Caribou Habitat Modeling for the South Selkirk Ecosystem Including Habitat Assessments for the Priest Lake Endowment Lands

21 November 2007

Prepared for:

Idaho Department of Lands
Boise, Idaho

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Cover Photo: Selkirk Crest near Hunt Lake on the Priest Lake endowment lands, viewed from Horton Ridge. Photo by Trevor Kinley.

ABSTRACT

"Mountain caribou" are an endangered ecotype of woodland caribou with an historic range in northwest Montana, northern Idaho, northeast Washington and southeast and south-central British Columbia. They inhabit old conifer forests in high-snowfall regions, rely almost entirely upon arboreal hair lichens for late-winter forage, and typically make seasonal migrations on an elevational gradient. Within the USA, areas recently inhabited by mountain caribou have been mainly in Idaho, including the Priest Lake endowment lands (PLEL) of the Idaho Department of Lands (IDL). Animals in that area are part of the South Selkirk subpopulation and inhabit an area known as the South Selkirk Ecosystem. A recovery zone above about 4500' has been designated in Washington and Idaho.

At the request of IDL, we conducted habitat assessments for PLEL and the South Selkirk Ecosystem generally. In this document, we present (1) ecosystem-wide seasonal habitat models developed with the use of radiotelemetry data and GIS-based mapping of vegetation and terrain; (2) an ecosystem-scale evaluation of caribou priority areas based on a generalization and seasonal amalgamation of habitat models; and (3) fieldwork conducted to assess habitat values at a finer scale on PLEL.

Using methods applied previously for other subpopulations of mountain caribou, we conducted scale-dependent habitat modeling for the South Selkirk Ecosystem. This analysis was based on topographic features (elevation, slope, terrain curvature, aspect, solar energy), generalized mapping of vegetation types (overstory tree species, seral stage, canopy closure, non-forested designation), and radiolocations of caribou obtained from 1987 through 2004. We employed three spatial scales of analysis, based on movement rates and expected radiolocation error levels. Seasons (early winter, late winter, spring, calving, summer) were delineated based on observed dates of elevational shifts among radiocollared caribou in relation to patterns identified elsewhere in mountain caribou range. We assessed univariate habitat selection by caribou (i.e. examining one habitat variable at a time) and applied multivariate techniques to determine the combination of variables in relation to scale that best describes and predicts habitat selection for each season. Models were portrayed as maps of predicated habitat suitability. Selection patterns differed in strength and sometimes in direction across scales and seasons. However, mountain caribou in the South Selkirk Ecosystem generally selected old, relatively open spruce-subalpine fir forests at higher elevations across seasons. In many locations, particularly in PLEL, identified habitat extended farther downslope for early winter than other seasons, including at least the transition from spruce-subalpine fir to cedar-hemlock forests.

Based on seasonal habitat models, we identified the relative habitat priority of lands across the South Selkirk Ecosystem. The purpose was to look at the "big picture" of how PLEL compared to the rest of the ecosystem in terms of providing caribou habitat. We generalized each pixel of each seasonal caribou map to reflect the median value within the surrounding 50 km^2, then determined the lowest predicted habitat value of each pixel for any season. From the resultant map, we identified habitat values corresponding to 50, 75 and 92% of caribou radiolocations and mapped their outer bounds as Priority 1, 2

and 3 habitats. The largest unit of high-priority habitat was within British Columbia, but another large node was centered on PLEL and adjacent land in Kaniksu National Forest. Although this approach was intended for ecosystem-scale (not stand- or drainage-level) use, the highest value area within PLEL evidently occurs along its eastern edge, with lands in the northwest corner being of considerably lower priority. Mapping was not available for the southernmost portion of the caribou recovery zone within PLEL.

We conducted field inspections in 10 areas of PLEL, noting ecological conditions relevant to caribou and comparing model ratings with observed conditions. Sites were located from the northwest corner of PLEL to near the southern limit of the caribou recovery zone, and spanned a range of predicted habitat values, elevations and levels of caribou activity. In general, fieldwork confirmed the utility of habitat model ratings. Conditions at sites we visited were consistent with expectations from previous research on seasonal patterns of habitat selection and foraging modes. Summaries and photograph of each site visited are included in this report.

ACKNOWLEDGMENTS

This report was prepared on contract to the Office of the Attorney General under the supervision of L. Jorgensen and S. Strack, Idaho Department of Lands. We appreciate the logistical support, orthophotos, maps and insights provided by M. Shanilec, IDL; GIS assistance provided by W. Koski and T. McManus, IDL; GIS and telemetry data provided by T. Laser, USDA Forest Service; telemetry data provided by J. Almack of Washington Department of Fish and Wildlife, W. Wakkinen of Idaho Department of Fish and Game, and J. Krebs and J. Gwilliam of Fish and Wildlife Compensation Program (Columbia Basin), and advice, field observations and review of B. McLellan, BC Ministry of Forests and Range.

