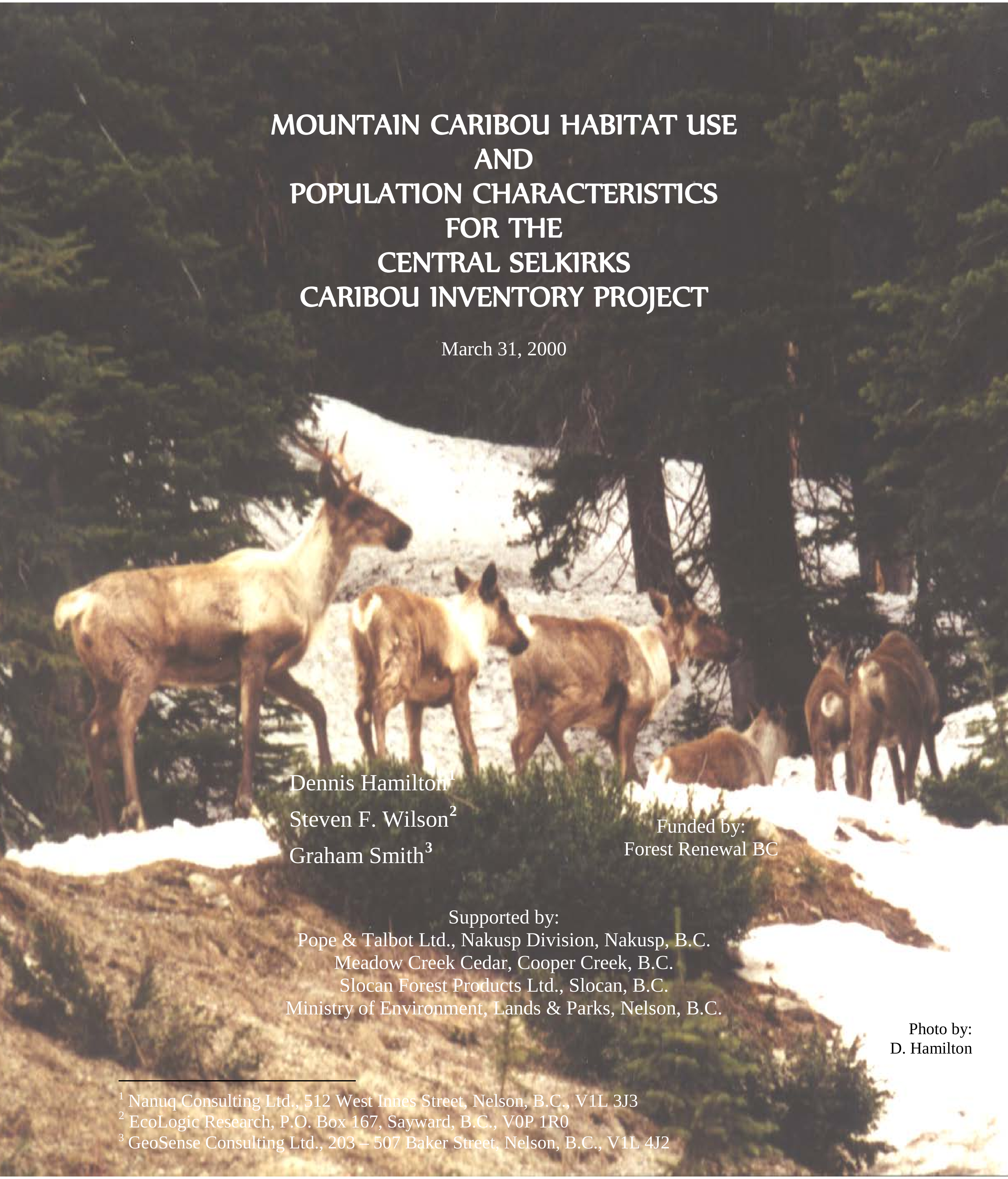

MOUNTAIN CARIBOU HABITAT USE AND POPULATION CHARACTERISTICS FOR THE CENTRAL SELKIRKS CARIBOU INVENTORY PROJECT

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EXECUTIVE SUMMARY

Mountain caribou (*Rangifer tarandus caribou*) are a species at risk in British Columbia. Of the 13 sub-populations in the central and southeastern portions of the province, the Central Selkirk caribou sub-population is one of the top conservation concerns, and management for the species in the Kootenay region has the potential to cause considerable socio-economic disruption. In 1996, Forest Renewal British Columbia (FRBC), in cooperation with Pope & Talbot Limited, Meadow Creek Cedar, Slocan Forest Products and the Ministry of Environment, Lands and Parks, established a four-year partnership to study the mountain caribou sub-population of the Central Selkirk Mountains. The project was designed to provide the population and habitat inventory data necessary to effectively integrate the needs of mountain caribou with forest landscape planning and operational management.

Thirty-five (35) caribou were collared from 1992 to 2000, including fourteen (14) since 1996. Confirmed and probable causes of mortality ranged from natural causes and avalanches to predation. Monitoring of six (6) caribou ended prematurely when the collar rot straps rotted and released the collars. There was no obvious trend in population size over the four (4) years of the study, although our ability to detect changes was limited by survey methods and the short duration of the study. Total population estimates ranged from 213 – 263 animals. The Central Selkirk caribou sub-population appeared to occur in two (2) geographically distinct herds in the Nakusp and Duncan portions of the project area. Home ranges of female caribou averaged 173 km^2 while those of males averaged 254 km^2.

Caribou use of different habitats was driven primarily by their elevational migration behaviour. Caribou in the Central Selkirks were found at high elevations in late winter and summer/fall, and at lower elevations in spring and early winter. In seasons where animals were in transition from high to low elevation habitat (i.e., spring and early winter), the caribou were found within a broad elevation range and in a variety of different habitats. As a result, identifying critical habitats during these transitional periods was difficult.

Landscape level modelling of forest cover and terrain attributes suggested that, in general, the Nakusp herd was found in older forests, at higher elevations (except early winter), on gentler slopes, and in areas of less forest cover than random locations. Use of forest cover types varied by season. There were fewer data available for the Duncan herd, and fewer variables were retained in the final models. Relationships with older forests and specific forest cover types were less evident in the Duncan. A multiscale analysis technique, developed by C. Apps and T. Kinley, generated maps of caribou habitat that were more intuitive than maps derived from single-scale analyses.

At the stand level, caribou telemetry sites could be distinguished from random sites in most seasons by their higher elevations (except in early winter), gentler slopes (except in late winter), and greater moisture in spring and summer/fall. Tree/vegetation characteristics were also important in distinguishing among seasons; late winter sites were distinguished by their lower horizontal cover values, greater amounts of coarse woody debris and more arboreal lichens. Early winter sites had more windthrow, coarse woody debris and lichens, but less branch

litterfall, than random sites. Early winter sites were also older, had lower crown closures, and more stems/ha. Although field researchers developed a good "feel" for caribou habitat at the stand level, the habitat attributes were difficult to capture in the stand level model. This was partly a sample size issue, particularly in transitional seasons when caribou are using a variety of habitats across a broad elevation range.

Maps resulting from the landscape models are suitable for broad-scale forestry planning; however, there are several limitations that need to be considered before they are applied to land use and operational planning. Provincial standard capability/suitability mapping may be useful in further refining the delineation of caribou habitat. At the stand level, expert opinion is invaluable in defining important habitat elements in the field. More refined models of stand level habitat may be possible with additional field sampling, particularly in the spring and early winter seasons.

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ACKNOWLEDGEMENTS

Neil Munro, the aerial monitoring spotter/recorder must be acknowledged for long, bumpy hours spent in a fixed wing aircraft locating the collared caribou. He relied on pilots Chris Royals and Robin Tidswell from Nelson Mountain Air, and Dave Mair from Silvertip Aviation in Revelstoke. Field crews of Doug Seaton, Paul Seaton, Brenda Herbison, Pierre Raymond, Dave Seaton, Neil Munro and Trevor Hamilton put in the long hours getting to and from remote caribou locations to conduct summer and winter field sampling. The task of overall project coordination between Meadow Creek Cedar, Slocan Forest Products, Ministry of Environment, Lands and Parks and Pope & Talbot was performed by Donna Underwood from Pope & Talbot. Frances Swan has now assumed this responsibility as Ms. Underwood has recently moved to Nelson. Cheryl Hillier from Meadow Creek Cedar and Pat Cutts from Slocan Forest Products have also assisted in this regard. Rhiannon Daloise provided the professional clerical services needed to complete the report, and Michael Panian acted as contract monitor on behalf of the Ministry of Environment, Lands and Parks. Michael Quinn provided many thoughtful comments on an earlier draft along with a project quality assurance report (Appendix IV).

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1.0 INTRODUCTION

Two (2) ecotypes of woodland caribou (*Rangifer tarandus caribou*) are present in British Columbia; the northern ecotype and the mountain ecotype. The northern ecotype is found throughout the gentle, open and vast terrain of the northern boreal forest and alpine tundra – feeding on terrestrial lichens, plants and shrubs year-round. In contrast, the mountain ecotype occupy mountainous terrain within the Columbia Mountains and Rocky Mountains of the central and southeastern portion of the province – feeding on a variety of plants and shrubs during the spring, summer and fall. However, during the winter, the mountain caribou rely almost entirely on arboreal, or forest, lichens. Mountain caribou further exhibit seasonal migration movements from valley bottoms to the alpine, predator avoidance strategies and winter lichen dependence that distinguishes them from their northern counterparts (Wildlife Branch 1997).

In 1984, the Committee On the Status of Endangered Wildlife in Canada (COSEWIC) considered both western populations of woodland caribou to be *vulnerable* nationally (Kelsall 1984); that is, a species of special concern because it is particularly sensitive to human activities or natural events. Mountain caribou within British Columbia are on the provincial *Blue List of Species at Risk*. Species on the Blue List are considered to be *sensitive or vulnerable* indigenous species that are not threatened or endangered, but are at risk (Wildlife Branch 1997). Reasons may include human settlement and resource development conflicts, declining population numbers, predation, and reduction or loss of suitable habitat (BC Environment, Wildlife Branch 1991). In the western United States, the small remaining herd of mountain caribou in the southern Selkirk Mountains is considered *endangered* under the US *Endangered Species Act* (Wildlife Branch 1997).

It is estimated that about 2,500 mountain caribou are currently distributed among 13 sub-populations in central and southeastern British Columbia (Simpson *et al* 1997, Wildlife Branch 1997). The Central Selkirk caribou sub-population is ranked sixth out of the 13 sub-populations in terms of conservation priority for management (Simpson *et al.* 1997). The Ministry of Environment, Lands and Parks based this conservation ranking on provincial review that included

1. long term population viability (populations size, population trend, connectivity with other populations);
2. habitat and population threats (predation, access, forestry, winter recreation, risk of fire);
3. habitat protection (protected, inoperable, special management); and
4. habitat capability/suitability (distribution of suitable habitat, fragmentation).

This provincial review also included a preliminary assessment of the implications of caribou conservation on socio-economic factors such as timber supply, local community dependency on industrial forestry, potential employment reductions, tourism and lumber markets. The review concluded that, relative to the other twelve (12) caribou sub-populations, management for caribou in the Central Selkirks had potentially the highest socio-economic implications in the province (Simpson *et al* 1997).

It is generally accepted that mountain caribou populations in the Kootenays have declined since the late 1800's (Russell *et al.*1975, Stevenson and Hatler 1985). In 1900, the now-separate sub-populations of the Southern Selkirk Mountains, Southern Purcell Mountains, and Central Selkirk Mountains were probably all one interbreeding population that included several additional herds that are now extinct. There were major declines in caribou numbers around Kootenay Lake and other low elevation valleys as changes in land use accelerated after 1900 (Russell *et al.* 1975). By the early 1970's, mountain caribou were rare or had disappeared from many previously occupied areas (Russell *et al.* 1975). From the mid-1970's to the present, land use in caribou ranges has included timber harvesting and associated road-building, heli-skiing, and other recreational activities. Caribou hunting seasons were closed in 1973 due to low numbers and poor hunter success – except for an open season hunt in 1991 that harvested four (4) animals (Woods *pers. comm.*). Caribou have generally persisted to the present in areas occupied since the mid-1970s. Russell *et al.* (1975) estimated a population of 250 mountain caribou in the Central Selkirk Mountains.

In 1992, the Wildlife Branch began a program of capture, radio-collaring and aerial monitoring of mountain caribou in the Duncan River portion of the study area. Additional collars were added in the Nakusp and Lardeau portions of the study area in 1995 and 1996. From 1992 to 1996, Wildlife staff and contractors, as well as staff from the Ministry of Forests and Parks Canada, monitored collared caribou. The present Forest Renewal BC funded study began in the fall of 1996, but telemetry data collected during 1992-1996 period were included in our analyses.

In the fall of 1996, Forest Renewal British Columbia (FRBC), in cooperation with Pope & Talbot Limited, Meadow Creek Cedar, Slocan Forest Products, and the Ministry of Environment, Lands and Parks established a four-year partnership agreement to study the entire mountain caribou sub-population in the Central Selkirks. The project was initiated to provide the population and habitat inventory data necessary to effectively integrate the needs of mountain caribou with forest landscape planning and operational management. The Arrow Forest District provided some additional funding in 1998.

This is the final report for the FRBC partnership agreement inventory project on the Central Selkirk mountain caribou sub-population. We present a general description of the study area, followed by the methods and results of the caribou trapping effort, radio telemetry work, field sampling, population censuses, and habitat characterization at the landscape and stand levels. We then generate landscape and stand level models of caribou habitat in the Central Selkirk study area. Finally, we present recommendations for management of the Central Selkirk sub-population.

2.0 METHODS

2.1 STUDY AREA

The project area was delineated in 1996 based on known and suspected caribou distribution, previous telemetry point location data, local knowledge, and professional judgment of biologists and researchers. The project area was located within the North Columbia Mountains Ecoregion and southern portions of the Central Columbia Mountains and North Columbia Mountains Ecosections, and covered approximately 609,510 ha (Figure 1). The area was characterized by steeply sloping mountainous terrain dominated by mature forest within the Interior Cedar-Hemlock (ICH), Engelmann Spruce-Subalpine fir (ESSF), and Alpine Tundra (AT) biogeoclimatic zones. The higher elevations were typically Alpine Tundra Parkland (ATp). The rolling nature of much of the high elevation terrain generally provided favourable terrain for caribou throughout large portions of the project area. Steep rock and glaciers were also common, with avalanche chutes in most valleys.

The Engelmann Spruce-Subalpine Fir wet cold variant 4 (ESSF wc4) and Engelmann Spruce-Subalpine Fir wet mild variant (ESSFwm) dominated the mid to upper elevation forest zone. Mid to lower slope forests included 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) (Figure 2).

2.2 CARIBOU CAPTURE, RADIOCOLLARING AND MORTALITY MONITORING

In February 1992, the first three (3) caribou from the Central Selkirk sub-population were captured and equipped with VHF radio transmitter collars in the Duncan River drainage. In 1995, fourteen (14) additional caribou in the Hamling Lakes/Halfway River/Cape Horn/Wilkie Creek areas were captured and equipped with VHF radio transmitters.

When this project began in 1996, our objective was to maintain radio-collars on approximately 10% of the total Central Selkirk estimated caribou sub-population of 250 animals. Assessing the existing distribution of collars, relative to overall caribou distribution, identified areas considered for capture/collaring. During March 1997 and April 1998, Bighorn Helicopters of Cranbrook, BC was sub-contracted to capture and equip additional caribou with VHF radio transmitter collars.

Site investigations and necropsies were conducted according to Resource Inventory Committee protocol as soon as practical following the discovery of collared caribou mortality. A copy of the mortality report was sent to the contract monitor following the site investigation. Femur, jaw, teeth, fecal, rumen, and other samples collected at the site were forwarded to John Flaa, Parks Canada in Revelstoke for possible laboratory analysis, pending future funding.

2.3 AERIAL MONITORING OF RADIOCOLLARED CARIBOU

We conducted aerial monitoring of caribou equipped with VHF radio transmitters to locate collared animals in order to provide point location data for analysis of population distribution and seasonal habitat use patterns. Collared caribou were located using a twin-engine Cessna 337 fixed-wing aircraft and a Lotek STR1000 scanning receiver. Depending on weather conditions, monitoring flights were attempted weekly from the beginning of November to mid-January and bi-monthly through the rest of the year. From 1992 to the fall of 1996 there were a total of 121 telemetry flights by previous researchers. From the beginning of this study in fall 1996 until March 2000, an additional 73 telemetry flights have been conducted, and over 1,700 telemetry point locations of radio collared caribou were recorded (Figure 3). Approximately three to four hours of flying time was required to locate collared caribou within the 609,510 ha of the project area.

During each flight, telemetry point locations were recorded on 1:15,000 (1997) or 1:30,000 (1995) air photos – depending on air photo coverage within the study area. Following each flight, the spotter/recorder transferred the telemetry point location data from the air photos to an ArcView Geographic Information System (GIS) platform. Digital TRIM (slope, aspect and elevation) and forest cover (timber type, age class, tree height, crown class and stocking level) data were recorded for each telemetry location.

Telemetry accuracy was checked each year by locating two (2) test collars at known locations, and also through field investigations of caribou mortality detected during telemetry monitoring flights. The test collar and retrieved mortality collar field locations were generally within a range of 30 to 60, and never more than 80 meters, from the telemetry aerial monitoring location records.

2.4 POPULATION ESTIMATES

We based population estimates on aerial surveys flown in March 1996, April 1997, and April 1999. Surveys were conducted according to Resource Inventory Committee standards (http://www.for.gov.bc.ca/ric/Pubs/teBioDiv/Ungulate/index.htm). Total counts of adults (unmarked and marked by radio collars) and calves were made within identifiable geographic blocks of the study area. We calculated a population estimate for the entire study area as well as separate estimates for the Nakusp and Duncan herds (see below). The ratio of marked animals seen to the known number of marked animals was used as a measure of sightability. Because no calves were marked, there was a bias in the estimation procedure that led to conservative estimates of total population size; that is, no sightability correction was applied to calf numbers. Population estimates were calculated with program Noremark using the Lincoln-Peterson mark-resight procedure, and 90% confidence intervals (White 1996).

2.5 HOME RANGE ESTIMATES

We estimated home ranges by the minimum convex polygon method (MCP; Mohr 1947). We used this method rather than a kernel estimator (Worton 1987, 1989, Seaman *et al.* 1998) because <20 locations were normally recorded for any given caribou during a calendar year, and kernel-based estimates are not reliable for sample sizes of <30 locations (Seaman *et al.* 1999).

We calculated annual minimum convex polygon home ranges for caribou located ≥15 times during a calendar year and at least once during each season. We also calculated multi-year home ranges for caribou located ≥20 times over the course of the study. We compared the size of male and female annual and multi-year home ranges with a 2-tailed 2-sample t-test assuming unequal variances. For the comparison of annual home ranges, home ranges of the same animal in different years were considered independent.

2.6 Landscape Level Modelling of Caribou Habitat Based on Broad Habitat Types

We classified caribou habitat according to 13 broad habitat types identifiable from the air. This habitat classification and recording system was a continuation of previous caribou telemetry monitoring and data recording conducted in the Central Selkirks from 1992 to 1996 under the direction of Ministry of Environment, Lands and Parks. On telemetry flights we recorded the habitat type where collared caribou were located, as well as other habitats (maximum of two) within a 200m radius of the caribou telemetry location. Nearby habitats for data collected before 1997 were based on caribou track observations during winter telemetry flights.

We generated a database of random telemetry locations to characterize habitat available to caribou on the study area. A 95 percent fixed kernel home range (Worton 1987, 1989, Seaman *et al.* 1998) based on all caribou telemetry locations (n = 1,707) was plotted on the study area, and 200 random points were selected from within the home range area. Random points were located from the air on telemetry flights, and habitats were identified by the methods used for collared caribou locations.

Data were pooled among caribou and years for analyses. Separate analyses were conducted for the entire dataset and for each of four seasons as defined by the elevational movement of caribou throughout the year (Table 1); seasons were defined by approximate dates that marked changes in caribou use of habitats at different elevations. Caribou used high elevation areas in late winter and summer, but dropped to low elevations during early winter and spring. Because the greatest variation in the elevational distribution of caribou occurred in early winter and spring, we termed these seasons as “transitional”.

Variables for the multivariate analysis were the 13 different habitat types. Pearson correlations suggested that none of the candidate variables were highly correlated ($r \leq 0.42$).

We used a multiple logistic regression analysis to examine resource selection (Manly *et al*. 1993, Menard 1995, Mace *et al.* 1999). Logistic regression analysis is well suited to resource selection problems because it regresses independent variables (in this case, habitat types) against a dichotomous dependent variable (“used” or “unused”). We used the same 200 random locations in each regression analysis due to the difficulty and cost of collecting data from these locations. This simultaneous inference increased the probability of Type I error in results; therefore, we interpreted coefficients based on an alpha of 0.025.

Logistic regression can accommodate categorical data (habitat types) through the use of 0 – 1 indicator variables. The primary drawback of the method is that the dependent variable in wildlife resource selection studies is not strictly dichotomous because there is an unknown probability that randomly chosen resource units classified as “unused” were actually used by animals; therefore, the resulting selection models are conservative (Mace *et al.* 1999).

Categorical variables with *n* categories were coded to *n* – 1 indicator variables. Habitat type indicator variables were coded relative to *rock/ice/lakes*. This habitat type was known to be used very little by caribou, and we expected significant coefficients for other habitat types to be positive. Although categorical variables are accommodated by logistic regression analysis, statements about the selection or avoidance of specific attributes must be made relative to the selection or avoidance of the reference indicator variable, which has an assigned coefficient of 0. As well, related categorical variables should be retained or dropped as a group from any "reduced" models (Manly 1993, Menard 1995); therefore, we retained all variables in the final model (Mace *et al.*1999).

Significant ($P < 0.1$) positive coefficients indicated selection and significant negative coefficients indicated avoidance. We used 2 X 2 contingency tables to measure the classification accuracy of the models. The predicted value we used as a decision point to classify observations as either telemetry or random locations was the value that maximized the sum of the percentages of correctly classified locations. This was necessary because improving the model fit for the first category (*e.g.,* used) by shifting the decision point would worsen the model fit for the second category (*e.g.,* unused). Using the sum of percentages ensured we maximized goodness of fit for both categories of locations. We also reported the "odds ratio," which is an overall measure of goodness of fit based on the classification tables. Values >1 suggested a model was better at predicting the classification of a location than expected by chance (Statistica 1995).