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CHAPTER 1: INTRODUCTION

BACKGROUND

Woodland caribou (*Rangifer tarandus caribou*) historically inhabited much of Canada and the northern tier of states. However, their distribution has declined over the past several hundred years, particularly along the southern limit. As of 2007, caribou occur regularly within the lower 48 states only in northern Idaho, with occasional use likely in northeastern Washington and sporadic sightings reported from northwestern Montana. Woodland caribou are now listed by the United States Fish and Wildlife Service as endangered in Idaho and Washington, and a recovery zone has been designated there (Selkirk Mountain Woodland Caribou Recovery Team 1994, Almack 2000). Caribou in this area belong to an ecotype generally known as "mountain caribou" (Heard and Vagt 1998, Stevenson et al. 2001). This ecotype is distinguished from other woodland caribou primarily by (1) its residence in high-snowfall conifer forests within the inland Pacific Northwest, (2) its almost complete dependence on arboreal hair lichens (especially *Bryoria*) for late-winter food, typically in old forests, and (3) seasonal migrations that are generally elevational rather than latitudinal.

The only other jurisdiction in which mountain caribou occur is British Columbia, where they inhabit wetter areas within the east-central and southeast portions of the province. Mountain caribou in British Columbia have declined from an estimated 2450 in 1997 (Mountain Caribou Technical Advisory Committee 2002) to about 1900 in 2006 (Hatter 2006). They are on the provincial "red list" indicating they are threatened or endangered (Mountain Caribou Technical Advisory Committee 2002), and along with portions of the range of another ecotype of woodland caribou are geographically listed as threatened nationally (Thomas and Gray 2002). The population occurs as a series of subpopulations (Wittmer et al. 2005; simplified version shown in Figure 1) having limited interchange at the northern end of their range and essentially no interchange farther south.

Animals occurring within Idaho and Washington are part of the South Selkirk subpopulation, which extends from the West Arm of Kootenay Lake in the north to the Priest Lake basin in the south. The population has consisted of well under 100 individuals for several decades, spurring status and distribution reporting (Flinn 1956, Evans 1960, Freddy 1974, Layser 1974, Johnson 1985, Manley 1986); habitat-use and foraging research (Freddy 1979, Rominger and Oldemeyer 1989, 1990, Servheen and Lyon 1989, Rominger et al. 1994, 1996, 2000, Rominger 1995); fire-history interpretation (Allen 1999); and the translocation of 103 animals from elsewhere in the range of woodland caribou by the Idaho Department of Fish and Game from 1987 to 1990 and by the Washington Department of Fish and Wildlife from 1996 to 1998 (Compton et al. 1995, Warren et al. 1996, Almack 2000). As of 2007, the minimum population was 42 caribou (W. Wakkinen, Idaho Dept. Fish and Game, pers. comm.). While the majority of recent activity by members of this subpopulation has been in British Columbia, there has been significant use over the past two decades of land within the United States, and there appears to remain

both some caribou use and significant habitat value there. Among the many jurisdictions supporting mountain caribou within the USA is the Idaho Department of Lands (IDL) on its Priest Lake endowment lands (PLEL).

IDL commissioned the following report, which employs GIS- and ground-based approaches to identify habitat values at multiple spatial scales. It includes chapters that (1) use caribou telemetry data and vegetation and topographic mapping to develop seasonal habitat models predicting caribou habitat values across the entire South Selkirk Ecosystem, (2) amalgamate seasonal modeling to identify ecosystem-level habitat priority areas, and (3) report the results of on-site habitat investigations. Thus, this report provides the ecosystem and local contexts for caribou habitat values within PLEL.

STUDY AREA

Our ecosystem-wide analysis area was defined by locations of radiocollared caribou in the southern Selkirk Mountains of British Columbia, Washington and Idaho (Figure 1). Caribou range in the southern Selkirks was bounded by the West Arm of Kootenay Lake to the north, the South Arm of Kootenay Lake and the Kootenay River to the east, roughly 48º30' N to the south, and the Salmo and Pend Oreille rivers to the west.