2.7 LANDSCAPE LEVEL MODELLING OF CARIBOU HABITAT BASED ON FOREST COVER AND TERRAIN ATTRIBUTES

We used a similar analysis to examine selection of overstory forest tree species, forest structure, and terrain attributes. Caribou locations and an equal number of random locations (n = 1,707) were digitally overlaid on raster coverages of 16 different variables. Excluded from the analysis were locations for which no forest cover data were available, either because of gaps in the digital coverages, or because locations were in non-forested habitats (*e.g.*, alpine, lakes). An equal number of telemetry and random locations were used for each regression analysis. We analyzed the data for the entire study area as well as for the Duncan and Nakusp herds separately.

Variables for the logistic regression analysis included percent cover of tree species as derived from forest cover datatables. Tree species were combined into nine (9) categories; deciduous (DECID), fir species (B_SUM), western redcedar (CW), Douglas fir (FD), hemlock species (H_SUM), larch species (L_SUM), whitebark pine (PA), lodgepole and western white pine (PL_PW), and spruce species (S_SUM).

Also included in the analysis were variables that described forest structure - age class (PROJ_AGECL) and site index (SITE_INDEX). Crown closure was considered but excluded from the analysis because it was highly correlated with both forest structure variables ($r > 0.73$).

Elevation (ELEV_GIS) and slope (SLP_GIS) were derived directly from TRIM data. The absolute value of curvature (CURV), which is the first derivative of slope, was used to represent the ruggedness of the landscape. Ruggedness is an important aspect of habitat for many wildlife species (Beasom 1983). We used the absolute value because negative curvature values represent concavity and positive values convexity, and equally positive or negative values may be interpreted as equally rugged. Our final terrain variable was an index of solar radiation (SOLAR; Kumar *et al.* 1997) that we used as a substitute for aspect. SOLAR represented an estimate of the solar radiation received at each pixel during a day at the midpoint of the four seasons (and the mean for all seasons combined). It had several advantages over slope. First, it is a continuous variable, and therefore, was easier to analyze than aspect. Second, aspect is often used as an abstract measure of solar radiation, but is unreliable in rugged terrain, as is most of this study area. Finally, solar radiation generated meaningful values on gentle slopes, unlike aspect.

Our model building procedure differed from that used for the selection model based on habitat types. Because we were interested in developing a predictive model of caribou habitat, we wanted to retain the most parsimonious subset of variables in the final model. We started by including all variables in an initial model, and then dropping clearly non-significant variables (Wald statistics $P < 0.30$) in a “reduced” model (Manly 1993). This procedure was necessary to reduce computing time in the next step in the model building process, which was to select the most parsimonious model based on different subsets of variables according to the Akaike Information Criterion (AIC; Statistica 1995). Variable inclusion based on AIC is more accurate than inclusion based on the significance of Wald statistics (Menard 1995); therefore, there were instances where variables that were not significant at $P = 0.1$ were included in final models. The model with the highest AIC was not necessarily the one chosen as the final model because models that differ in AIC values from the most parsimonious model by <2 have considerable support. Therefore, we chose the model with the most degrees of freedom with an AIC value that differed by <2 from the model with the highest AIC. Model fit was considered significant if the χ^2 value of the reduced model was significantly different from the intercept-only model (Statistica 1995). We used 2 X 2 contingency tables based on a cut-off of 0.5 to measure the classification accuracy of the model.

To visualize model results, we calculated predicted values from the logistic regression coefficients, and calculated new raster layers representing the suitability of habitat for caribou in each of the four seasons and all seasons combined.

2.8 Multiscale Landscape Level Modelling of Caribou Habitat Based on Forest Cover and Terrain Attributes

We also conducted a multiscale analysis of caribou habitat selection to derive a spatially explicit model of caribou habitat at the landscape scale. Our methods paralleled those developed for the analysis of East Purcell and Revelstoke sub-populations (Apps and Kinley 1995, Apps *et al.* 1998, C. Apps *pers.comm*., and T. Kinley *pers.comm*.). Attributes were averaged within circles of 250 ha, 1,000 ha, 2,500 ha, and 5,000 ha centred on telemetry point locations and on random points located at a distance of twice the radius of the circle in a random direction from each telemetry point.

We dropped larger scale variables where they were highly correlated with corresponding variables calculated at smaller scales (*i.e.,* the same variables averaged in a smaller circle). Model building was based on the same logistic regression procedure used for the other landscape models, except that the large number of variables precluded us from using AIC to derive the most parsimonious model. Instead, final models included variables that were significant in the saturated model at an alpha of 0.1 based on Wald statistics.

Model fit was considered significant if the χ^2 value of the reduced model was significantly different from the intercept-only model (Statistica 1995). We used 2 X 2 contingency tables based on a cut-off of 0.5 to measure the classification accuracy of the model, and then mapped output as described in the previous section.

2.9 Stand Level Modelling of Caribou Habitat Based on Forest Cover and Terrain Attributes

We collected attribute data at the stand level for telemetry point locations and for a similar number of random locations (see Figure 4) within the 95% kernel composite home range (stratified by ecosection). Data collection methods differed somewhat between the 1998 and 1999 field seasons. In 1998, the sample of telemetry locations selected for stand level analysis was chosen to be representative of the entire dataset. In 1999, telemetry locations were chosen randomly from among the entire dataset stratified by season. In addition, a prism sweep was used for sample tree selection in 1999 to reduce any potential bias of selecting representative sample trees within a 20m x 20m plot, as was done in 1998 (Appendix I).

Data were stratified by season for analysis. Again, we used logistic regression analysis to determine resource selection by caribou at this spatial scale. Correlations among predictor variables were ≤0.72. Aspect was dropped from the analysis because 46% of telemetry point locations investigated were on slopes ≤25% where aspect had little meaning. Also, variables collected at plots in only the 1999 field season were excluded to maintain reasonable sample sizes.

2.10 Stand Level Tree Composition

Tree composition data were collected at telemetry and random sites, but were not included in the main stand level model because doing so would have added approximately 70 variables to the logistic regression making analysis and interpretation very difficult. Instead, we examined differences in tree composition at telemetry and random sites by compiling the presence/absence of different species in different strata at each site. We used presence/absence as the currency of tree species structure rather than the number of stems of each species, because one or a few sites with large numbers of trees could have easily influenced an analysis based on the number of stems. We considered only sites with tree cover, and pooled species into the same nine (9) categories used in the landscape level model. We tested for differences in tree species structure with χ^2 tests for each stratum, using frequency of tree species presence among telemetry sites as the “observed” frequency and among random sites as the “expected” frequency. Tree species categories with expected frequencies of 0 were dropped from analyses. In addition, the DECID category (1 “expected” observation) was dropped from the analysis of the A1 stratum to meet the assumption of the χ^2 test (Roscoe and Byars 1971, Neu *et al.* 1974). Data were insufficient to test for differences in frequencies for the veteran stratum.

2.11 Statistical Analyses

All means are expressed ± 1.64 standard errors (SE) to correspond to a 90% confidence interval.

3.0 RESULTS

3.1 Caribou Capture, Radio-collaring and Mortality Monitoring

A total of thirty-five (35) caribou were captured and equipped with VHF radio collars from 1992 to 2000. Fourteen (14) caribou were collared under this FRBC inventory project, which began in the fall of 1996 (Table 2). The others were collared as part of previous caribou telemetry monitoring studies conducted from 1992 to 1996 under the direction of the Ministry of Environment, Lands and Parks. Field investigations of mortality events suggested a variety of confirmed and probable causes ranging from natural causes and avalanches to predation (Table 3). Over the course of the study there were no collar failures or malfunctions, although signals transmitted from collars carried by caribou in the Duncan since 1992 weakened before emitting mortality signals in 1998. Monitoring of six (6) caribou ended prematurely when the rot straps fastenings on the radiocollars rotted through. As of 31 March 2000, fourteen (14) VHF collars remained active.

3.2 Population Estimates

Three (3) population censuses were conducted in the spring of 1996, 1997, and 1999. A total of 207 caribou were classified with 12 of 14 collars spotted in 1996; 222 caribou were classified with 22 of 23 collars spotted in 1997; and 178 caribou were classified with 14 of 17 collars spotted in 1999. Lincoln-Peterson estimates and confidence intervals could be calculated only where >0. Never during any of the surveys were all of the collared caribou spotted. Total and adult population estimates for survey years are listed in Table 4. There was no evidence of a trend in caribou population numbers over the course of the study.

3.3 Home Range Estimates

Multi-year home ranges were approximately twice the size of annual home ranges, and annual home ranges varied considerably between years within and between years among caribou (Appendix II). Males home ranges (annual: $x = 218 \pm 51$ km^2, multi-year: $x = 445 \pm 83$ km^2) were generally larger than females ranges (annual: $x = 167 \pm 20$ km^2, multi-year: $x = 330 \pm 47$ km^2; annual: $n = 54$, $t = 1.53$, $P = 0.14$; multi-year: $n = 30$, $t = 1.99$, $P = 0.08$). It was clear from plots of lifetime home ranges that animals in the Duncan and Nakusp areas behaved like separate herds (Figure 5).

3.4 Landscape Level Modelling of Caribou Habitat Based on Broad Habitat Types

Use of habitat types by caribou, based on raw frequencies, was similar among seasons (Table 5). Meadow and cedar-spruce habitats were dropped from subsequent analyses because they were not represented in the sample of random locations.

For the resource selection model of caribou habitat based on habitat types, caribou selected ESSF and subalpine habitats relative to rock/ice/lakes in all seasons, ICH in all seasons except late winter, and avalanche chutes in spring and summer/fall. Alpine habitats were avoided in early winter and selected in late winter. Clearcuts and burns were selected in the spring and semi-mature forests in early winter (Table 6). Models of each season and for all seasons combined were significantly different than intercept-only models, and classification rates suggested that model fit was better than that of random models (Table 7).

3.5 LANDSCAPE LEVEL MODELLING OF CARIBOU HABITAT BASED ON FOREST COVER AND TERRAIN ATTRIBUTES

There were differences between telemetry and random locations in the mean values of the fifteen (15) variables included in regression models, although some differences were very small (for all seasons combined; see Table 8). We based most of our interpretation of results on the habitat models run separately for the Nakusp and Duncan herds (see Discussion). Notwithstanding, the results of data analysis and habitat mapping for the pooled Nakusp and Duncan caribou herds are presented in Appendix III and Figures 6-10.

All logistic regression models for the Nakusp herd differed significantly from the intercept-only models (Table 9; Figures 11-15). In general, the Nakusp herd was in older forests, at higher elevations (except early winter), on gentler slopes, and in areas of less forest cover than random locations (Table 9). Use of forest cover types varied by season. Classification of telemetry and random locations by the models suggested a better fit than predicted by random models (Table 10).

There were fewer data available for the Duncan herd, and fewer variables were retained in the final models. Relationships with older forests and specific forest cover types were less evident (Table 11; Figures 16-20). The fit of models to the data was poorer for the Duncan herd than for the Nakusp herd (Table 12).

3.6 MULTISCALE LANDSCAPE LEVEL MODELLING OF CARIBOU HABITAT BASED ON FOREST COVER AND TERRAIN ATTRIBUTES

Means of habitat variables at the 5000 ha scale were highly correlated with means at 2500 ha (most >0.80, all ≥0.70); therefore, we considered only variables at 250 ha, 1000 ha, and 2500 ha scales. Other larger scale variables were also dropped from the analysis because of correlations: DECID (1000), ELEV (2500), FD (2500), L_SUM (2500), PLPW (2500), AGE (2500), and SITE_INDEX (2500).

At the scale of 250 ha, caribou telemetry locations in the Nakusp herd (compared to random locations) were on gentler slopes in the late winter and summer/fall, and in less rugged terrain in spring and early winter (Table 13). Caribou were associated with sites with higher solar radiation in spring and early summer. Elevation was a significant variable at the 1,000 ha scale; caribou locations in all seasons except spring were at higher elevations than random locations (Table 13). Also at the 1,000 ha scale, caribou were found in older forests in spring and summer/fall. At the 2,500 ha scale, caribou were in locations with higher solar radiation in summer/fall, and less sunny areas in early winter (Table 13). Caribou were associated with a variety of different forest cover types at various scales (Table 13; Figures 16-20). In other words, caribou didn't consistently select forest attributes at any specific scale and important attributes differed among seasons. Models of each season and for all seasons combined were significantly different than intercept-only models, and classification rates suggested that model fit was better than that of random models (Table 14).

Models for spring and early winter could not be calculated for the Duncan due to sparse data. In general, habitat relationships for the Duncan herd were more apparent at broader scales (Table 15). Both the late winter and summer/fall models were significantly different than intercept-only models, and model fit was better than random models (Table 16).

3.7 STAND LEVEL MODELLING OF CARIBOU HABITAT BASED ON FOREST COVER AND TERRAIN ATTRIBUTES

Univariate means for several stand level variables were similar at telemetry (all seasons combined) and random sites (Table 17); however, important differences emerged in the multivariate analysis by season (Table 18). Specifically, caribou telemetry sites could be distinguished from random sites in most seasons by their higher elevation (except in early winter), gentler slopes (except in late winter), and greater moisture in spring and summer/fall. Tree/vegetation characteristics were also important in distinguishing among seasons; late winter sites were distinguished by their lower horizontal cover values, greater coarse woody debris and more lichens. Early winter sites had more windthrow, coarse woody debris and lichens, but less branch litterfall than random sites. Early winter sites were also older, had lower crown closures, and more stems/ha. Model fit was better than that of random models (Table 19).

3.8 STAND LEVEL TREE COMPOSITION

Tree species structure differed between telemetry and random sites, and among strata (Table 20, Appendix III). Fir species occurred more frequently on telemetry than on random sites among all strata except A1. Species usually more common on random sites included western redcedar, hemlock species, larch species, and lodgepole/western white pine.

4.0 DISCUSSION

4.1 CARIBOU CAPTURE, RADIOCOLLARING AND MORTALITY MONITORING

The project goal of maintaining radio transmitter collars on roughly 10 % (~25 collars) of the total estimated caribou population (~250 animals) was made difficult at times due to caribou mortality and dropped collars. During the study, twelve (12) collared caribou died, and in the last eighteen (18) months of the study, six (6) collars were dropped when the rot straps wore away. Nevertheless, caribou capture and collaring efforts in 1997 (seven collars) and 1998 (seven collars) ensured that, generally, radio collars were distributed throughout represented portions of caribou distribution within the study area. Aerial monitoring flights provided a further opportunity by project staff for many visual observations of other caribou in their natural habitats. No attempts were made to capture and collar additional caribou in the final two (2) years of the project.

In the last year of the study, collar rot straps were effectively resulting in collars dropping off the animals. Therefore, there is no proposed plan for collared caribou re-capture and collar removal after project completion. Furthermore, within Pope & Talbot's Tree Farm License No. 23 (TFL#23) portion of the Central Selkirk caribou study area, further funding has been recently approved that would see three to four additional caribou captured and equipped with radio collars in the spring of 2000. All collared caribou within TFL#23 will be monitored and additional early winter habitat attribute field sampling will be conducted through fiscal year 2000/01. As the sole funding support for additional caribou inventory within the Central Selkirks, Pope & Talbot proposes to increase telemetry and field data sample sizes within TFL#23 – leading to development of standardized habitat capability/suitability ratings and mapping for the early winter season. Telemetry monitoring of other active collars within the overall Central Selkirk caribou study area, but outside of TFL#23, will be recorded only when incidental to monitoring for collared caribou within TFL#23.

The exact cause of most caribou mortalities was unknown despite the best effort of field researchers to investigate all mortalities. Even for eight (8) cases of what appeared to have strong evidence of cause of mortality, the telemetry flights were not conducted often enough to allow us to detect mortality signals and make site investigations within a time period that would ensure an accurate assessment of the exact causes of mortality. Distinguishing between predation and other types of mortality was often difficult because carcasses were frequently scavenged. Wolves (*Canus lupus*) and grizzly bears (*Ursus arctos*) are considered major predators of caribou (Bergerud *et al.* 1984, Seip 1992). The sample of confidently identified mortalities was very small in this study, and general conclusions about mortality causes or trends are difficult.

4.2 POPULATION ESTIMATES

Within the Kootenay region there are four (4) other populations of mountain caribou in addition to the Central Selkirk population (Simpson *et al.* 1997). The North Columbia Mountains support approximately 400 caribou (McLellan *et al.* 1994) and the Central Rockies population is estimated at 50 caribou (Simpson *et al.* 1997). In the southern portion of the region both the

South Purcells and South Selkirks caribou populations are declining. A recent census in the South Purcells identified only 18 caribou from a population estimated to be between 80-100 less than a decade ago (T. Kinley *pers. comm.*). The South Selkirks population is estimated at 50 animals; however, the current population has been supplemented over the past decade with transplanted animals from other populations (J. Almack *pers. comm.*). Including a Central Selkirk caribou population estimate of 250 animals, the Kooteney region supports over 800 animals out of a total estimated provincial population of 2400 mountain caribou (Simpson *et al.* 1994).

Based on historical reports of caribou abundance in the Kootenays, there is strong evidence that caribou populations declined and became fragmented during the 1800's and early 1900's. The population estimates in the Central Selkirk Mountains in the 1970's suggested a herd size similar to that estimated in this study (Russell *et al.* 1975). We found no evidence of a trend in population estimates over the course of the study; however, estimates were based on only three (3) annual counts and the sample of the population that was collared was small, particularly among the Duncan herd. Therefore, our ability to detect changes in the population was limited.

4.3 HOME RANGE ESTIMATES

Annual home ranges for both male and female caribou were considerably smaller than home ranges calculated over the term of the study for collared individuals. This suggested that home range fidelity was relatively low for caribou on this study area. Caribou were known by direct observations to have distinct seasonal home ranges; however, data were insufficient to confidently estimate the size and location of seasonal ranges based on radio telemetry data.

Caribou generally exhibit seasonal migration patterns within their annual home ranges, but large variations over and among years is common (Paquet 1997). Studies in the Revelstoke area by Simpson and Woods (1987) reported that caribou annual home range sizes varied from 112 km^2 to 860 km^2. South Selkirk caribou exhibit annual home ranges from 131 km^2 to 173 km^2 (Scott and Servheen 1985).

4.4 LANDSCAPE LEVEL MODELLING OF CARIBOU HABITAT BASED ON BROAD HABITAT TYPES

Caribou use of broad habitat types was driven primarily by their elevational migration behaviour. As reported for other caribou sub-populations in southern British Columbia (Servheen and Lyon 1989, Seip 1992, Simpson and Woods 1987, Stevenson *et al.* 1994), caribou in the Central Selkirks were found at high elevations in late winter and summer/fall, and at lower elevations in spring and early winter. High elevation habitat types were used significantly more than predicted by a random model in all seasons, while other lower elevation habitats were important in spring and early winter. The fact that high elevation habitats were used in all seasons points to a central difficulty in quantifying the behaviour of caribou in seasons where animals were in transition from high to low elevation habitat (*i.e.*, spring and early winter). Essentially, caribou were found within a broad elevation range in a variety of different habitat types. As a result, identifying critical habitats was very difficult. In addition, the importance of seasonal movements between critical habitats pointed to the need to delineate movement corridors – something very difficult using conventional telemetry methods (see Recommendations).

In general, the habitat types used in this analysis, as well as the fact that data from few random locations could be practically collected due to remote access and associated cost related constraints, limited the interpretation of this analysis to broad generalizations about caribou habitat use. However, it was important to record the actual habitats that caribou were located in because of issues of accuracy and precision with forest cover maps.

4.5 Landscape Level Modelling Of Caribou Habitat Based on Forest Cover And Terrain Attributes

Seasonal models of caribou habitat based on forest cover and terrain attributes were again driven by elevational migrations of caribou. In general, the migration of the Duncan herd was less pronounced, due to the distinctly different terrain occupied by this herd. The broad Duncan River valley and its side drainages were the principal landscape features used by caribou in the area. In contrast, animals in the Nakusp typically moved along ridgetops and through multiple drainages.

Relationships between caribou and the variables included in the model-building process were stronger for the Nakusp herd than for Duncan caribou. This was largely a function of sample size; few caribou were collared in the Duncan, and the resulting models were based on few locations.

During aerial telemetry monitoring, field surveys and censuses, we observed no caribou in the northwestern portion of the study area. The models suggested that there are few areas in the northwestern part of the study area that provided suitable caribou habitat, and those areas that were suitable were widely dispersed and isolated from one another. This fits with our knowledge of the distribution of caribou within the study area.

The landscape models resulted in maps that are suitable for broad-scale forestry planning; however, there are several limitations that need to be considered before they are applied in land use and operational forest planning. First, the independent habitat variables used in the models were largely derived from available Ministry of Forests forest cover and terrain (TRIM) information. Forest cover was developed for broad application at the management unit scale, such as Tree Farm License (TFL) or Timber Supply Area (TSA) planning and assessments (C. Hauk and L. Price *pers. comm*.). It was never intended for operational use at the drainage or forest stand level. Second, mapping information was not consistent throughout the study area. Mapping appeared to be more refined in the TFL than in the TSA (*e.g.*, more accurate delineation of forest cover types). Third, there were limitations imposed by using forest cover as one of the principal mapping layers. Alpine and non-productive forest was not considered in the development of the landscape models, despite being used by caribou, because these areas were either not mapped or inaccurately mapped in forest cover. Field crews found that areas classified as alpine by forest cover maps were in fact often located in ESSF forest types (e.g., up to 50% of field sites investigated in the CCM ecosection).

The behaviour of caribou themselves also limited the utility of the landscape models. Field observations (*e.g.*, tracks, pellets, trails) indicated that caribou from the Nakusp herd moved extensively along ridgetops and used a number of important movement corridors throughout the southern half of the study area. The landscape models did not reflect the importance of these areas because bi-monthly telemetry flights resulted in a distribution of telemetry points that better represented “destination” areas where caribou spent a lot of time, rather than corridors where caribou spent minimal time while travelling. Field personnel identified and mapped a number of major and minor movement corridors (classified as ‘major’ or ‘minor’ by the frequency of telemetry and visual observations of caribou in those areas – see Figure 21). The proper management of seasonal movement corridors should be considered as important as the management of habitat identified by the habitat models.