The ecosystem lies within the Southern Columbia Mountains ecosection, an area of high ridges and mountains interspersed with wide valleys and trenches (Demarchi 1996, Demarchi et al. 2000). Biogeoclimatic zones, defined on the basis of climax vegetation on zonal sites have been defined for British Columbia (Braumandl and Curran 1992, Meidinger 2006), correlating approximately to climax series that have been defined for Idaho (Cooper et al. 1991). Biogeoclimatic zones include the Interior Cedar-Hemlock (ICH) zone at low elevations (corresponding mainly to the *Tsuga heterophylla*, *Pseudtsuga menziesii* and *Thuja plicata* series with limited occurrence of the *Abies grandis* series); Engelmann Spruce-Subalpine Fir (ESSF) zone between about 5100' and 6400' (consisting mainly of the *Abies lasiocarpa* series with perhaps limited coverage of the *Tsuga mertensiana* series), and the Interior Mountain-heather Alpine (IMA) zone at high elevations. The woodland and parkland subzones occur at the upper end of the ESSF zone, and are transitional between the closed-canopy forests of the ESSF proper and the IMA (Research Branch 2003). They correspond to several of the highest-elevation habitat types defined for the *Abies lasiocarpa* series. Dominant tree species include lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), hybrid white spruce (*Picea glauca* x *engelmannii*), western white pine (*Pinus monticola*), grand fir (*Abies grandis*) ponderosa pine (*Pinus ponderosa*) and trembling aspen (*Populus tremuloides*) in the ICH zone, and Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), lodgepole pine, whitebark pine (*Pinus albicaulis*), alpine larch (*Larix lyalli*) and mountain hemlock (*Tsuga mertensiana*) in the ESSF zone. Stand ages vary from recent cutblocks, burns and other clearing to old-growth forest.

Land tenure within the ecosystem is a mosaic of private lands, both in large forestry tracts and small holdings, Idaho Department of Lands property (PLEL), national forests (Colville and Kaniksu), provincial Crown land managed primarily for forestry, Harrop-Procter Community Forest, provincial parks (West Arm, Stagleap), and a provincial wildlife management area (Midge Creek). Levels of development vary from unroaded wilderness to land managed and roaded for timber production and, along the periphery, a network of highways and secondary routes connecting rural residential and small agricultural holdings. Active and abandoned mines are scattered throughout, particularly at higher elevations, along with roads constructed for exploration and mine access. One major all-season road (Highway 3) bisects the ecosystem east-west just north of the Canada-USA border. Elevations range from about 1750 to 7900 feet.

A recovery zone for the South Selkirk mountain caribou subpopulation has been designated (Selkirk Mountain Woodland Caribou Recovery Team 1994), which includes portions of PLEL (Figure 2). Boundaries of the recovery zone were designated cooperatively with various resource agencies under the auspices of the recovery steering committee (S. Audet, USDA Fish and Wildlife Service, pers. comm.). The field-based portion of this project was restricted to PLEL, particularly the portion of it within and adjacent to the recovery zone boundary. IDL holdings are located on the north, east and south sides of Priest Lake (Figure 2). The northern and eastern boundaries approximate heights of land. The PLEL unit abuts or surrounds lands of other ownership, primary Kaniksu National Forest to the east and west and state parks and private holdings along Priest Lake and the Priest River. Our fieldwork extended slightly outside of PLEL in one location where a node of very high caribou use straddled state and federal lands, and where access to PLEL was most feasible via federal lands.

All land (184,858 acres) within PLEL has been classified as being primary forest (productive), secondary forest (less productive, or areas where forestry is precluded due to other management considerations), or non-forest/noncommercial (Anonymous 2000). All three classes span a range of elevations, but the primary land does not occur at the highest elevations, and only minor portions of the secondary and non-forest/noncommercial lands occur on the valley bottom (Figure 2). The primary base covers 56% of PLEL and is composed mainly of western hemlock, Douglas-fir, western redcedar, and grand fir, each of which make up > 11% of total volume. Western larch, Engelmann spruce, lodgepole pine, ponderosa pine, western white pine, subalpine fir and whitebark pine each contribute less than 7% to total volume. Paper birch, trembling aspen and black cottonwood are not inventoried and are minor components of the primary base. Due to past disturbances and timber harvest, only 22% of the primary base (by area) is composed of large sawtimber, and roughly 10% is older than 150 years (Anonymous 2000). An extensive road system exists through most of the primary landbase (Figure 2). Much less information is available for the secondary landbase, but most portions of it appear to be heavily dominated by subalpine fir, Engelmann spruce and western hemlock, with lesser amounts of whitebark pine, alpine larch, western white pine, mountain hemlock and other species. The majority of whitebark pine appears to be dead or dying. The road network is far more limited in the secondary landbase

(Figure 2). Stand ages in the secondary landbase appear to be, on average, considerably older than those in the primary landbase. Across both the primary and secondary lands in the northern half of PLEL, stands have been classified as ranging from 0 to 348 years (T. Layser, USDA Forest Service, unpublished data).

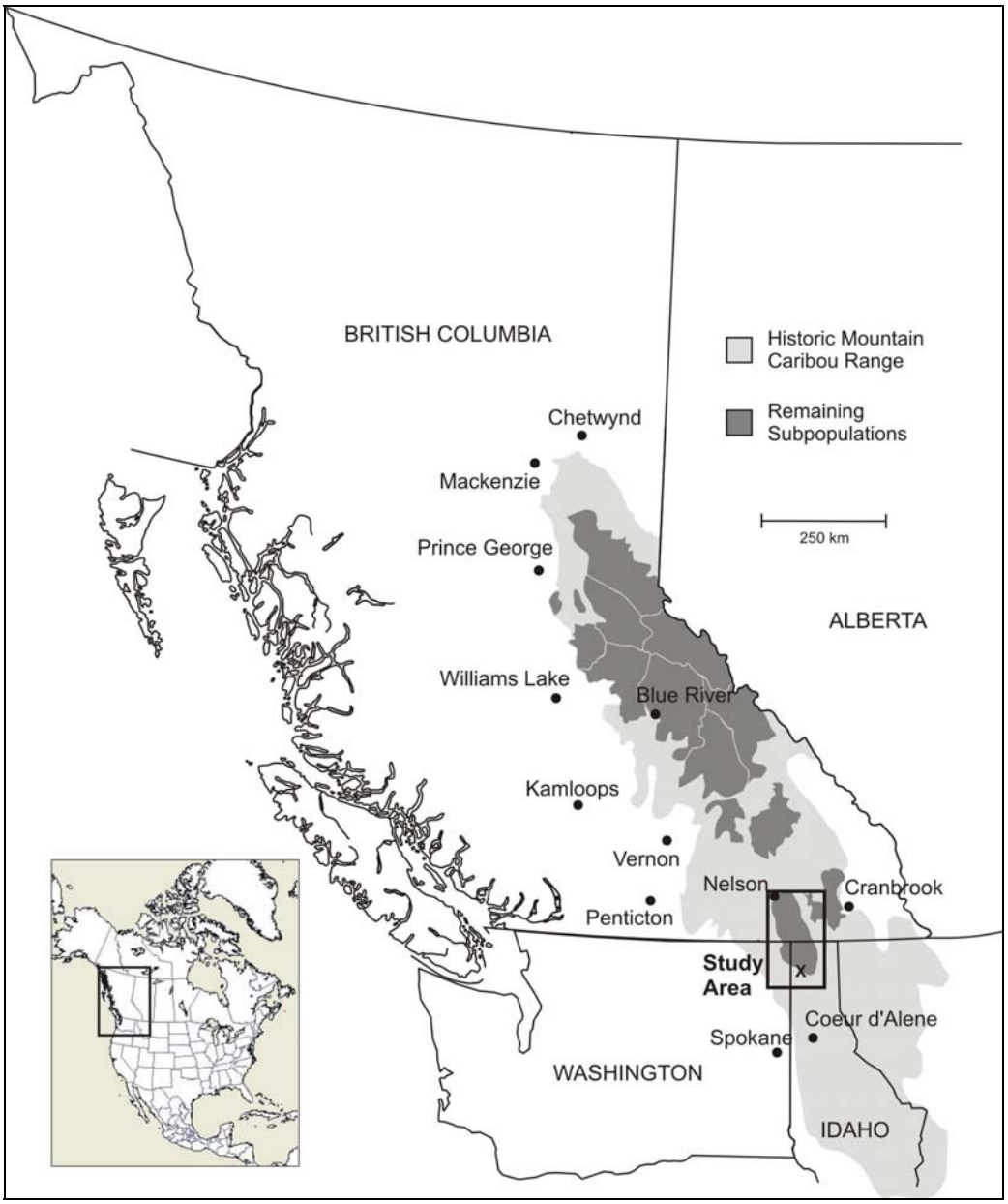

Figure 1. Recent general mountain caribou distribution and the study area location, encompassing the South Selkirk Ecosystem of northern Idaho, northeastern Washington and southeastern British Columbia. Adapted from Spalding (2000) and Mountain Caribou Technical Advisory Committee (2002). Within the "Study Area", the "x" symbol indicates the location of Priest Lake. The total range has recently been determined to be divided into more subpopulations than shown above (Wittmer et al. 2005).