We considered telemetry accuracy to be a minor problem in determining the habitats used by caribou; however, we suspected that disturbance caused by telemetry monitoring flights might have underestimated the use of some non-forested habitats. For example, we often observed caribou in forested habitats adjacent to avalanche tracks in spring. We suspected that the caribou used the avalanche tracks but moved into the adjacent forest cover habitat as the aeroplane approached. Habitat sampling by field crews confirmed that caribou consistently used avalanche tracks and other forest openings as foraging areas.

Model development was made more difficult by the broad habitat use of caribou, particularly during the spring and early winter transition periods, when caribou moved between high and low elevation areas and used a variety of habitats. As a result, the random locations considered “unused” in the model-building process were similar to caribou locations. The result was poor fitting models for these seasons. The problem of random locations falling within suitable caribou habitat was an issue of some concern in all seasons.

Available input layers restricted the usefulness of the landscape models. We suspect that there were important habitat variables that influenced caribou use, but that could not be measured at the landscape scale. Field observations suggested that lichen abundance (particularly lichen loads on blowdown and in recently logged areas) was an important variable that influenced caribou habitat use. Field observations of caribou use areas were often associated with the occurrence of whitebark pine trees. However, forest cover inadequately described the distribution of these areas, mostly because whitebark pine was a minor component of forest stands. There was also evidence that fine-scale topographic features such as slope position and moisture regime were important to caribou, but were too small to be captured by the digital elevation model. One critical variable that could not be considered was snow conditions (depth and consolidation), which is known to drive changes in caribou habitat use, particularly during transition periods (J. Flaa *pers. comm*., Simpson *et al.* 1994 and Stevenson *et al.* 1994).

Finally, the classification of habitat into quality classes must be interpreted cautiously. The amount of “high quality” habitat (*i.e.,* >0.75 on landscape maps) varied extensively by season. The values mapped represented the degree to which each point on the landscape maps fit the model that best discriminated between caribou and random locations. Therefore, models that discriminate poorly between caribou and random locations will generate maps that are dominated by moderate probability values. Such maps do not indicate that little high quality habitat actually exists on the landscape.

4.6 MULTISCALE LANDSCAPE LEVEL MODELLING OF CARIBOU HABITAT BASED ON FOREST COVER AND TERRAIN ATTRIBUTES

The multiscale maps generated the best ‘intuitive’ representation of caribou habitat on the Central Selkirks study area based on the expert opinion of those involved with the telemetry monitoring, winter trailing, field sampling and data collection. There are two (2) sets of possible explanations for this; one based on observer interpretations and one based on caribou biology. First, the maps were based on models that were essentially smoothed over a greater spatial extent. As a result, the effective scale of the models was probably more appropriate for making generalizations about caribou habitat at the project area scale. Second, the scales used in the analysis may better represent the scales at which selection actually occurs in caribou. Of course, this was exactly the purpose of deriving the multiscale models. That being stated, the interpretation of model variables and coefficients was difficult – the multiscale models, by definition, included three times as many candidate variables as the single scale models, and few patterns were evident among spatial scales or seasons. There was also the difficulty of interpreting the biological relevance of attributes that contribute to the final models at different spatial scales.

4.7 STAND LEVEL MODELLING OF CARIBOU HABITAT BASED ON FOREST COVER AND TERRAIN ATTRIBUTES

We were surprised that leading species did not come out as an important variable in any of the stand level models. We also expected stems/ha and branch litterfall to be more important variables in distinguishing sites used by caribou from random sites. Field researchers acquired a good “feel” for the types of habitats that were commonly used by caribou simply through the investigation of many such sites. However, distilling the characteristics of sites into a few measurable variables was very difficult, particularly in seasons when caribou used a variety of habitats. Sample size was also an issue in model development. The expense and difficulty of collecting plot data in the rugged, isolated terrain within a study area of this size restricted the analysis to far fewer plots than is likely necessary to generate reliable models.

Our results were similar in many respects to other studies. During early winter, caribou in the southern Selkirk mountains also used areas on moderate slopes with high levels of windthrow, lichens, and less canopy cover than random plots (Rominger and Oldemeyer 1989). The southern Selkirk caribou also used high elevation areas with high lichen loads in late winter (Servheen and Lyon 1989).

There was some refinement in the data collection process between 1998 and 1999. We believed these changes were necessary to improve the stand level model, but the changes did affect the ability of the analyses to resolve habitat associations. One of the significant challenges of the stand level model was to capture the complexity of stand composition in a few variables relevant to caribou. We concede that considering only leading species in the model and separately analyzing species abundance among all seasons combined was an imperfect solution.

5.0 CRITIQUE OF INVENTORY PROTOCOLS

Many of the implications of inventory and data development to model deficiencies have been presented in the sections above. In summary, we used the most current data collection and analysis techniques; however, there were several issues regarding the inventory and modeling methods that could affect the results and recommendations of the study.

The independent habitat variables used to develop the caribou habitat models rely on existing variables, or mapped attributes, derived from forest cover and TRIM data bases. The accuracy of forest cover mapping does not reliably depict actual forest stand type or important caribou habitat attributes (*e.g.*, lichen abundance and availability, branch litterfall, blowdown, coarse woody debris, seeps and wet areas).

There were limitations with respect to availability of additional input layers for landscape-level modelling. For example, other than limited field 'trailing' of caribou during early winter, there was no data available on snow depth or snow consolidation conditions, which researchers feel are important factors influencing caribou seasonal movements and habitat selection. In addition, there was limited mapping of alpine areas, a habitat used by caribou for a large portion of the year.

Bi-monthly aerial telemetry monitoring and data may not accurately reflect the true behaviour of caribou (*e.g.*, travel corridors versus "destination" habitats). Caribou also tend to be distributed across a broad range of elevations and habitat types during the early winter and spring transition periods. The resultant plot data and larger sample sizes needed to capture habitat suitability for caribou were made somewhat impractical by the expense (*e.g.*, helicopter access) associated with field sampling within the rugged, isolated, and difficult to access terrain representative of much of the study area. In addition, data collection and sample sizes were impacted during significant portions of the study in that there was limited telemetry monitoring conducted from April to November of 1997 (three flights) and no summer field sampling or data collection conducted during 1996 or 1997 due to approval delays.

Bi-monthly telemetry monitoring flights were not frequent enough to determine exact cause of collared caribou mortality. By the time the mortality was discovered and the site investigated the carcasses were most often scavenged, making necropsy difficult and mortality assessment mostly speculative.

These issues could not be adequately resolved within the constraints of this project. Expert knowledge acquired during the course of the study assisted in addressing some of the problems.

6.0 MANAGEMENT RECOMMENDATIONS

The results of this project led to the development of three (3) different landscape level models of caribou habitat for the Central Selkirks project area. The model products and associated strengths and weaknesses have been outlined in sections above. In terms of application, it is most important to recognize that models are decision support tools to be used in combination with professional judgement and interpretation (Antifeau 1998).

The Kootenay/Boundary Land Use Plan Implementation Strategy and component caribou guidelines identify mature and old seral forest retention percentages within broadly mapped caribou areas. Stand level management objectives and silviculture strategies for winter habitat are also provided. In terms of the spatial application of the forest retention requirements for caribou, the multiscale habitat maps represent the project team's best 'intuitive' estimation of caribou habitat quality on the Central Selkirks project area. These maps can assist in identifying broad scale areas where caribou have been observed and areas where habitat is similar. Interpretation and application of the maps should be restricted to the watershed scale and larger, and the qualifications noted in the discussion should be carefully considered.

Within identified caribou habitat areas, stand level habitat attributes for different seasons were identified by analyses. Again, there are cautions associated with the analyses, mostly regarding small sample sizes. However, with the results of other studies a consensus is starting to emerge about the importance of variables such as lichens, coarse woody debris, horizontal sight distance, windthrow, branch litterfall, stand age, and stand structure characteristics. The analyses did not necessarily capture all of the important caribou habitat characteristics in a few simple variables, and conveying the characteristics of caribou habitat in a statistically defensible but operationally applicable manner remains a challenge, particularly with limited data.

Throughout the project, staff was encouraged to record personal observations related to project goals and objectives and caribou/habitat interactions in general. The cumulative total of this experience equates to over 600 person days conducting a combination of field surveys of caribou telemetry and random sites, winter trailing of caribou, population censuses, investigating collared caribou mortality and aerial monitoring of collared caribou. This knowledge proved invaluable during the development and assessment of the statistically derived models. Further application of this knowledge through consultation at the forest development and silviculture prescription planning and through consultative field reviews of proposed development activities is recommended.

The natural hot springs occurring at Halcyon and in the Halfway, Kuskanax, and St. Leon drainages are used as mineral licks by caribou throughout the year. Caribou telemetry locations in the vicinity of these hot springs combined with field investigations confirmed use of these hot springs, not just by caribou but also mule deer, goats and bears. All of these areas are developed to some degree for human recreation and use and are easily accessible – both Kuskanax and Halcyon support commercial developments. In this context, it is strongly recommended that a management strategy be initiated to ensure the long-term maintenance and wildlife access to these unique and important habitats. Land purchase and/or Wildlife Habitat Area designation options should be considered.

The Central Selkirk caribou exhibit seasonal migration and movement patterns similar to other mountain caribou sub-populations. Notwithstanding, specific management strategies for maintenance of habitat linkage zones between identified seasonal habitats need to be developed at the landscape level. The biophysical differences between Central Columbia Mountains ecosection (Nakusp herd) and North Columbia Mountains ecosection (Duncan herd) should also be considered to the extent that caribou habitat and seasonal migration patterns differ within these distinct units of the Central Selkirks. A preliminary reconnaissance level mapping of migration routes has been provided as a basis for consideration (Figure 20).

For more than 25 years, forest harvesting in mountain caribou ranges has been a management concern within British Columbia (Stevenson *et al* 1999). Within the Central Selkirks, commercial and public recreation activities such as cat skiing, heli-skiing, and snowmachine use may also have impacts on caribou habitat use, habitat selection and/or habitat avoidance. While additional studies may be required to validate this hypothesis, it is recommended that a consultative process involving government, industry, stakeholders and user groups be initiated to scope the extent of the problem, identify research needs and develop interim management strategies to address conflict areas. A public education awareness program and public access management planning should necessarily be components of this overall initiative.

We also recommend that any additional habitat mapping for caribou consider Standards for Wildlife Habitat Capability and Suitability Ratings in British Columbia (RIC 1995, Demarchi *et al* 1997). This approach provides provincial standards for wildlife habitat capability and suitability ratings to be applied at scales from 1:250,000 to 1:20,000. The ratings define the relative importance of mapped ecological units (site series) to wildlife populations for the specific purpose of making land management decisions. In addition to suitability ratings, the capability ratings are required by resource managers and planners for making short and long term strategic land use decisions and trade-offs regarding caribou mapping and guideline application. The provincial mapping procedures further accommodate anthropogenic effects on suitability ratings. This aspect of identifying human influences (*e.g*., hot springs resource development, heli-skiing, cat-skiing, snowmachine use, 4x4 quad use) on caribou habitat suitability was considered by all staff to have varying implications to caribou habitat suitability, selection and use – particularly during the winter recreational use period (see Information Needs section below).

The potential use of GPS collars was examined twice - once during project study design in 1996, and again through an independent evaluation (Kinley 1998). The major considerations in decisions to use VHF collars for this project were cost and potential data biases associated with use of GPS collars in valley bottom old growth cedar/hemlock forests and steep rugged terrain. As GPS technology evolves with respect to the above, it may be appropriate to consider use of GPS collars to generate larger telemetry data sample sizes for the early winter period, when aerial telemetry monitoring is often hindered by inclement weather. Identification of specific movement corridors, particularly in remote, isolated portions of the study area such as the Duncan River, may also benefit from use of GPS collars. Notwithstanding the above, the advantages of bi-monthly and weekly fixed wing flights associated with monitoring of VHF collars proved extremely important in providing researchers with an overall understanding of the project area, ecology and behaviour of caribou – which proved to be invaluable in interpreting and assessing habitat model results.

7.0 INFORMATION NEEDS

The task of integrating forest development planning with the habitat needs for caribou as identified through strategic planning direction, guidelines and habitat suitability mapping can be extremely challenging and complex. In this context, important caribou habitat and management issues not addressed or only partially addressed by this report include:

- habitat capability ratings to assist in strategic long term caribou and forest management planning and decision making;
- consideration of anthropogenic influences on caribou habitat suitability, selection and use (e.g., snowmachine use, commercial recreation, commercial developments, public access);
- operational forest management strategies and silviculture practices aimed at retention of specific caribou habitat attributes and forest structural components at the forest stand level (see Discussion and Management Recommendations sections); and,
- a caribou/timber/biodiversity adaptive management strategy whereby baseline resource assumptions are followed by operational harvesting and alternative silviculture trials, monitoring and amendments to current practices and rules as results dictate.

Within the term of this study, one collared caribou from the Duncan herd was located outside of the study area within the upper McMurdo Creek area of the East Kootenays. In 1998, three mature bulls were reporting swimming across the Arrow Lakes towards the Monashee (an area in the Okanagan supporting approximately 20 caribou). Despite several years of telemetry monitoring in the Central Selkirks and adjacent areas in Revelstoke, South Purcells, South Selkirks and Monashee, little is known regarding overall population interaction or exchange between these sub-populations. Given the current trend of declining caribou populations in the South Purcells, South Selkirks and Monashee, potential population connectivity between these sub-populations should be further examined.