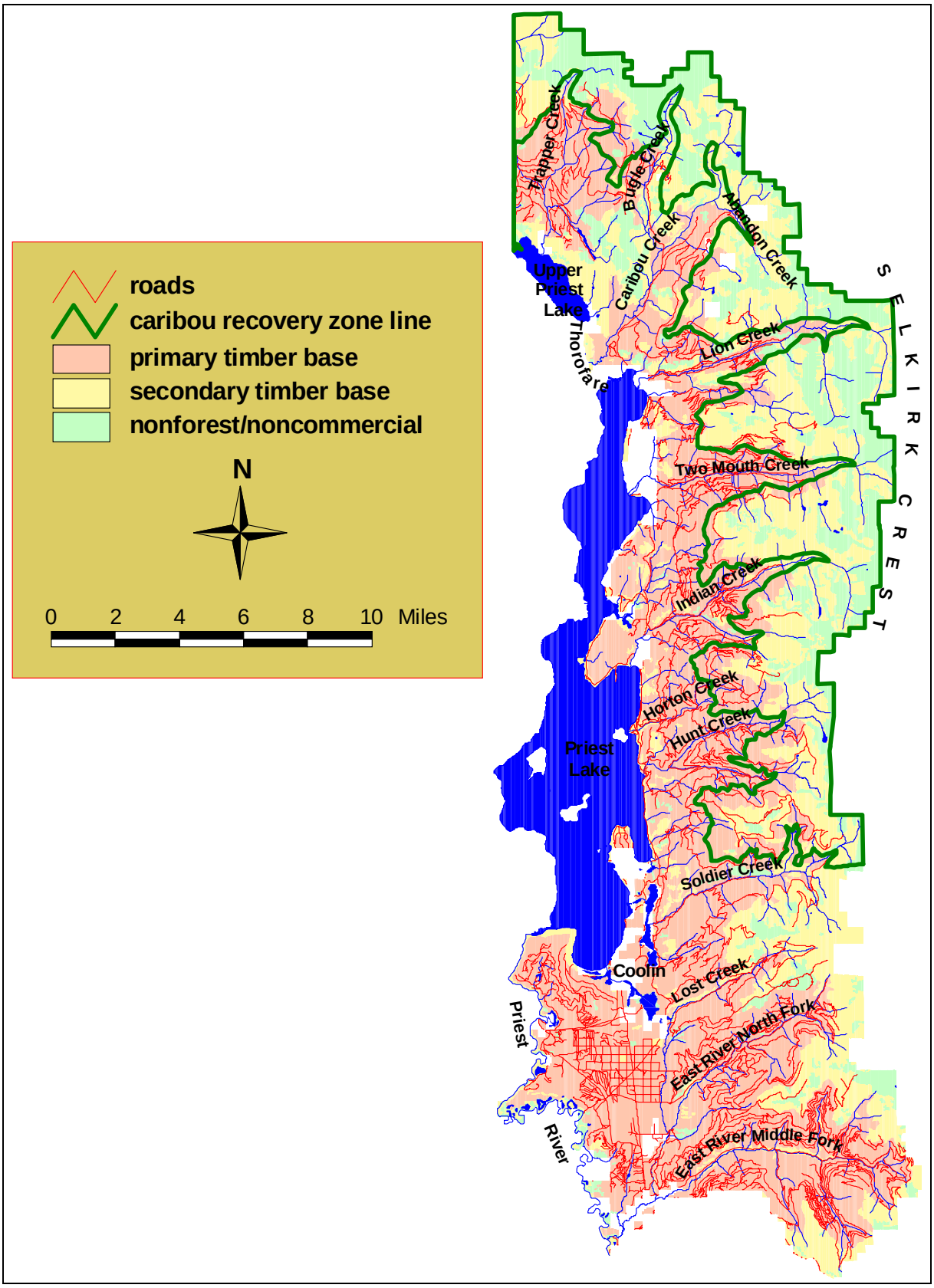

Figure 2. Priest Lake endowment lands of the Idaho Department of Lands.

CHAPTER 2: MULTI-SCALE HABITAT MODELING

METHODS

APPROACH

Central to our evaluation was the need for an objective spatial depiction of the relative quality of landscapes to mountain caribou across the South Selkirk Ecosystem, including State of Idaho lands. Given the long-term study of mainly translocated caribou within this ecosystem, the most objective approach to achieving this goal was to use raw location data of radiocollared caribou and existing databases of habitat-related attributes to derive empirical (data-driven) models of seasonal caribou habitat quality. We applied methods described by Apps et al. (2001) for the Revelstoke and Central Rockies subpopulations, and which have also been applied in deriving habitat models for 3 other mountain caribou subpopulations or groups of subpopulations (Apps and Kinley 2000a, 2000b, Hamilton et al. 2000). This is a multi-scale approach that accounts for the varied importance and influence of forest, landcover and terrain attributes to caribou depending on the landscape size considered. These relationships are then integrated into a single spatial model of caribou habitat for each season (see below) that accounts for the changing importance of many landscape attributes to caribou depending on the scale considered. Specific methods are described below.

CARIBOU LOCATION DATA

Telemetry Data Sources

Using VHF radiotelemetry techniques, mountain caribou have been monitored in the South Selkirk Ecosystem since animals were first translocated there to supplement the resident population in March of 1987 (Almack 2000). We obtained a database of the resulting caribou radiolocation data, totaling 8,564 records of location coordinates from 117 animals over a 17 year period (1987 – 2004), based on data collected by the Idaho Department of Fish and Game, Washington Department of Fish and Wildlife, and the Fish and Wildlife Compensation Program (Columbia Basin) in British Columbia. The average sampling interval was 12.6 days (SD = 22.6). Based on accuracy testing, VHF locations were considered accurate to +/- 50 m, with an additional expected error of +/- 100 m for locations referenced using an aircraft-mounted GPS during 1996-2000, due to military satellite “selective availability” (J. Almack, Washington Dept. Fish and Wildlife, pers. comm.). We proceeded through several steps to screen these data for errors and to derive a database of caribou locations assumed to be representative of preferred and independently selected habitats.

Influence of Translocation on Data

Using caribou location data to derive models of relative habitat quality requires the assumption that radiocollared caribou are familiar with the broad landscape in which they live and make informed choices about sites that are most likely to meet their requirements. However, radiocollared caribou in the south Selkirk Ecosystem were mainly translocated animals that were radiocollared at the time of their initial release. Until they achieved some level of familiarity with their surroundings, it can be expected that their use of habitats would be influenced by initial exploratory movements and the biologists' choice of release sites. We assumed that this influence would persist for up to 1 month post-release, and we excluded these data from our analyses.

Seasonal Cutpoints

Mountain caribou exhibit different habitat selection patterns characterized by marked shifts in elevation use. These patterns relate to the different requirements of and changing constraints on mountain caribou as seasons change. Seasonal differences in habitat selection and foraging strategies of mountain caribou are largely related to snow conditions, the general patterns of which have been described (Stevenson et al. 2001, Simpson et al. 1997) specific to Early Winter (EW), Late Winter (LW), Spring (SP), Calving (CA) and Summer (SU) caribou seasons.

It is important that analyses and modeling of mountain caribou habitat take seasonal differences into account. This requires splitting the caribou location data into different seasons and deriving independent habitat models from each set. Although Stevenson et al. (2001) provided dates that can be used to generally define caribou seasons, there can be considerable variation among regions and years as to if and when caribou actually shift to a different foraging and habitat use pattern. Because the most definitive attribute of seasonal variation in habitat selection by mountain caribou is elevation, Apps et al. (2001) defined seasonal breaks according to distinct shifts in elevation use. We adopted this approach to define seasonal cut-dates for the South Selkirk data, exploring variation in elevation use by caribou throughout the year and between sexes (Figure 3). Based on elevation-use plots through the year, by sex, we defined the following seasonal cut-dates: EW ends 18 January, LW ends 19 April, SP ends 7 July, SU ends 16 October, and CA (females only) starts 1 June and ends 7 July. Applying these dates to the radiotelemetry database resulted in 1068 to 3120 radiolocations per season (Table 1, Figure 4).