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FIGURE 1: CENTRAL SELKIRK CARIBOU INVENTORY STUDY AREA

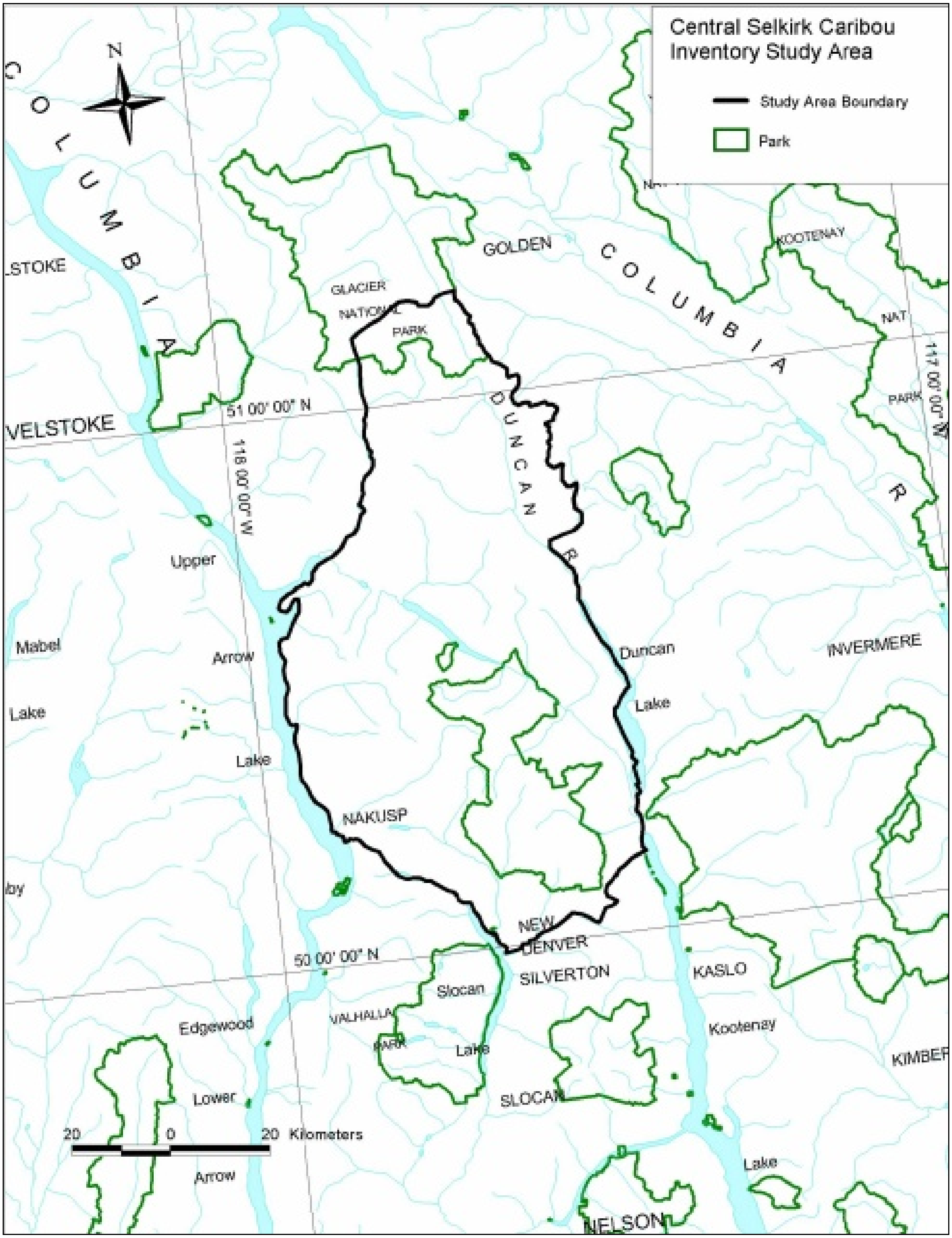

FIGURE 2: BIOGEOCLIMATIC ECOSYSTEM CLASSIFICATION FOR CENTRAL SELKIRK CARIBOU STUDY AREA

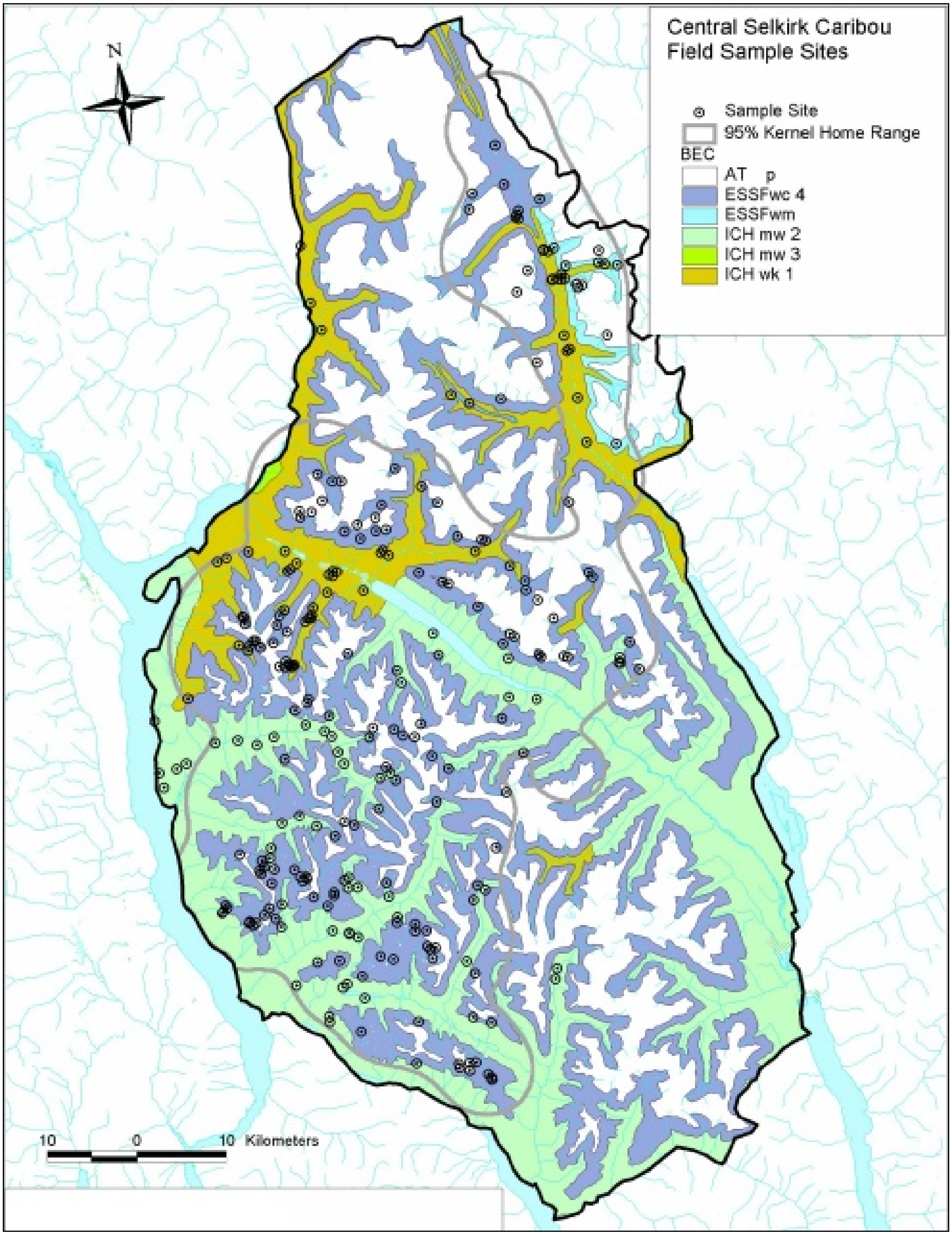

FIGURE 3: CENTRAL SELKIRK CARIBOU TELEMETRY LOCATIONS

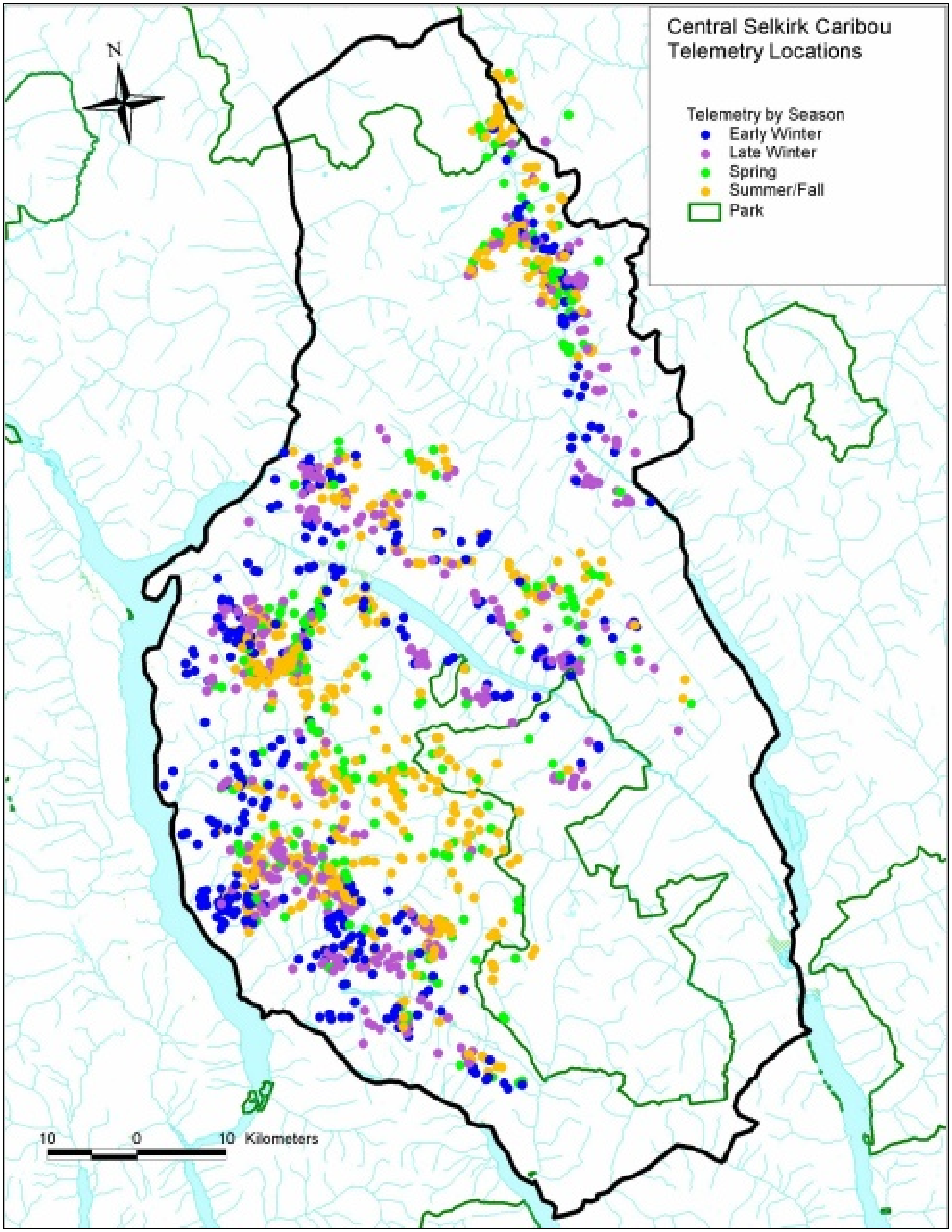

FIGURE 4: CENTRAL SELKIRK CARIBOU FIELD SAMPLING SITES

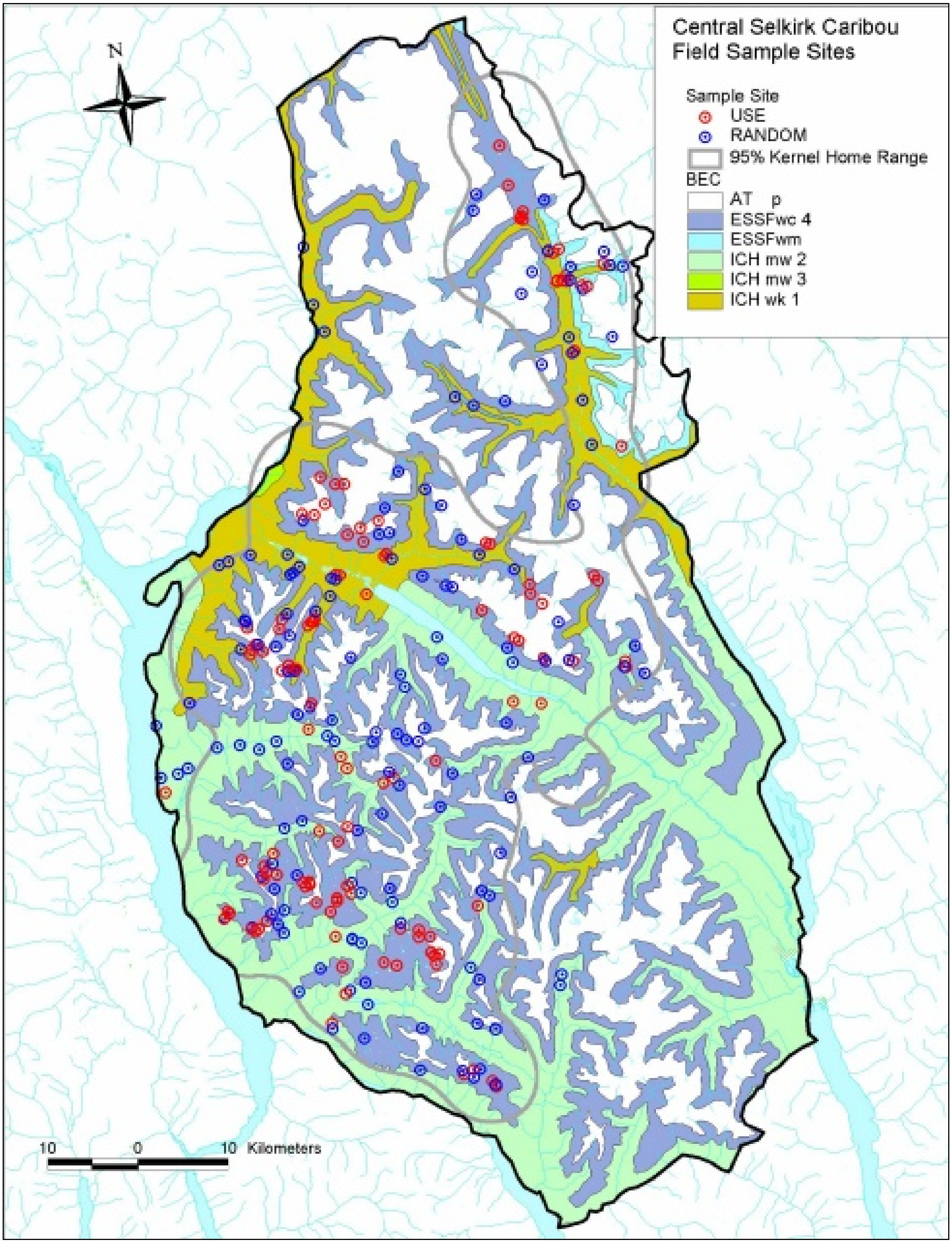

FIGURE 5: CENTRAL SELKIRK CARIBOU LIFETIME HOME RANGE AREAS

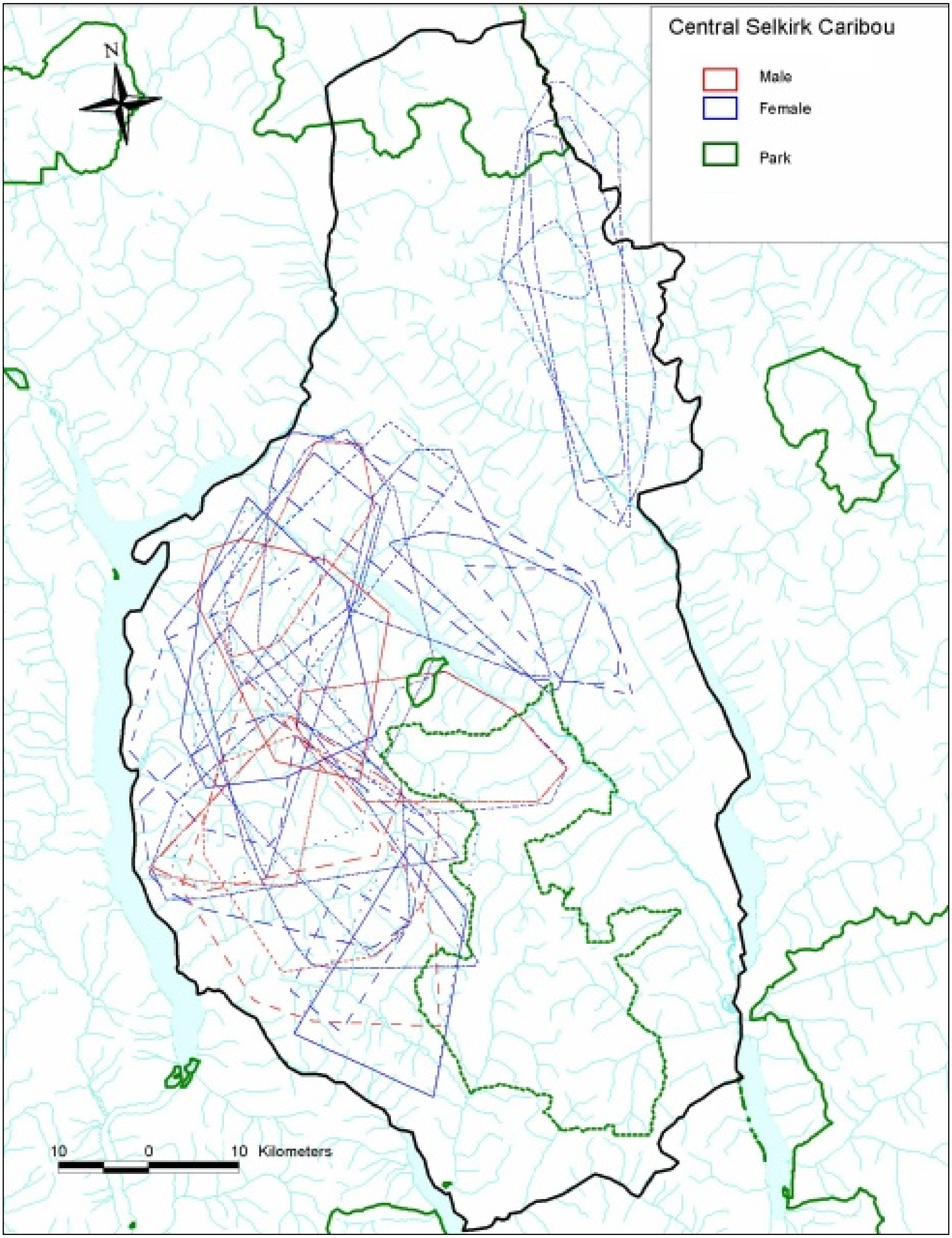

FIGURE 6: LANDSCAPE LEVEL MODEL – FOREST COVER/TRIM FOR ENTIRE STUDY AREA (ALL SEASONS)

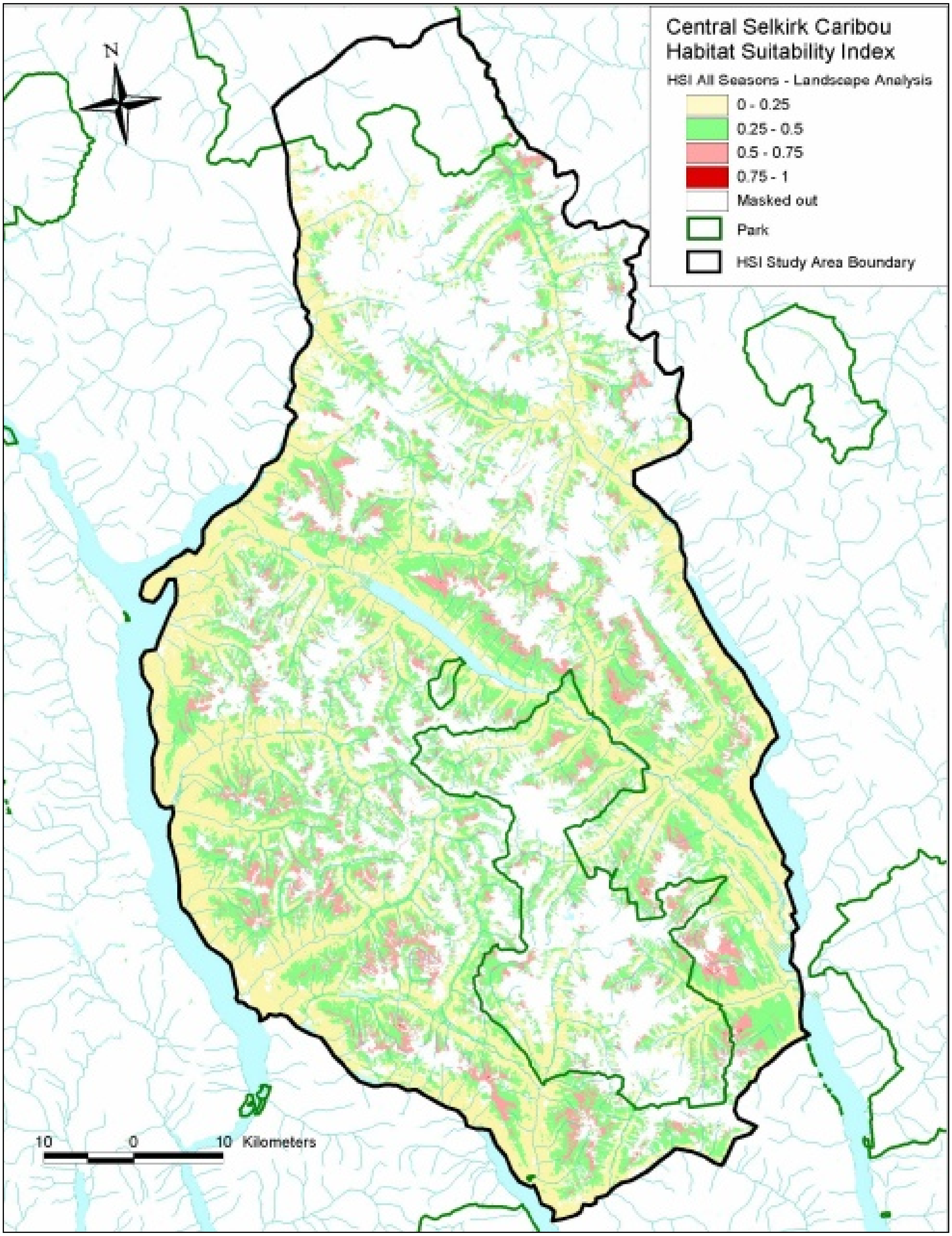

FIGURE 7: LANDSCAPE LEVEL MODEL – FOREST COVER/TRIM FOR ENTIRE STUDY AREA (SPRING)

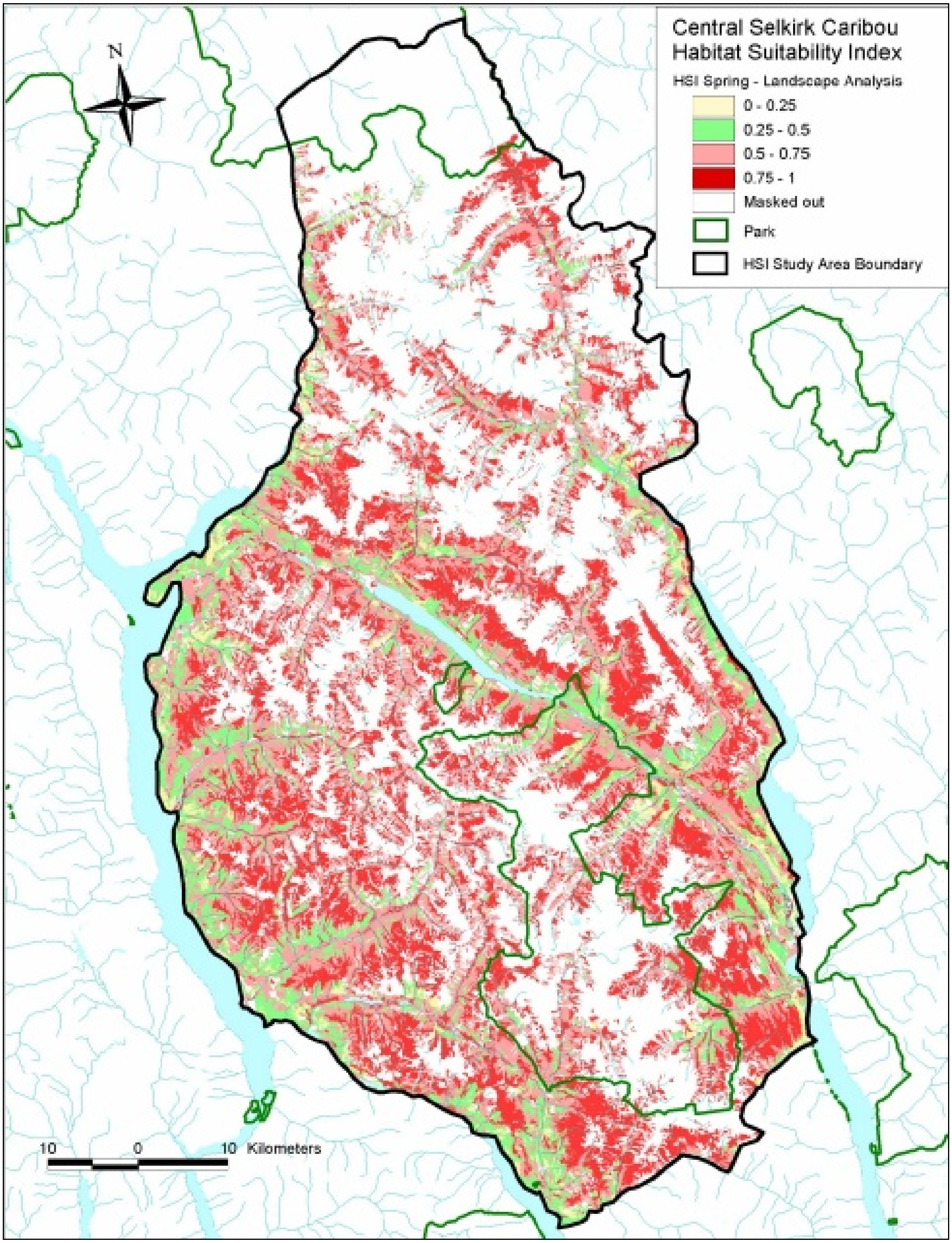

FIGURE 8: LANDSCAPE LEVEL MODEL - FOREST COVER/TRIM FOR ENTIRE STUDY AREA (SUMMER/FALL)

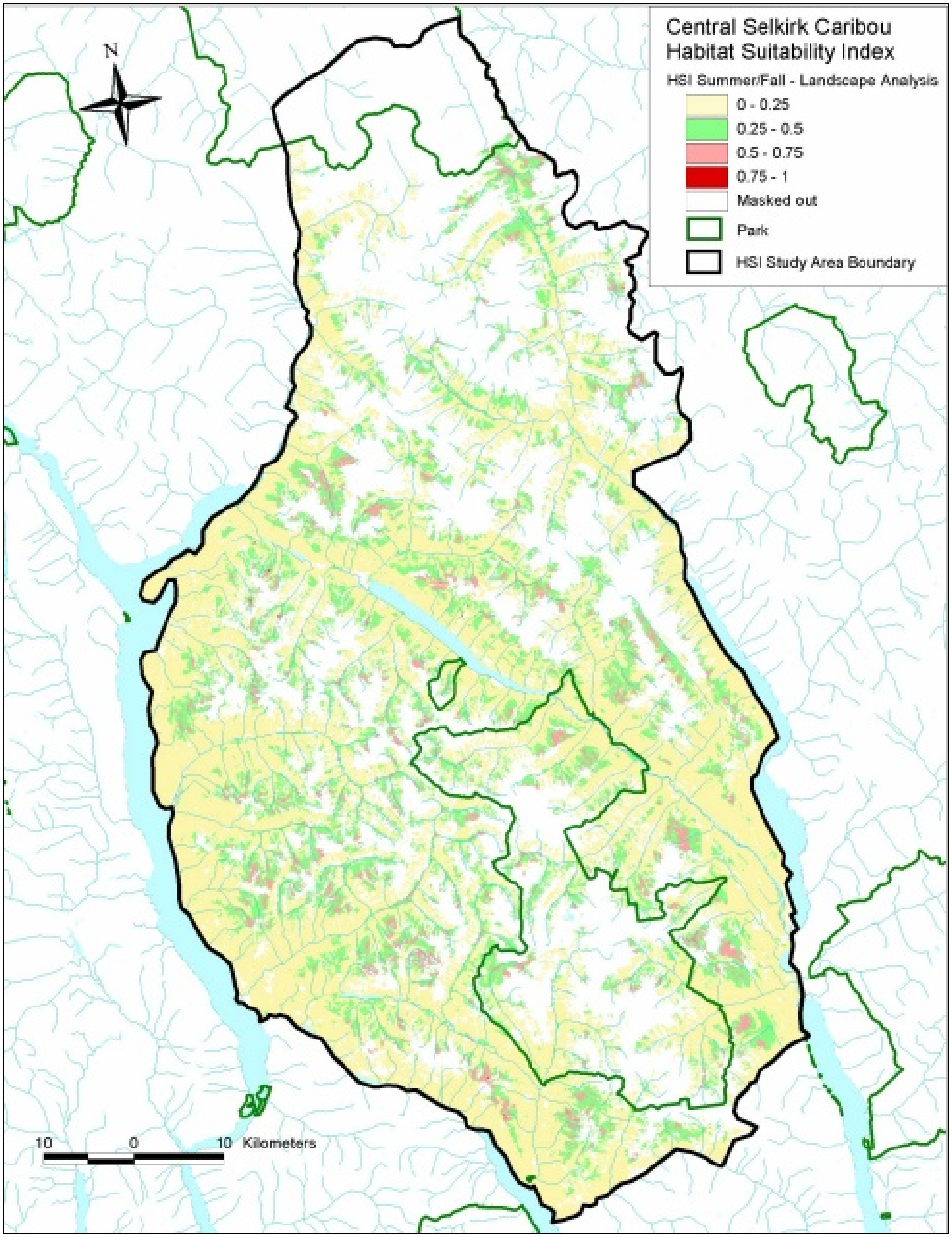

FIGURE 9: LANDSCAPE LEVEL MODEL - FOREST COVER/TRIM FOR ENTIRE STUDY AREA (EARLY WINTER)