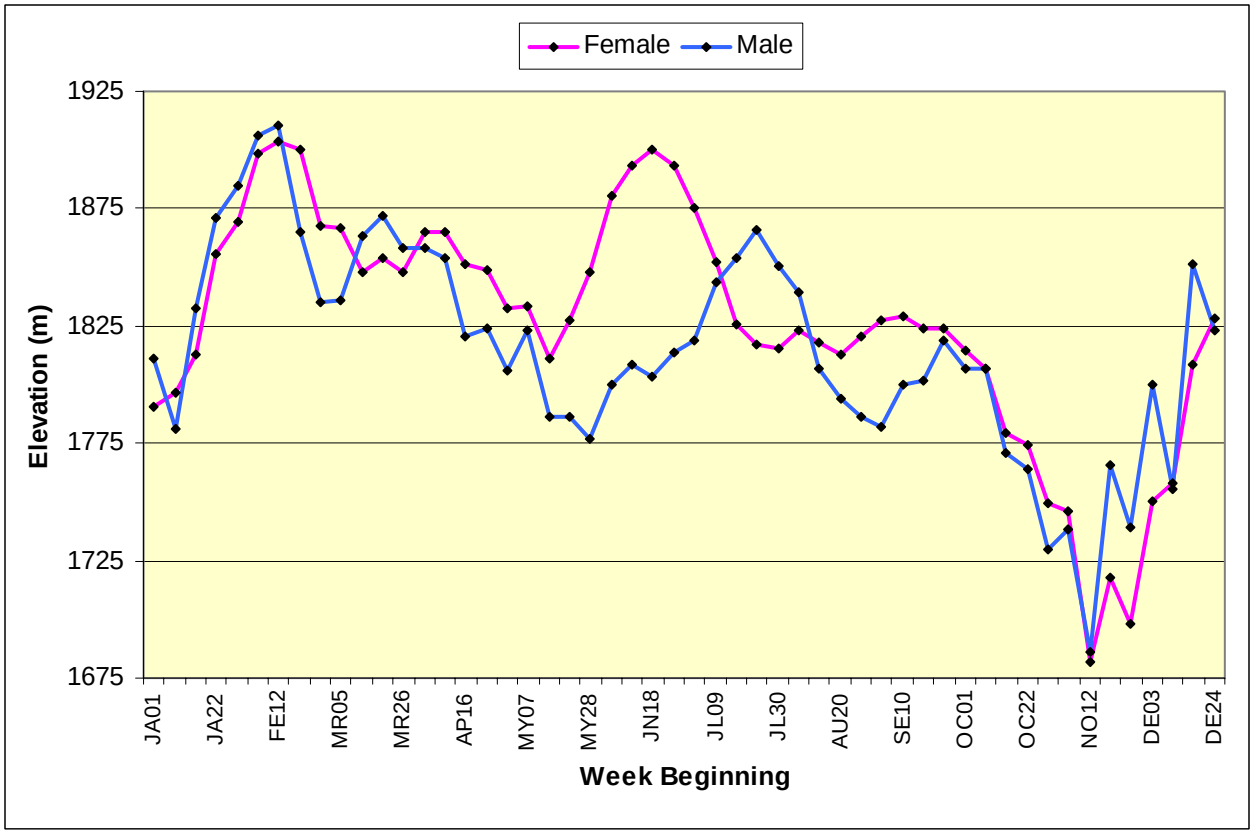

Figure 3. Running 3-week mean elevations used by radiocollared mountain caribou in the South Selkirk Ecosystem, Idaho, Washington, and British Columbia, 1987-2004.

Table 1. Distribution of caribou radiolocation data by animals, season, and years, within the South Selkirk Ecosystem, Idaho, Washington, and British Columbia. Radiolocations obtained within 1 month of release of translocated animals not included in totals.

Season	Locations	Animals (M/F)	Monitoring Period
Early Winter	1370	21/61	1987-2003
Late Winter	1074	20/57	1988-2004
Spring	1534	30/83	1987-2004
Calving	1068	0/80	1987-2004
Summer	3120	29/77	1987-2003
TOTAL	8166	31/86	1987-2004