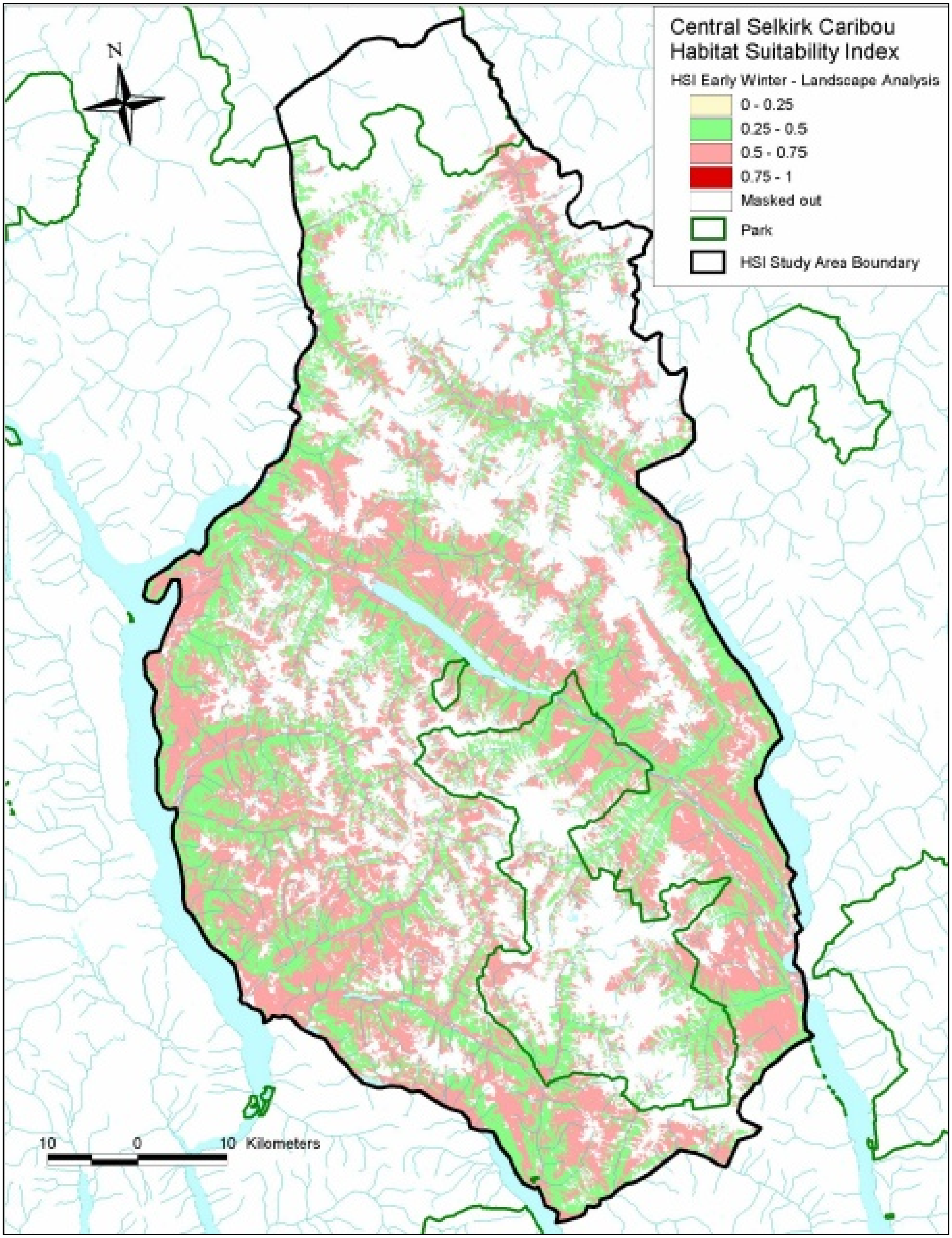

FIGURE 10: LANDSCAPE LEVEL MODEL - FOREST COVER/TRIM FOR ENTIRE STUDY AREA (LATE WINTER)

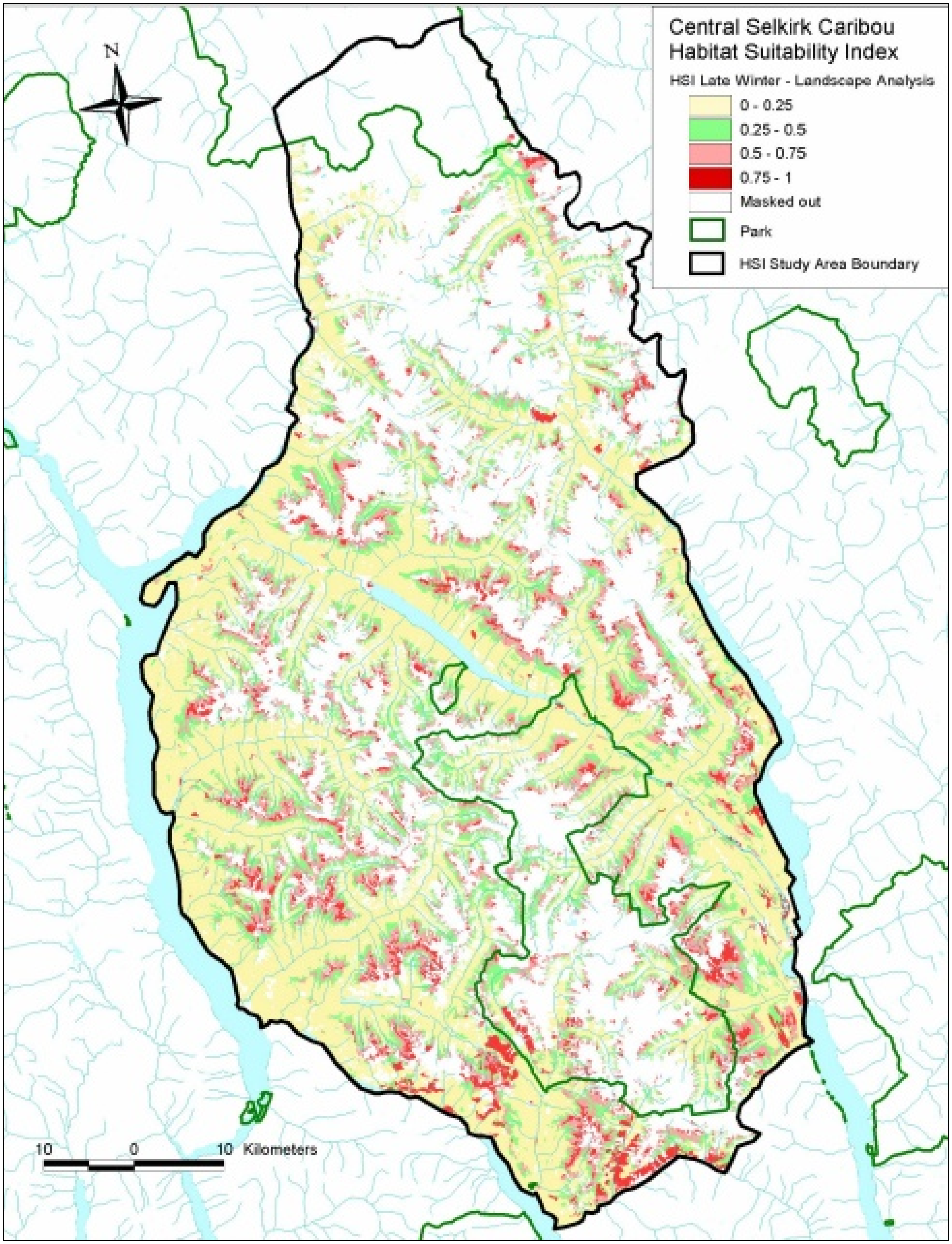

FIGURE 11: LANDSCAPE LEVEL MODEL - FOREST COVER/TRIM FOR DUNCAN/NAKUSP SUB-POPULATIONS (ALL SEASONS)

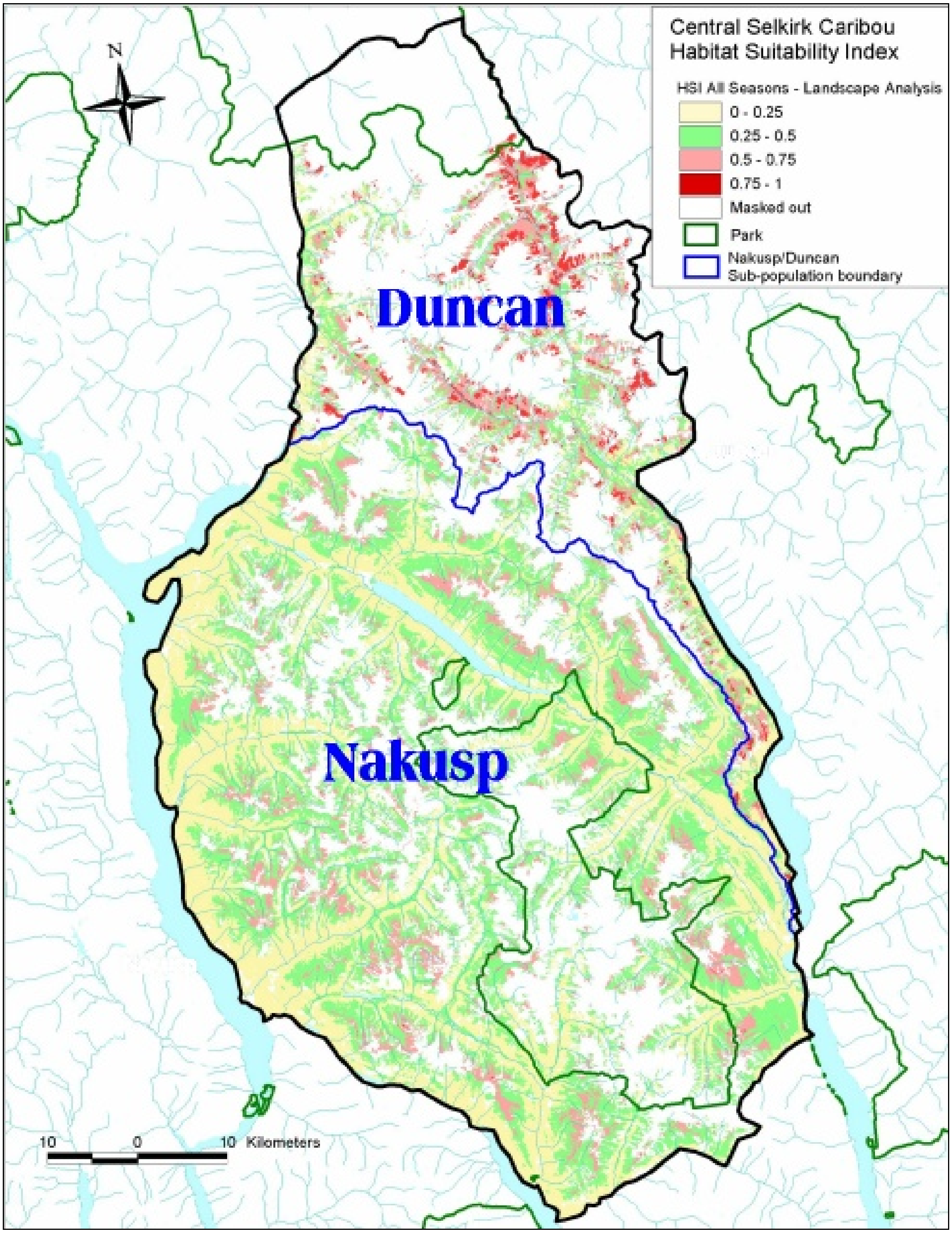

FIGURE 12: LANDSCAPE LEVEL MODEL - FOREST COVER/TRIM FOR DUNCAN/NAKUSP SUB-POPULATIONS (SPRING)

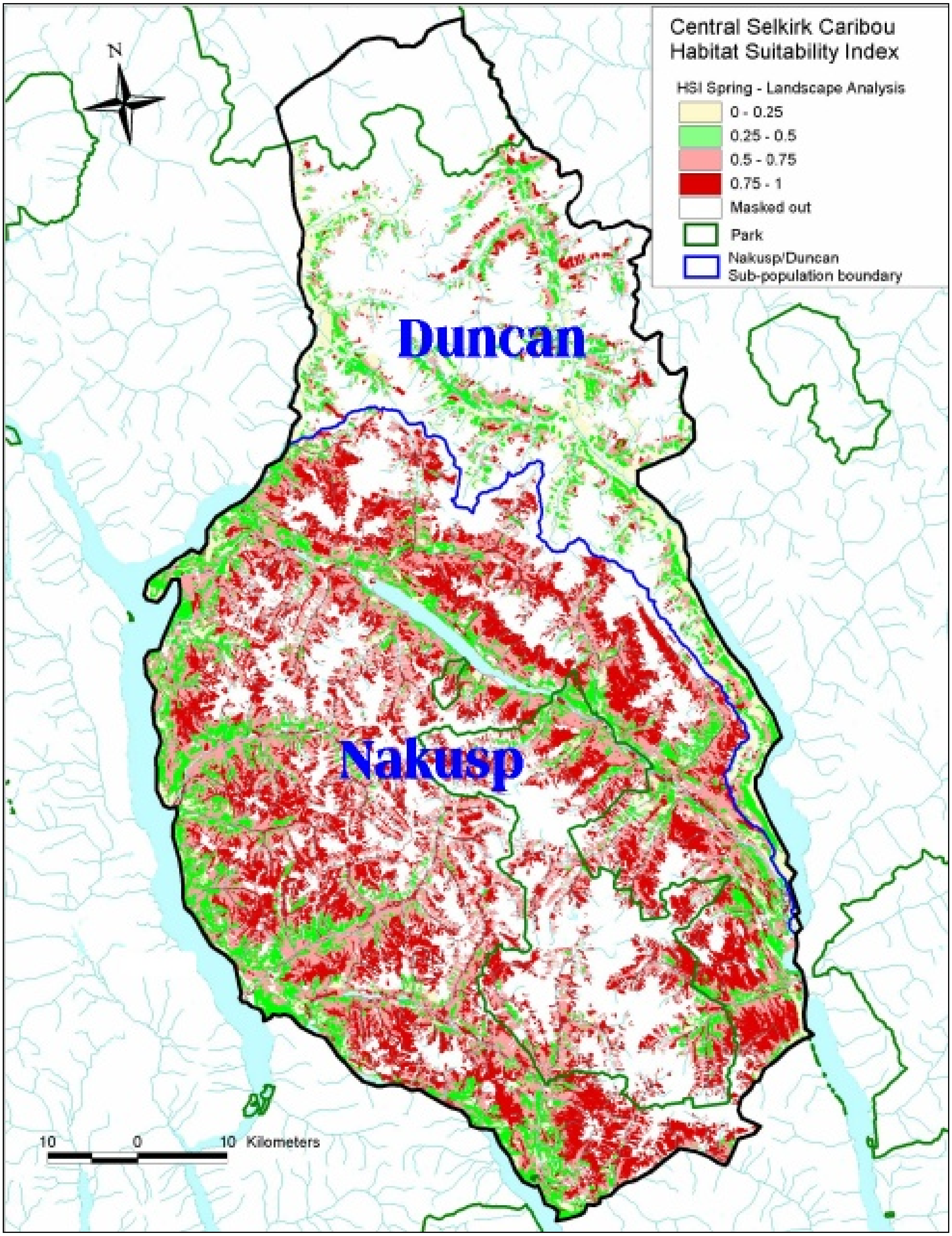

FIGURE 13: LANDSCAPE LEVEL MODEL - FOREST COVER/TRIM FOR DUNCAN/NAKUSP SUB-POPULATIONS (SUMMER/FALL)

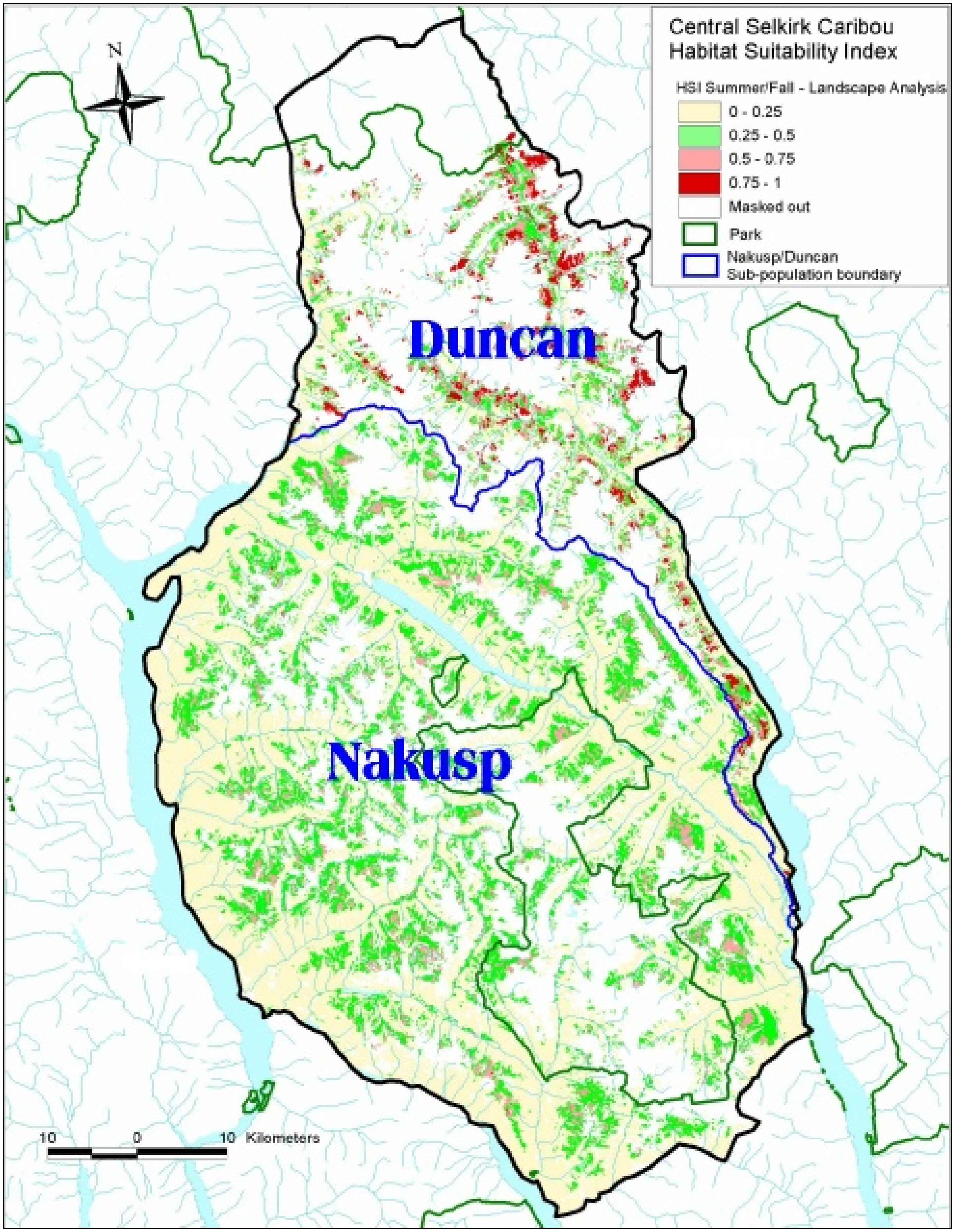

FIGURE 14: LANDSCAPE LEVEL MODEL - FOREST COVER/TRIM FOR DUNCAN/NAKUSP SUB-POPULATIONS (EARLY WINTER)

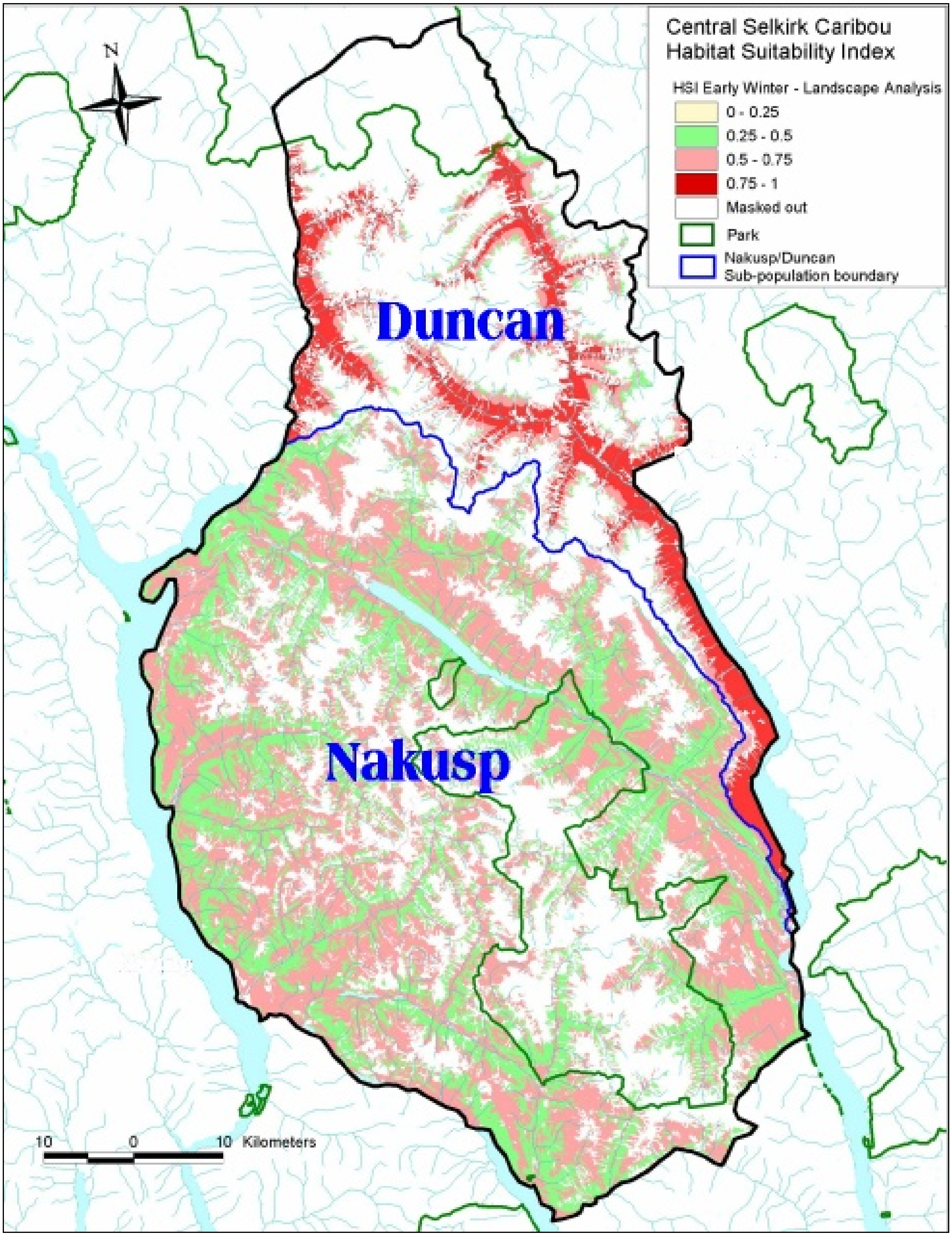

FIGURE 15: LANDSCAPE LEVEL MODEL - FOREST COVER/TRIM FOR DUNCAN/NAKUSP SUB-POPULATIONS (LATE WINTER)

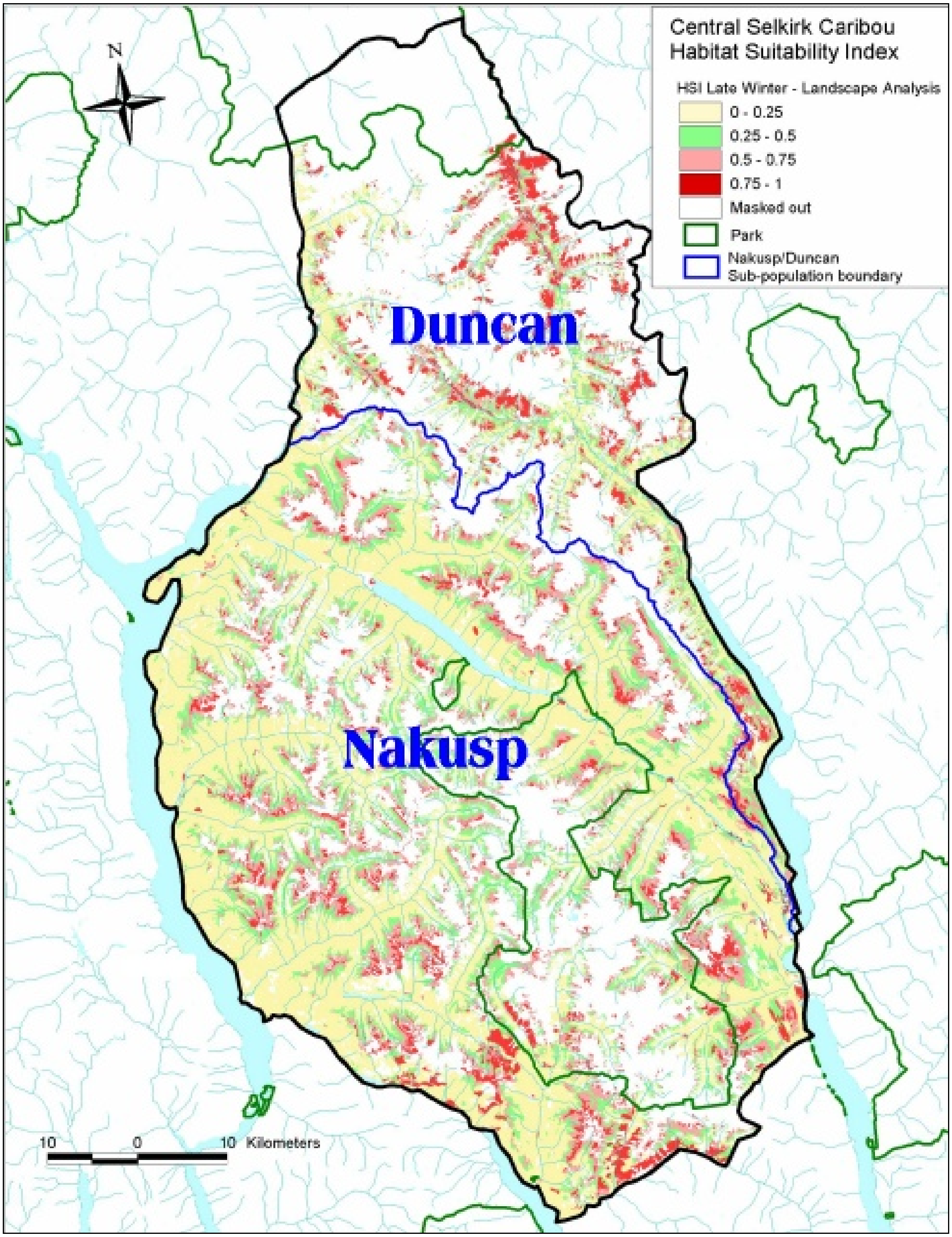

FIGURE 16: LANDSCAPE LEVEL MODEL - MULTISCALE FOR DUNCAN/NAKUSP SUB-POPULATIONS (ALL SEASONS)

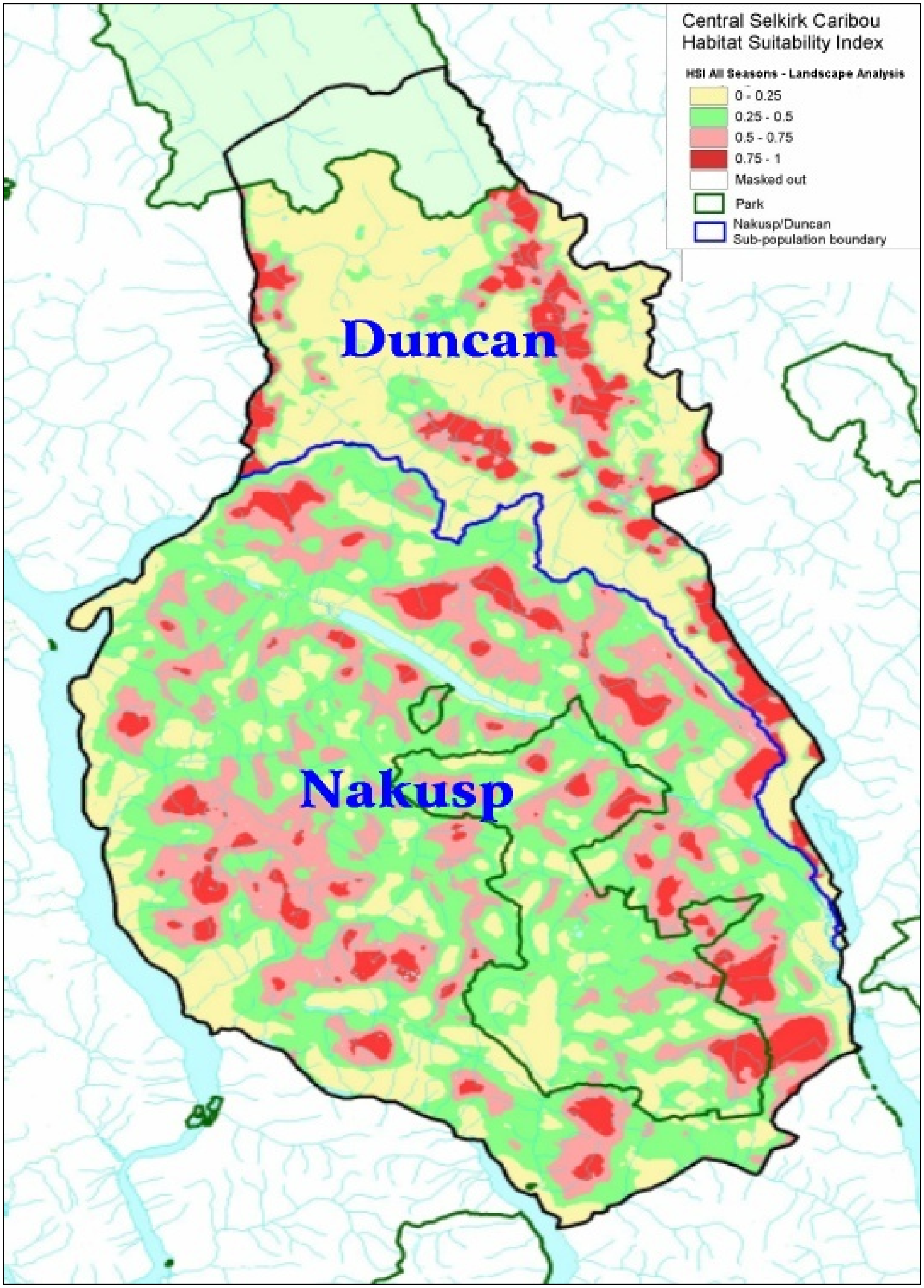

FIGURE 17: LANDSCAPE LEVEL MODEL - MULTISCALE FOR DUNCAN/NAKUSP SUB-POPULATIONS (SPRING)

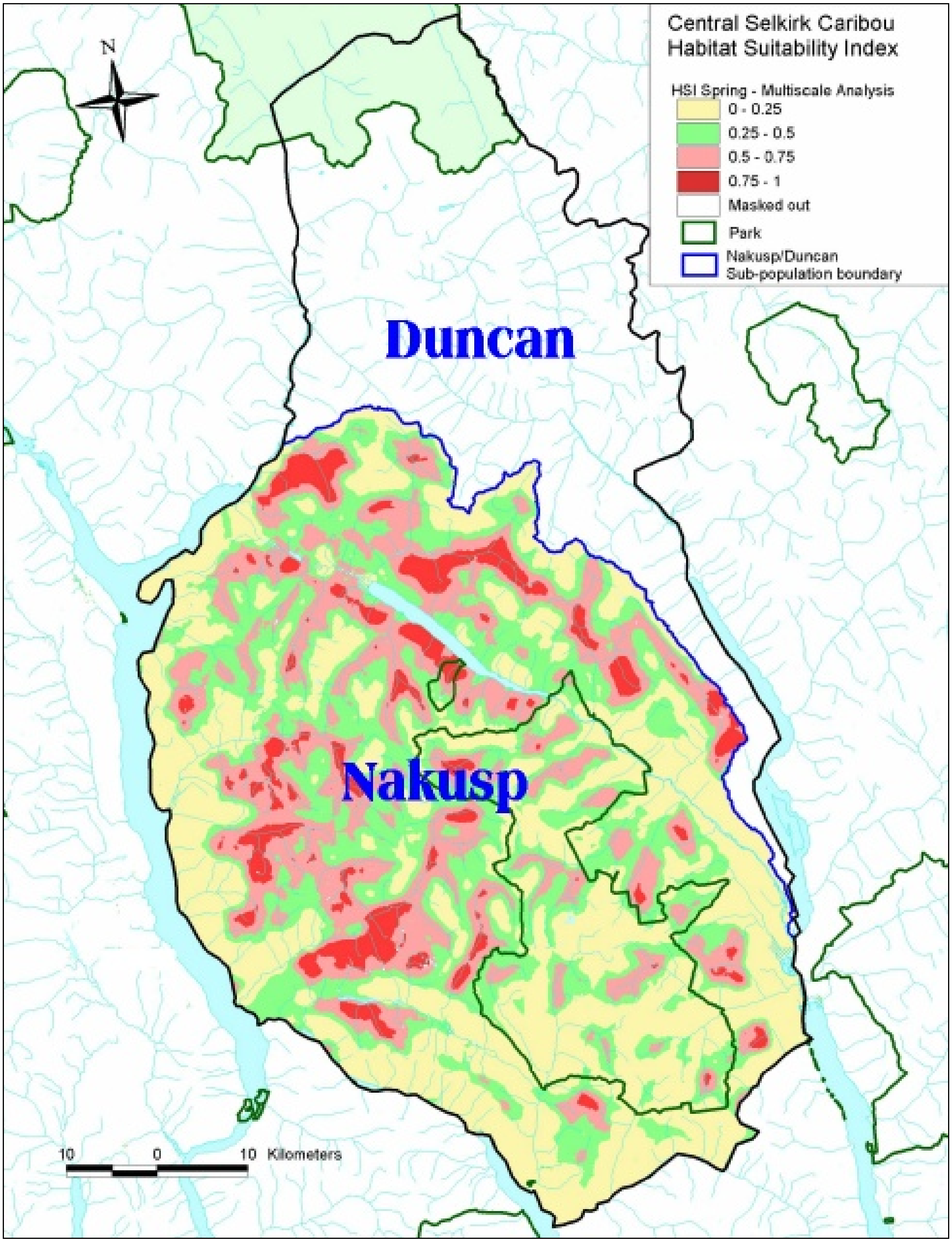

FIGURE 18: LANDSCAPE LEVEL MODEL - MULTISCALE FOR DUNCAN/NAKUSP SUB-POPULATIONS (SUMMER/FALL)

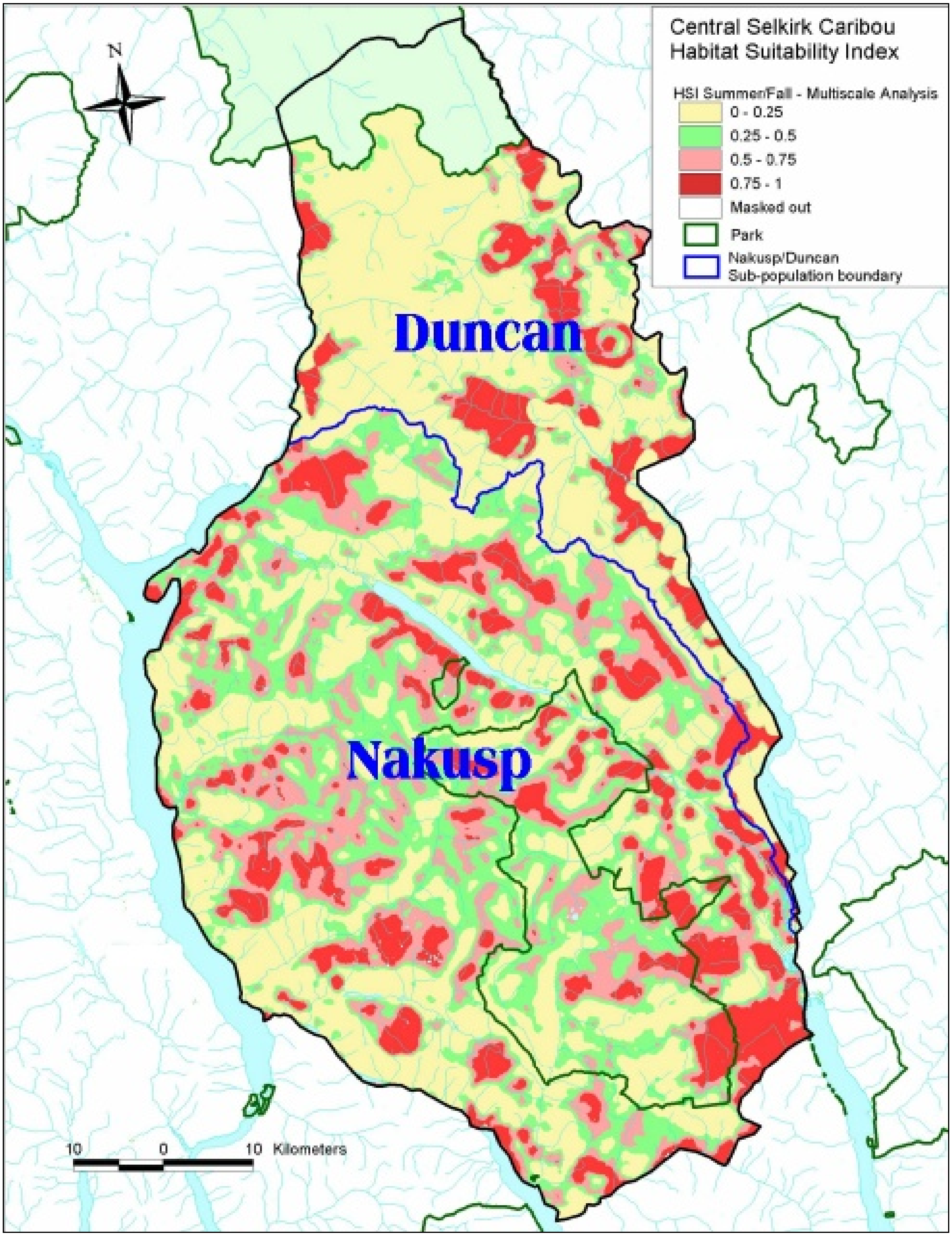

FIGURE 19: LANDSCAPE LEVEL MODEL - MULTISCALE FOR DUNCAN/NAKUSP SUB-POPULATIONS (EARLY WINTER)

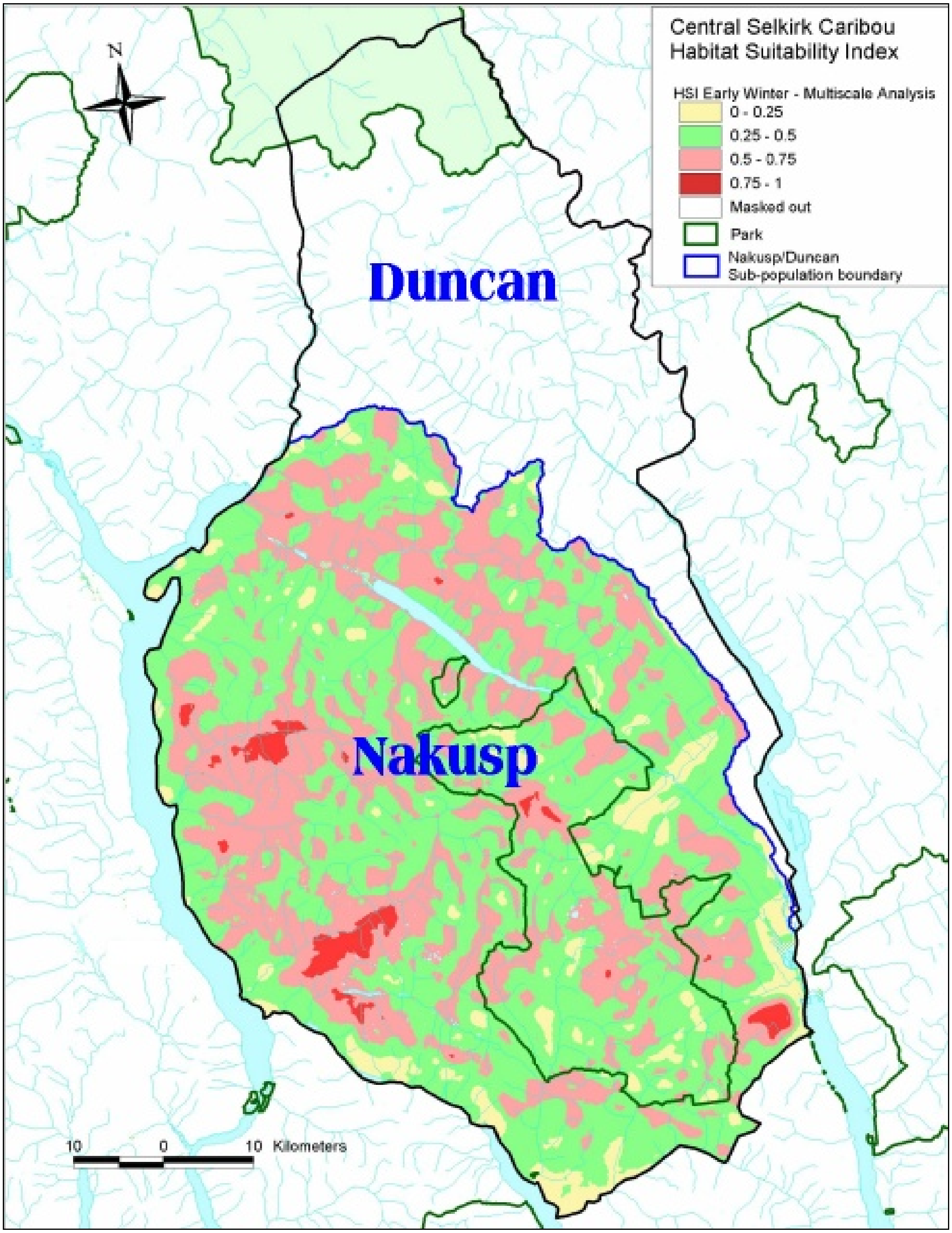

FIGURE 20: LANDSCAPE LEVEL MODEL - MULTISCALE FOR DUNCAN/NAKUSP SUB-POPULATIONS (LATE WINTER)

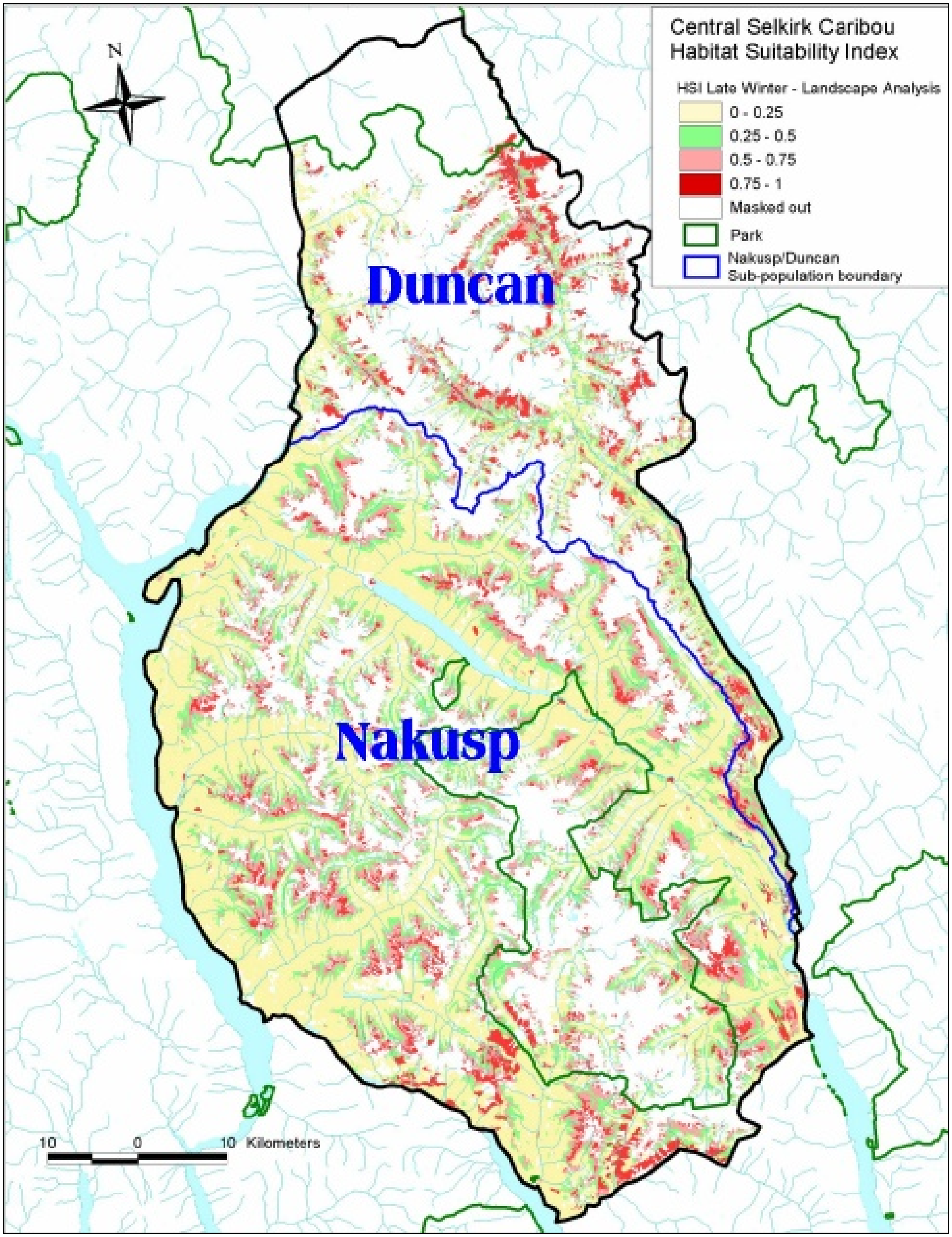

FIGURE 21: CENTRAL SELKIRK CARIBOU MIGRATION ROUTES

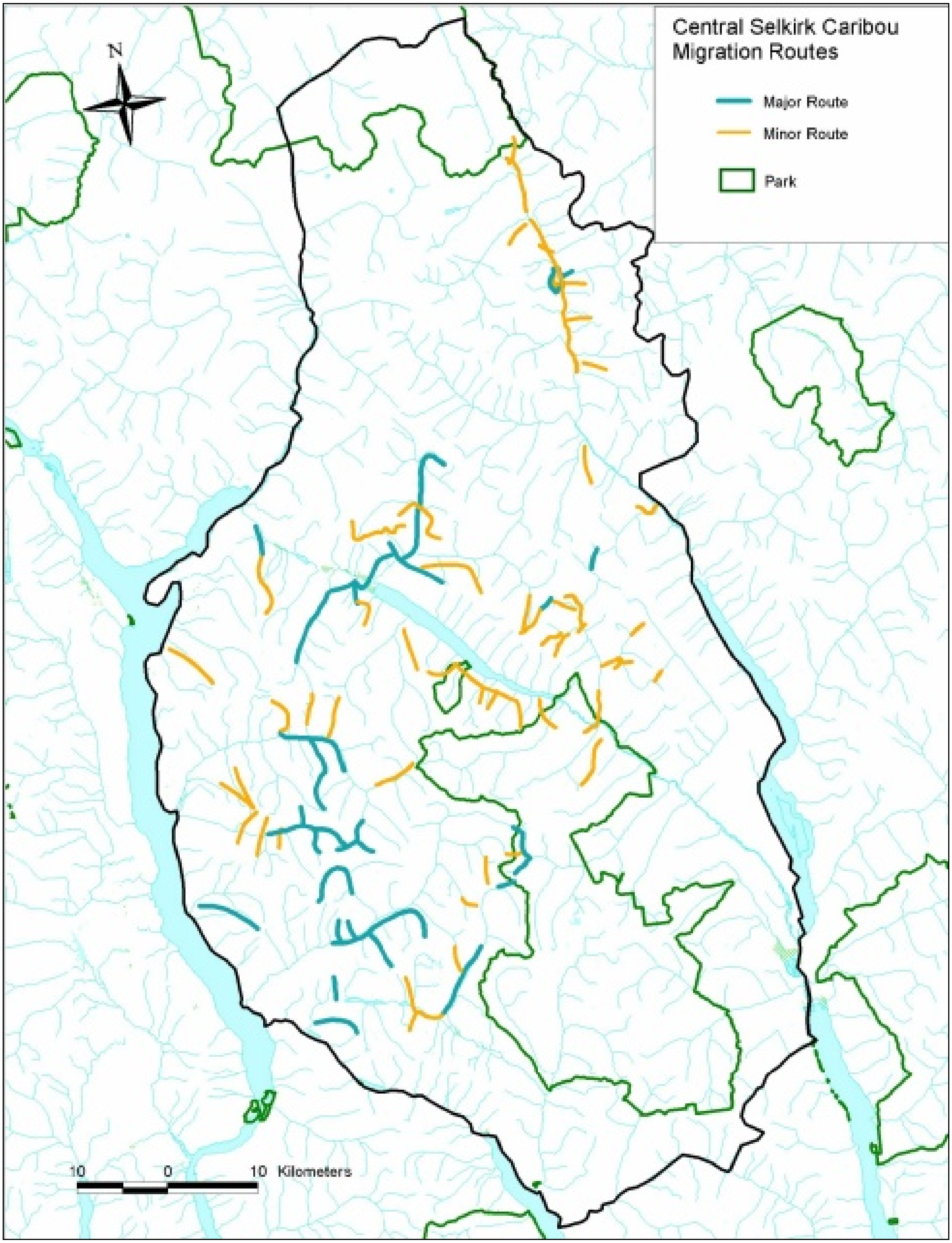

TABLE 1: SEASONS DEFINED BY ELEVATIONAL MOVEMENTS OF CARIBOU

Season	Code	Start date	End date
Early winter	EW	25 October	15 January
Late winter	LW	16 January	12 May
Spring	SP	13 May	30 June
Summer/fall	SU/FA	1 July	24 October

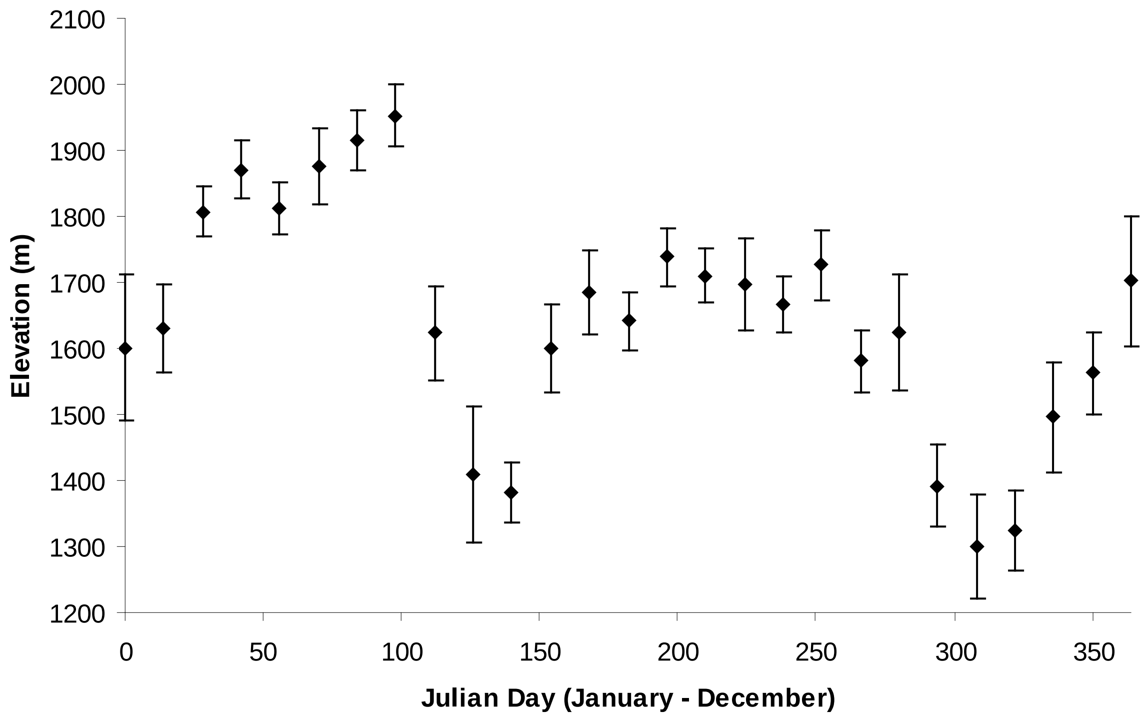

TABLE 2: CARIBOU COLLARED IN THE CENTRAL SELKIRK STUDY AREA. WHERE THE STATUS FIELD IS BLANK, CARIBOU WERE CARRYING FUNCTIONING COLLARS AS OF 31 DECEMBER 1999

Identifier	Frequency	Date Collared	Location	Status	Sex
54	150.115	Feb-92	Duncan	Dead Oct-98	M
55	150.133	Feb-92	Duncan	Dead Jun-98	F
53	150.150	Feb-92	Duncan	Dead Mar-93	F
1	151.060	Mar-95	Fitzstubbs		M
2	151.070	Mar-95	Wood	Dead Jul-97	F
3	151.150	Mar-95	Ione Falls	Dead Jul-99	F
4	151.176	Mar-95	Wood	Dead Jul-97	F
5	151.015	Mar-95	St. Leon	Dead Feb-97	F
6	151.036	Mar-95	Turner		F
7	151.090	Mar-95	Cape Horn		M
8	151.099	Mar-95	Cape Horn/Wilkie	Dead Nov-97	F
9	151.045	Mar-95	Hill		F
10	151.079	Mar-95	Hill		M
11	151.119	Mar-95	Halfway	Dead Sep-97	F
12	151.184	Mar-95	Wilkie		F
13	151.130	Mar-95	Halfway	Dead Aug-95	F
14	151.110	Mar-95	Healy	Dead Aug-96	F
15	151.025	Mar-96	Lardeau	Dead May-99	F
16	150.810	Mar-96	Healy Ck.	Dead Jul-99	F
17	151.006	Mar-96	Pollman Ck.	Dead Mar-99	F
18	151.434	Mar-96	Payne Creek	Dead Sep-97	F
19	151.260	Mar-97	Mt. Goat Creek		F
20	151.110	Mar-97	Swedish	Dead Jan-98	F
21	151.206	Mar-97	Swedish		F
22	151.142	Mar-97	Mt. Johnson	Dead Jul-97	F
23	151.195	Mar-97	Mt. Johnson	Dead Apr-98	M
24	151.330	Mar-97	Tenderfoot	Dead Jul-99	F
25	151.412	Mar-97	Mobbs Ck.	Dead Aug-99	F
26	151.572	Apr-98	Hamling Lakes		F
27	151.482	Apr-98	Ranch Ridge		F
28	151.581	Apr-98	Ranch Ridge	Dead Aug-98	M
29	151.420	Apr-98	Silvercup		F
30	151.130	Apr-98	Upper St. Leon		M
31	151.350	Apr-98	Nacillewaet		M
32	151.590	Apr-98	St. Leon/Gardner		F

TABLE 3: CONFIRMED AND PROBABLE CAUSES OF MORTALITY AMONG COLLARED CARIBOU ON THE CENTRAL SELKIRK STUDY AREA

Cause	# of caribou
Suspected poaching	1
Predation:	
Grizzly bear	4
Cougar	1
Wolverine	1
Natural (suspected heart attack)	1
Unknown	7
Total	15

TABLE 4: TOTAL AND ADULT-ONLY POPULATION ESTIMATES ON THE CENTRAL SELKIRK STUDY SITE (based on total count spring aerial surveys).

The ratio of marked animals seen to total marked animals was used as an index of sightability. "Minimum" is the actual number of animals seen on the surveys, "estimate" is based on Lincoln-Peterson indices, where they could be calculated.

Study area	All age classes			Adults only		
Year	Minimum	Estimate	90% CI	Minimum	Estimate	90% CI
1996	211	268	230-354	189	246	208-332
1997	223	231	223-266	206	214	206-239
1999	181	213	190-266	167	199	176-252
Nakusp only						
1996	186	211	191-264	167	192	172-245
1997	203	211	203-236	186	194	186-219
1999	155	182	162-226	143	170	150-214
Duncan only						
1996	25	-	-	22	-	-
1997	24	-	-	20	-	-
1999	26	-	-	24	-	-

TABLE 5: FREQUENCY OF CARIBOU AND RANDOM LOCATIONS IN DIFFERENT HABITAT TYPES, BY SEASON

	Season					
Habitat type	All	Late winter	Spring	Summer/Fall	Early winter	Random
Alpine	77	35	7	34	1	24
Subalpine	486	244	72	106	64	28
Meadow	3	0	0	2	1	0
Essf	586	117	82	257	130	34
Clearcuts	22	2	9	5	6	10
Burns	32	8	11	11	2	7
Cedar-hemlock	276	34	59	79	104	36
Slidepath	108	8	51	41	8	19
Immature	20	3	3	8	6	5
Riparian	12	1	3	8	0	2
Cedar-spruce	27	5	5	8	9	0
Rock/ice/lake	19	5	0	11	3	26
Semi-mature	36	5	2	4	25	9
Total	1704	467	304	574	359	200

TABLE 6: LOGISTIC REGRESSION RESULTS FOR RESOURCE SELECTION ANALYSIS BASED ON BROAD HABITAT TYPES

Rock/Ice/Lake was the reference category and was not included in the analysis

	All seasons n=1907, -2LL=1179 Chi²(10)=101 p<0.001			Late winter n=670, -2LL=665 Chi²(10)=152 p<0.001			Spring n=504, -2LL=605 Chi²(10)=72 p<0.001		
Variable	Estimate	SE	p-level	Estimate	SE	p-level	Estimate	SE	p-level
Intercept	0.693	0.240	0.004	-0.693	0.340	0.041	-1.649	0.488	0.001
Alpine	0.473	0.335	0.159	1.070	0.431	0.013	0.417	0.650	0.522
Subalpine	2.161	0.309	0.000	2.858	0.394	0.000	2.593	0.537	0.000
ESSF	2.154	0.298	0.000	1.929	0.392	0.000	2.529	0.529	0.000
Clearcuts	0.095	0.451	0.833	-0.916	0.846	0.279	1.543	0.670	0.021
Burns	0.827	0.481	0.086	0.827	0.619	0.182	2.101	0.687	0.002
ICH	1.344	0.298	0.000	0.636	0.415	0.126	2.143	0.532	0.000
Slidepaths	1.045	0.346	0.003	-0.172	0.541	0.751	2.636	0.557	0.000
Immature	0.693	0.555	0.211	0.182	0.805	0.821	1.138	0.878	0.195
Riparian	1.099	0.801	0.170	0.000	1.271	1.000	2.054	1.035	0.047
Semi-mature	0.693	0.443	0.118	0.105	0.653	0.872	0.145	0.922	0.875
Rock/Ice/Lake	0.000	0.000	1.000	0.000	0.000	1.000	0.000	0.000	1.000

	Summer/fall n=774, -2LL=795 Chi²(10)=90 p<0.001			Early winter n=559, -2LL=616 Chi²(10)=113 p<0.001		
Variable	Estimate	SE	p-level	Estimate	SE	p-level
Intercept	-0.214	0.293	0.467	-0.693	0.340	0.041
Alpine	0.562	0.396	0.156	-2.485	1.076	0.021
Subalpine	1.545	0.362	0.000	1.520	0.408	0.000
ESSF	2.236	0.346	0.000	2.034	0.390	0.000
Clearcuts	-0.480	0.621	0.440	0.182	0.618	0.768
Burns	0.666	0.566	0.239	-0.560	0.871	0.520
ICH	1.000	0.356	0.005	1.754	0.391	0.000
Slidepaths	0.983	0.404	0.015	-0.172	0.541	0.751
Immature	0.684	0.641	0.286	0.875	0.694	0.207
Riparian	1.600	0.843	0.058	-17.510	3846.3	0.996
Semi-mature	-0.597	0.669	0.372	1.715	0.516	0.001
Rock/Ice/Lake	0.000	0.000	1.000	0.000	0.000	1.000

TABLE 7: CLASSIFICATION RATES AND ODDS RATIOS FOR RESOURCE SELECTION MODEL BASED ON HABITAT TYPES

	Percent correctly classified				
	All seasons	**Late winter**	**Spring**	**Summer/fall**	**Early winter**
Telemetry	62.8	76.8	91.4	64.6	90.0
Random	69.0	69.0	37.4	68.0	46.5
Odds ratio	3.8	7.4	6.3	4.2	7.8

TABLE 8: MEANS AND STANDARD ERRORS FOR VARIABLES USED IN THE LANDSCAPE LEVEL MODEL

Based on forest cover and terrain attributes (all seasons combined). Note that standard errors are not valid for data expressed as percentages, but are included for descriptive purposes.

	Telemetry			Random		
	n	**mean**	**1.64SE**	**n**	**mean**	**1.64SE**
CURV	1226	0.18	0.01	998	0.17	0.01
ELEV_GIS	1242	1637.20	14.61	999	1462.09	19.90
SLP_GIS	1242	41.60	0.85	999	49.21	1.09
SOLAR	1242	12711.58	75.40	999	12555.66	87.11
PROJ_AGECL	1242	7.34	0.10	999	6.40	0.14
SITE_INDEX	1242	12.18	0.21	999	13.13	0.26
DECID	1242	0.09	0.06	999	1.01	0.40
B_SUM	1242	39.51	1.53	999	27.91	1.72
CW	1242	6.18	0.70	999	10.38	1.03
FD	1242	3.24	0.61	999	8.85	1.06
H_SUM	1242	16.16	1.27	999	22.09	1.54
L_SUM	1242	0.64	0.25	999	1.53	0.38
PA	1242	0.83	0.22	999	0.62	0.21
PL_PW	1242	1.51	0.38	999	3.60	0.61
S_SUM	1242	29.63	1.24	999	20.82	1.38

TABLE 9: CARIBOU HABITAT MODEL COEFFICIENTS FOR THE NAKUSP HERD BASED ON FOREST COVER AND TERRAIN ATTRIBUTES

	All seasons			Late winter			Spring		
	n=1868, -2LL=2259			n=496, -2LL=439			n=303, -2LL=340		
	Chi²(5)=313 p<0.001			Chi²(8)=248 p<0.001			Chi²(9)=79 p<0.001		
Variable	**Estimate**	**SE**	**p-level**	**Estimate**	**SE**	**p-level**	**Estimate**	**SE**	**p-level**
Intercept	-2.585	0.544	0.000	-5.254	0.915	0.000	-1.563	1.922	0.416
CURV							2.432	0.924	0.009
ELEV_GIS	0.002	0.000	0.000	0.004	0.001	0.000	0.001	0.001	0.048
SLP_GIS	-0.026	0.003	0.000	-0.033	0.007	0.000	-0.022	0.008	0.007
SOLAR	0.000	0.000	0.012	0.000	0.000	0.078	0.000	0.000	0.084
PROJ_AGECL	0.004	0.001	0.000	0.004	0.002	0.021	0.007	0.002	0.000
SITE_INDEX	0.042	0.015	0.005				0.109	0.039	0.005
DECID				0.070	0.048	0.149			
B_SUM				0.010	0.005	0.046			
L_SUM				0.039	0.016	0.017			
PL_PW				-0.044	0.022	0.049			
FD							-0.027	0.013	0.029
H_SUM							-0.007	0.006	0.300
PA							0.052	0.043	0.228

	Summer/fall			Early winter		
	n=630, -2LL=702			n=433, -2LL=559		
	Chi²(11)=169 p<0.001			Chi²(3)=10 p<0.025		
Variable	**Estimate**	**SE**	**p-level**	**Estimate**	**SE**	**p-level**
Intercept	-7.534	2.115	0.000	0.108	0.488	0.824
CURV	-1.849	0.640	0.004			
ELEV_GIS	0.002	0.001	0.001	0.000	0.000	0.205
SLP_GIS	-0.030	0.005	0.000	-0.012	0.006	0.044
SOLAR	0.000	0.000	0.002			
PROJ_AGECL	0.006	0.001	0.000	0.002	0.001	0.041
SITE_INDEX	0.069	0.031	0.027			
B_SUM	0.058	0.019	0.002			
CW	0.048	0.019	0.014			
FD	0.054	0.021	0.011			
H_SUM	0.059	0.019	0.002			
S_SUM	0.060	0.019	0.002			

TABLE 10: CLASSIFICATION RATES AND ODDS RATIOS OF TELEMETRY AND RANDOM LOCATIONS FOR THE LANDSCAPE LEVEL HABITAT MODEL FOR THE NAKUSP HERD BASED ON FOREST COVER AND TERRAIN ATTRIBUTES

	Percent correctly classified				
	All seasons	**Late winter**	**Spring**	**Summer/fall**	**Early winter**
Telemetry	77.7	83.1	78.3	79.3	97.1
Random	56.1	73.9	63.1	62.3	8.8
Odds ratio	4.4	13.9	5.2	6.3	3.2

TABLE 11: CARIBOU HABITAT MODEL COEFFICIENTS FOR THE DUNCAN HERD BASED ON FOREST COVER AND TERRAIN ATTRIBUTES

	All seasons			Late winter			Spring		
	n=262, -2LL=297			n=78, -2LL=69			n=47, -2LL=48		
	Chi²(7)=42 p<0.001			Chi²(5)=26 p<0.001			Chi²(5)=12 p<0.05		
Variable	**Estimate**	**SE**	**p-level**	**Estimate**	**SE**	**p-level**	**Estimate**	**SE**	**p-level**
Intercept	1.201	1.170	0.304	-1.592	2.099	0.448	-3.955	2.518	0.116
CURV	-2.808	1.036	0.007	-5.933	2.312	0.010			
ELEV_GIS	0.002	0.001	0.003	0.005	0.002	0.004	0.004	0.002	0.069
SLP_GIS	-0.023	0.007	0.001	-0.043	0.017	0.009			
PROJ_AGECL							0.009	0.004	0.023
SITE_INDEX	-0.071	0.050	0.161						
B_SUM	-0.026	0.008	0.001	-0.036	0.015	0.018	-0.050	0.023	0.029
CW	-0.017	0.009	0.066	-0.026	0.021	0.204	-0.042	0.024	0.079
FD	-0.036	0.021	0.092						
PL_PW							-0.180	0.145	0.215

	Summer/fall			Early winter		
	n=86, -2LL=87			n=52, -2LL=57		
	Chi²(8)=28 p<0.001			Chi²(2)=12 p<0.001		
Variable	**Estimate**	**SE**	**p-level**	**Estimate**	**SE**	**p-level**
Intercept	0.323	2.494	0.897	6.169	1.997	0.002
CURV	-4.730	2.703	0.080			
ELEV_GIS	0.004	0.001	0.008	-0.003	0.001	0.006
SLP_GIS	-0.030	0.014	0.032			
PROJ_AGECL				-0.007	0.003	0.046
SITE_INDEX	-0.168	0.104	0.104			
B_SUM	-0.035	0.018	0.051			
CW	-0.056	0.040	0.167			
H_SUM	0.018	0.017	0.314			
PA	-0.074	0.059	0.204			

TABLE 12: CLASSIFICATION RATES AND ODDS RATIOS OF TELEMETRY AND RANDOM LOCATIONS FOR THE LANDSCAPE LEVEL HABITAT MODEL BASED ON FOREST COVER AND TERRAIN ATTRIBUTES FOR THE DUNCAN HERD

	Percent correctly classified				
	All seasons	**Late winter**	**Spring**	**Summer/fall**	**Early winter**
Telemetry	90.0	94.5	80.6	79.2	87.5
Random	34.8	52.2	43.8	57.6	55.0
Odds ratio	4.8	18.9	3.2	5.2	8.6

TABLE 13: MULTISCALE HABITAT MODEL COEFFICIENTS FOR THE NAKUSP HERD BASED ON FOREST COVER AND TERRAIN ATTRIBUTES

	All seasons			Late winter			Spring		
	n=2810, -2LL=3426			n=764, -2LL=824			n=488, -2LL=574		
	Chi²(13)=468 p<0.001			Chi²(10)=235 p<0.001			Chi²(7)=102 p<0.001		
Variable	**Estimate**	**SE**	**p-level**	**Estimate**	**SE**	**p-level**	**Estimate**	**SE**	**p-level**
Intercept				-13.979	2.004	0.000	4.661	2.183	0.033
SLP (250)	-0.024	0.007	0.000	-0.034	0.010	0.001			
CURV (250)	-5.730	1.193	0.000				-10.185	2.087	0.000
B_SUM (250)				0.034	0.007	0.000			
DEC (250)				0.138	0.050	0.006	-0.517	0.278	0.063
FD (250)	0.017	0.007	0.011						
H_SUM (250)				0.036	0.012	0.003			
PA (250)	0.047	0.025	0.057						
AGE (250)	0.188	0.037	0.000						
S_SUM (250)	-0.026	0.005	0.000						
SOLAR (250)	0.000	0.000	0.000				0.000	0.000	0.064
B_SUM (1000)							-0.006	0.011	0.598
CW (1000)	0.062	0.010	0.000	0.057	0.029	0.050			
ELEV (1000)	0.003	0.000	0.000	0.007	0.001	0.000			
FD(1000)				0.065	0.018	0.000	-0.040	0.023	0.081
H_SUM (1000)				0.098	0.021	0.000			
L_SUM (1000)							-0.183	0.093	0.049
AGE (1000)	0.350	0.049	0.000				0.454	0.087	0.000
B_SUM (2500)	0.023	0.006	0.000						
H_SUM (2500)	-0.035	0.006	0.000	-0.075	0.015	0.000			
S_SUM (2500)				0.090	0.016	0.000			
SOLAR (2500)	0.000	0.000	0.000						

	Summer/fall			Early winter		
	n=940, -2LL=1022			n=618, -2LL=798		
	Chi²(16)=281 p<0.001			Chi²(6)=59 p<0.001		
Variable	**Estimate**	**SE**	**p-level**	**Estimate**	**SE**	**p-level**
Intercept	9.435	2.814	0.001	-2.007	0.717	0.005
SLP (250)	-0.044	0.014	0.002			
CURV (250)	-6.556	2.016	0.001	-6.835	1.792	0.000
FD (250)	0.151	0.037	0.000			
PA (250)	0.237	0.108	0.027			
SOLAR (250)	0.000	0.000	0.000			
B_SUM (1000)	-0.039	0.011	0.001			
ELEV (1000)	0.004	0.001	0.000	0.002	0.000	0.000
FD (1000)	-0.181	0.045	0.000			
L_SUM (1000)				0.025	0.017	0.137
PLPW (1000)	-0.240	0.078	0.002			
AGE (1000)	1.062	0.146	0.000			
S_SUM (1000)	-0.108	0.018	0.000			
S_IND (1000)	0.157	0.066	0.018			
SOLAR (1000)				0.001	0.000	0.026
CURV (2500)	-14.440	3.808	0.000			
CW (2500)	-0.075	0.031	0.014			
H_SUM (2500)	-0.067	0.018	0.000	0.053	0.010	0.000
SOLAR (2500)	0.000	0.000	0.001	-0.001	0.000	0.023

TABLE 14: CLASSIFICATION RATES AND ODDS RATIOS OF TELEMETRY AND RANDOM LOCATIONS FOR THE LANDSCAPE LEVEL HABITAT MODEL BASED ON FOREST COVER AND TERRAIN ATTRIBUTES FOR THE NAKUSP HERD

	Percent correctly classified				
	All seasons	Late winter	Spring	Summer/fall	Early winter
Telemetry	67.8	78.0	75.8	77.2	65.4
Random	64.6	69.4	66.0	72.6	61.2
Odds ratio	3.8	8.0	6.1	9.0	3.0

TABLE 15: MULTISCALE HABITAT MODEL COEFFICIENTS FOR THE DUNCAN HERD BASED ON FOREST COVER AND TERRAIN ATTRIBUTES

	All seasons			Late winter			Summer/fall		
	n=604, -2LL=556 Chi²(19)=282 p<0.001			n=176, -2LL=165 Chi²(16)=79 p<0.001			n=208, -2LL=162 Chi²(16)=126 p<0.001		
Variable	Estimate	SE	p-level	Estimate	SE	p-level	Estimate	SE	p-level
Intercept	3.927	4.607	0.394	-6.343	4.968	0.202	0.570	4.634	0.902
SLP (250)	-0.049	0.015	0.001						
CURV (250)							0.014	0.057	0.804
DEC (250)	0.177	0.130	0.172	0.175	0.320	0.583	-2.072	2.717	0.446
PA (250)	0.282	0.087	0.001	0.471	0.140	0.001	0.237	0.170	0.162
PLPW (250)							-0.801	0.895	0.370
SOLAR (250)							0.000	0.000	0.020
CW (1000)	-0.283	0.071	0.000	-0.481	0.140	0.001			
H_SUM (1000)	-0.159	0.041	0.000	-0.262	0.073	0.000	-0.377	0.114	0.001
PA (1000)	-0.473	0.188	0.012	-1.180	0.342	0.001	-1.151	0.449	0.010
PLPW (1000)	-1.996	0.589	0.001	-2.236	1.049	0.033			
AGE (1000)	1.269	0.276	0.000	2.437	0.659	0.000	3.453	0.774	0.000
S_SUM (1000)	-0.245	0.048	0.000	-0.478	0.111	0.000	-0.390	0.098	0.000
S_IND (1000)	0.424	0.116	0.000	0.893	0.220	0.000			
SLP (1000)	0.109	0.029	0.000				0.066	0.055	0.226
SOLAR (1000)				0.000	0.000	0.052	0.001	0.000	0.012
B_SUM (2500)	-0.219	0.043	0.000	-0.237	0.083	0.005	-0.526	0.118	0.000
CURV (2500)	-31.682	5.521	0.000	-28.791	10.315	0.005			
CW (2500)	0.131	0.094	0.162						
DEC (2500)	-0.805	0.223	0.000	-0.288	0.207	0.163			
H_SUM (2500)	0.130	0.052	0.013				0.155	0.137	0.257
PA (2500)	0.865	0.279	0.002				2.597	0.709	0.000
S_SUM (2500)	0.150	0.040	0.000	0.236	0.074	0.001	0.352	0.097	0.000
SLP (2500)				0.234	0.077	0.002	-0.209	0.059	0.000
SOLAR (2500)	0.000	0.000	0.878	0.000	0.000	0.152			

TABLE 16 CLASSIFICATION RATES AND ODDS RATIOS OF TELEMETRY AND RANDOM LOCATIONS FOR THE LANDSCAPE LEVEL HABITAT MODEL BASED ON FOREST COVER AND TERRAIN ATTRIBUTES FOR THE NAKUSP HERD

	Percent correctly classified		
	All seasons	Late winter	Summer/fall
Telemetry	83.8	78.4	83.7
Random	77.2	73.9	79.8
Odds ratio	17.4	10.3	20.2

TABLE 17: STAND LEVEL VARIABLE MEANS AND STANDARD ERRORS FOR TELEMETRY SITES (ALL SEASONS COMBINED) AND RANDOM SITES

	Telemetry sites			Random sites		
	n	Mean	1.64SE	n	Mean	1.64SE
Elevation	112	1596.7	58.4	155	1549.6	58.0
Moisture	114	3.5	0.2	157	2.9	0.2
Nutrient	114	98.6	2.5	157	88.9	4.3
Windthrow	114	1.7	0.1	157	1.7	0.1
Slope	110	32.8	3.1	131	43.3	3.0
Crown closure	114	54.5	4.6	157	48.0	4.7
Sightability	114	12.8	1.1	157	13.1	1.1
CWD (# pieces)	114	7.9	0.9	157	6.0	0.7
CWD	108	24.0	2.8	129	22.5	1.4
Plot lichen estimate	35	103.4	14.1	108	91.7	9.4
Stand age	100	159.3	10.0	102	156.6	8.7
Stems/ha	118	80.5	17.5	126	84.5	15.6
Lichen load	115	1.9	0.2	126	1.5	0.2
Branch litterfall	126	1.6	0.1	114	1.6	0.1

TABLE 18 COEFFICIENTS FOR THE STAND LEVEL MODEL BASED ON FOREST COVER AND ATTRIBUTE DATA COLLECTED AT THE STAND LEVEL

	All seasons			Late winter			Spring		
	n=234, -2LL=279			n=147, -2LL=96			n=155, -2LL=128		
	Chi²(8)=45 p<0.000			Chi²(5)=38 p<0.000			Chi²(3)=27 p<0.000		
Variable	**Estimate**	**SE**	**p-level**	**Estimate**	**SE**	**p-level**	**Estimate**	**SE**	**p-level**
Intercept	-4.587	1.273	0.000	-12.449	2.688	0.000	-5.978	1.982	0.003
ELEVATION	0.001	0.000	0.003	0.004	0.001	0.000	0.002	0.001	0.004
MOIST	0.200	0.130	0.125				0.641	0.235	0.006
WINDTHROW	0.564	0.237	0.017						
SLOPE_AV	-0.027	0.008	0.001				-0.037	0.013	0.004
SIGHT_AV	0.043	0.023	0.062	0.143	0.047	0.003			
CWD	0.050	0.029	0.088	0.116	0.052	0.027			
CWD_AVG	0.021	0.016	0.205	0.052	0.030	0.087			
LICH_AVG	0.254	0.125	0.041	0.545	0.225	0.015			

	Summer/fall			Early winter		
	n=154, -2LL=122			n=128, -2LL=97		
	Chi²(4)=30 p<0.000			Chi²(8)=32 p<0.000		
Variable	**Estimate**	**SE**	**p-level**	**Estimate**	**SE**	**p-level**
Intercept	37.497	30.644	0.221	-3.317	1.342	0.013
ELEVATION	0.002	0.001	0.001			
MOIST	0.532	0.212	0.012			
NUTR	-0.426	0.303	0.160			
WINDTHROW				0.838	0.413	0.043
SLOPE_AV	-0.042	0.014	0.002	-0.017	0.012	0.152
CROWN_AV				-0.067	0.024	0.005
CWD				0.096	0.057	0.095
AGE				0.010	0.005	0.039
STEMS_HA				0.005	0.002	0.033
LICH_AVG				0.413	0.224	0.065
BRANCH_L				-0.597	0.378	0.114

TABLE 19: CLASSIFICATION RATES AND ODDS RATIOS FOR THE STAND LEVEL MODEL

	Percent correctly classified				
	All seasons	**Late winter**	**Spring**	**Summer/fall**	**Early winter**
Telemetry	67.9	64.0	77.4	60.0	73.1
Random	74.6	89.3	69.4	85.5	84.3
Odds ratio	6.2	14.9	7.8	8.8	14.6

TABLE 20 RESULTS OF $\chi 2$ TESTS ON THE FREQUENCY OF OCCURENCE OF DIFFERENT TREE SPECIES ON TELEMETRY AND RANDOM SITES, BY STRATUM

Plus signs indicate that a species category occurred significantly more often on telemetry sites, minus signs indicate that a species category occurred significantly more often on random sites. Comparisons that were dropped from the analyses to meet the assumptions of chi-square tests are labeled 'n/a.' Empty cells denote frequencies that were not significantly different between telemetry and random sites.

	Stratum			
Species	**A1**	**A2**	**A3**	**DS**
Deciduous (DECID)	n/a			---
Fir species (B_SUM)		+++	+++	+++
Western redcedar (CW)	---			---
Douglas fir (FD)				
Hemlock species (H_SUM)	---		---	
Larch species (L_SUM)	---	---	n/a	---
Whitebark pine (PA)	n/a			
Lodgepole/western white pine (PL_PW)		---		---
Spruce species (S_SUM)	+++	---		

APPENDIX I

Variables, variable codes, and details of data collection methods for stand level attributes.

Variable	Code	Details
Elevation	ELEV	Altimeter reading or TRIM reference
Aspect	N,E,S,W_ASP	Degrees categorized into 4 cardinal directions
Moisture	MOIST	From site series classification
Nutrient	NUTR	From site series classification
Windthrow	WIND	See form FS 39DHSP 96/7 for criteria
Mean slope	SLOPE_AV	Average of up and downslope percent slope measured by clinometer
Crown closure	CROWN_AV	Mean of % crown closure estimates in 4 cardinal directions
Sightability	SIGHT_AV	Average of 4 sight board intersection counts from 4 cardinal directions. Intersections are counted from 15m on boards 0.5m above the ground.
Coarse woody debris (# pieces)	CWD	Number of pieces of downed wood >7.5cm in diameter and >0.5m above the ground intersecting hip chain string line
Average CWD diameter	CWD_AVG	Average of all pieces noted above
Plot lichen estimate	LICHEN_E	Estimate for entire plot (1999 only)
Age	AGE	Mean age of sample trees in V2 stratum (1998) or of all trees in prism sweep (1999)
Leading species	Bl, Hw, Sx, Cw	From timber type, categorical variable relative to other/none
Stems/ha	STEMS_HA	Count of all stems of all species in all strata
Average lichen load	LICH_AV	Mean of lichen class estimates for sample trees, from Armleder *et al.* (1992)
Branch litterfall	BRANCH_L	1 (low) - 3 (high) visual estimate for entire plot

APPENDIX II

Annual and multi-year home ranges for female caribou. The "Total" row lists the sum of sample sizes and mean home range size.

		1992		1993		1994		1995		1996		1997	1998		1999	Study		Mean	
Caribou	Sex	n	km²	n	km²	n	km²	n	km²	n	km²	n	n	km²	n	n	km²	km²	SD
2	f							19	84.5	23	55.4	6				48	109.4	70.0	20.6
3	f							17	230.5	20	184.6	10	20	74.5	14	81	537.7	163.2	80.2
11	f							19	98.4	23	211.0	8				50	457.0	154.7	79.6
12	f							19	77.2	23	79.5	11	20	133.4	14	87	298.0	96.7	31.8
13	f							10								10			
14	f							19	111.8	13						32	133.8	111.8	
15	f									20	133.3	10	20	140.1	8	58	184.9	136.7	4.8
16	f									18	125.4	9	21	218.0	14	62	449.0	171.7	65.5
17	f									19	302.7	9	21	327.8	7	56	480.1	315.2	17.7
18	f									19	169.1	8				27	179.2	169.1	
19	f											6	21	248.2	16	43	356.8	248.2	
20	f											5	1			6			
21	f											5	18	162.0	14	37	237.4	162.0	
22	f											3				3			
24	f											6	20	196.6	13	39	242.8	196.6	
25	f											6	20	160.1	15	41	312.9	160.1	
26	f												15	281.7	16	31	364.7	281.7	
27	f												15	160.8	16	31	286.4	160.8	
29	f												14		15	29	318.1		
4	f							19	323.6	23	142.2	7				49	438.4	232.9	128.3
5	f							19	122.1	23	232.2	4				46	510.2	177.1	77.8
6	f							18	150.8	23	214.6	8	20	122.4	15	84	413.1	162.6	47.2
8	f							17		20	282.0					37	407.3	282.0	
9	f							19	153.0	23	112.4	12	22	306.1	15	91	531.1	190.5	102.1
32	f												14		16	30	189.5		
53	f	21	50.3													28	52.9	50.3	
55	f	21	38.2	21	99.5	22	208.7	12		17	136.6	9	9			111	419.5	120.7	71.3
Total		42	44.3	21	99.5	22	208.7	207	150.2	307	170.1	142	291	194.8	208	1247	329.6	173.4	60.6

Annual and multi-year home ranges for male caribou. The “Total” row lists the sum of sample sizes and mean home range size.

		1992		1993		1994		1995		1996		1997	1998		1999	Study		Mean	
Caribou	Sex	n	km^2	n	km^2	n	km^2	n	km^2	n	km^2	n	n	km^2	n	n	km^2	km^2	SD
1	m							19		23	199.6	10	19	199.5	16	87	646.9	199.6	0.1
10	m							19	72.3	23	116.3	10	19	288.5	16	87	378.5	159.0	114.3
23	m											5	7			12			
28	m												7			7			
7	m							19	308.9	23	418.9	11	20	191.1	15	88	475.3	306.3	114.0
30	m												14		16	30	290.5		
31	m												15	444.0	14	29	499.6	444.0	
54	m	21	87.2	21	181.4	23	280.5	12		17	133.8	9	17	125.7		120	380.6	161.7	74.4
Total		21	87.2	21	181.4	23	280.5	69	190.6	86	217.2	45	118	249.8	77	460	445.2	254.1	75.7

APPENDIX III

Number of stems and frequency of occurrence of tree species, by category, at each canopy stratum for telemetry and random stand-level sites. Strata and species follow standard BC Forest Service abbreviations.

A1:

Telemetry			Random		
Species	**Stems**	**Frequency**	**Species**	**Stems**	**Frequency**
Bl	21	12	At	1	1
Cw	4	2	Bl	12	8
Fd	10	3	Cw	17	9
Hw	9	4	Fd	5	3
Pw	2	1	Hw	50	19
Sx	74	30	Lw	5	3
			Pl	1	1
			Sw	1	1
			Sx	38	21
Total	120	52		130	66

A2:

Telemetry			Random		
Species	**Stems**	**Frequency**	**Species**	**Stems**	**Frequency**
Ac	2	1	At	1	1
Bl	238	59	Bl	176	43
Cw	30	15	Cw	113	29
Fd	51	5	Ep	3	1
Hw	140	34	Fd	27	11
Pa	5	2	Hw	165	42
Pw	1	1	Lw	2	1
Se	3	1	Pa	9	4
Sx	95	40	Pl	119	6
			Pw	2	1
			Sw	1	1
			Sx	72	34
Total	565	158		690	174

A3:

Telemetry			Random		
Species	**Stems**	**Frequency**	**Species**	**Stems**	**Frequency**
Ac	1	1	Bl	271	53
Bl	344	69	Cw	88	28
Cw	69	23	Ep	8	2
Fd	39	5	Fd	21	7
Hw	112	34	Hw	236	49
Lw	1	1	Pa	6	3
Pa	22	8	Pl	17	3
Pw	5	2	Sx	68	29
Se	1	1			
Sw	1	1			
Sx	79	31			
Total	674	176		715	174

APPENDIX IV

QA Draft Review of:
Mountain Caribou Habitat Use and Population Characteristics for the Central Selkirks Caribou Inventory Project

prepared for
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INTRODUCTION

This Draft Review Report has been prepared under contract to Pope & Talbot Ltd. as per the Ministry of Environment, Lands and Parks (MELP) review process guidelines. Editorial and substantive comments have been made electronically within the document (Microsoft Word Review Function). Other minor suggested grammatical or word changes are identified using the highlighting feature. The reviewer recognizes that this is the fourth in a series of projects initiated in 1996. The context for the review is most clearly identified from the statement in the Work Plan Rationale section: "It is the intent of this project to provide the necessary caribou inventory framework to meet the planning and operational needs for caribou and timber management in the Central Selkirks." The Standards Agreement provided the guidelines for content expectations.

GENERAL COMMENTS

The report is written in clear, understandable language. There is little, if any, superfluous material. If anything, the report errs on the side of not including enough detail in some places. The tables and figures support the document, and the maps (at the scale provided) are very good.

Executive summary - was not provided in this draft so unable to comment.

Introduction - Generally well-written and provides most of the necessary information. The section would benefit from a further development of contextual information, especially on the species in question. I recognize that some of this was included in the 1996 proposal, but since this is the final report, it should appear in the document. In addition, it would be good to relate this work to other caribou habitat modeling that has occurred and is on-going in the area. The last point could potentially be handled in the methods section. The authors do make reference to Apps and Kinley's works (in the methods) but there should be a more direct methods comparison.

Methods - generally straight forward - some more detail needed in a few places. RIC protocols are followed, but the authors need to make specific reference to the respective manuals/documents. Statistical methods are sound and consistent with current work in this field (esp. Manley et al 1993).

Results - key information is here and supported by tables. Development of models is fairly clear. The authors should make reference to specific values when making statements about significance wherever possible.

Discussion - the limitations of the models are clearly identified. The authors might want to be more specific about future recommendations for research related to data collection and model development (this could also be a separate short section as well). It would be very useful, since the authors indicate the importance of professional experience, to have a paragraph that summarized the important habitat and habitat characteristics for caribou in the region (e.g., can the professional knowledge gained through this project be translated into some stand-level detail for the field operation level?) This is implied through reference to the model/maps, but would provide some excellent operational-level information.

There needs to be a stronger critique of inventory and modeling protocols in this section as well. The standards agreement (work plan) states that: "The implications to model development of data deficiencies … will also be investigated" - this needs further development in the report. The authors should comment on the number of collared caribou (minus mortality) and the goal of 10% collaring (efficacy). Additionally, a brief discussion related to the use of GPS collars would be valuable. Finally, no mention is made of handling collared caribou after project completion.

Management Recommendations - curiously, there is little in this section that specifically makes recommendations for management. I was expecting to find something akin to guidelines for human activity/access in the region related to known/predicted caribou habitat areas. There is a vague allusion to how some of the information is currently being used in TFL#23, but this is unclear. Based on the current study, it would be useful to have the authors comment on current guidelines and operations (especially forestry-related, but also recreation and access in general). As mentioned above, it might be instructive to have a future research recommendations section and a management recommendations section.