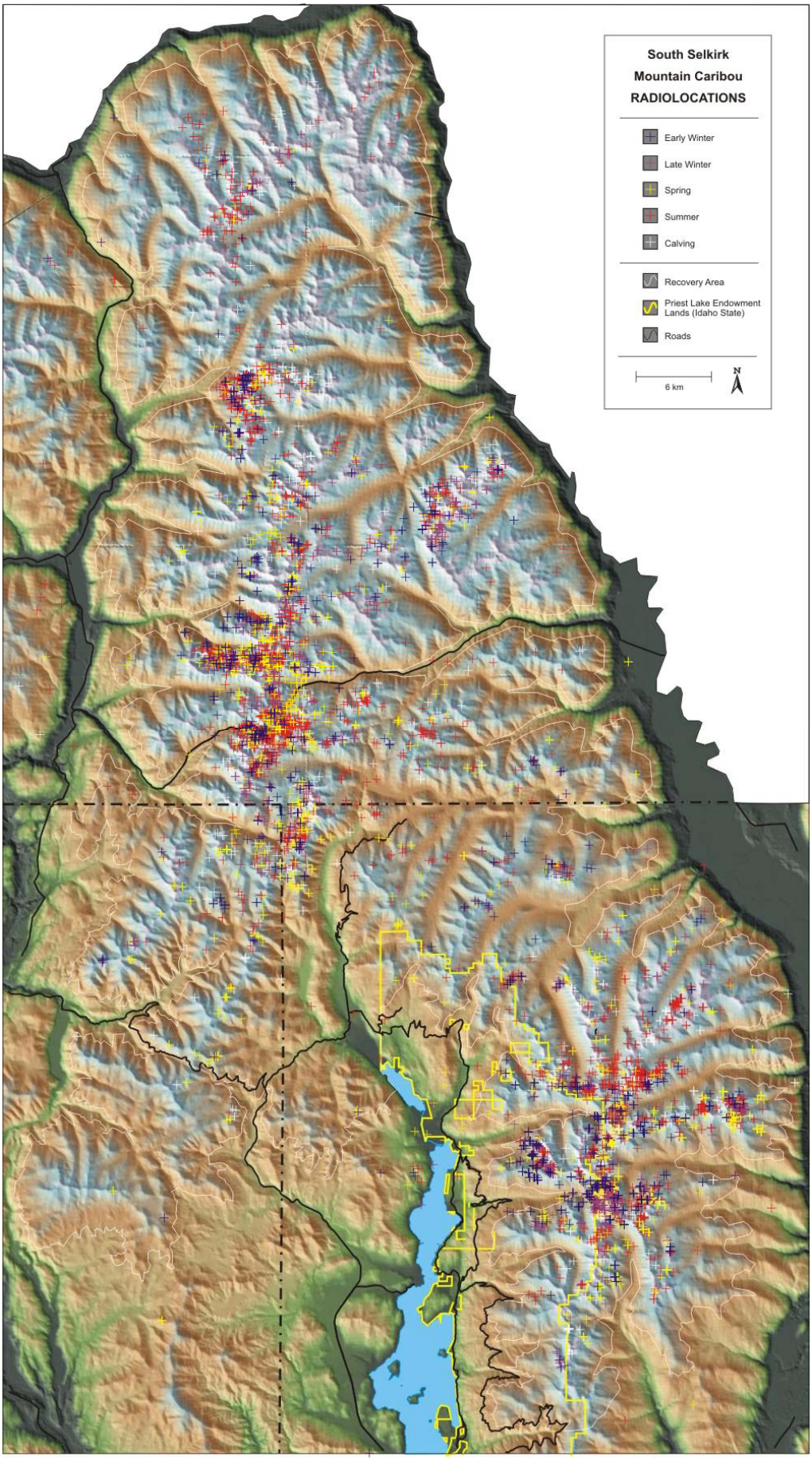

Figure 4. Seasonal radiolocations of mountain caribou in the South Selkirk Ecosystem, Idaho, Washington, and British Columbia, 1987-2004.

GIS HABITAT DATA

We assembled habitat data in a geographic information system (GIS) for a 5,800 km^2 area that encompassed the South Selkirk Ecosystem caribou recovery zone, including lands within Idaho, Washington, and British Columbia. Data were obtained from Tim Layser (USDA Forest Service, Priest River) and included a digital elevation model (DEM) derived from 1:20,000 or 1:24,000 scale data, forest overstory classification data compiled from respective state, federal, and provincial inventories (Resources Inventory Branch 1995; T. Layser, USDA Forest Service, pers. comm.), and various other data depicting roads, major lakes, jurisdictional boundaries, and the designated caribou recovery zone. The forest overstory classification data depicted forest cover type (16 classes), overstory canopy closure (4 classes), and seral stage (5 classes) and was based on a recent amalgamation and generalization of vegetation data from several state, provincial and US federal agencies (T. Layser, USDA Forest Service, pers. comm.). Within PLEL, the compiled, multi-jurisdictional vegetation coverage excluded lands below the caribou recovery zone boundary and south of Horton Ridge. We therefore excluded those areas from our analysis and resulting model predictions. From the DEM and forest overstory classification, we derived habitat variables associated with forest stand overstory and terrain attributes (Table 2). Most variables were directly extracted or derived from the above data sources. Terrain curvature reflected the maximum rate of change of a curve fit through each pixel in the context of its neighbors (Pellegrini 1995) as derived at each spatial scale considered (see below). Using known sun azimuths and the DEM, maximum solar insolation (kJ; SOLAR) was calculated for 1 day at the midpoint of each season; seasonal versions of this variable were used in corresponding season-specific analyses.

We selected overstory stand variables under the assumption that the ecology and habitat associations for mountain caribou are largely influenced by forest structure (Stevenson et al. 2001), and we attempted to match, to the extent possible, variables considered in previous analyses of mountain caribou habitat selection (e.g., Apps et al. 2001).

Table 2. Independent variables considered for analyses of habitat selection by caribou within the South Selkirk Ecosystem, Idaho, Washington, and British Columbia, 1987 – 2004. All variables are ratio-scale, and represent either the mean or proportional composition within a surrounding landscape.

Variable	Description
FC_S-F	Engelmann or hybrid white spruce (*Picea engelmannii* or *P. glauca* x *engelmannii*) & subalpine fir (*Abies lasiocarpa*)
FC_C-H	Western redcedar (*Thuja plicata*) & western hemlock (*Tsuga heterophylla*)
FC_GF	Grand fir (*Abies grandis*)
FC_P-L	Lodgepole pine (*Pinus contorta*) & western larch (*Larix occidentalis*)
FC_DF	Douglas-fir (*Pseudotsuga menziesii*)
FC_WP	Western white pine (*Pinus monticola*)
FC_MD	Mixed dry (3 or more co-dominant species typically occurring on dry sites)
FC_MM	Mixed mesic (3 or more co-dominant species typically occurring on mesic sites)
FC_ALP	Alpine
FC_SHB	Shrub cover
FC_NF	Non-forested – other
SERAL_1	Seral stage: non-forested
SERAL_2	Seral stage: stand reinitiation
SERAL_3	Seral stage: stem exclusion
SERAL_4	Seral stage: mature
SERAL_5	Seral stage: old growth
CANOPY	Canopy closure (%)
CANOPY_1	Canopy closure: 0-25%
CANOPY_2	Canopy closure: 26-50%
CANOPY_3	Canopy closure: 51-75%
CANOPY_4	Canopy closure: 76-100%
ELEV	Elevation (m)
SLOPE	Slope (%)
CURVA	Terrain curvature index
SOUTH	Aspect – south (%)
WEST	Aspect – west (%)
SOLAR	Daily solar energy (KJ; calculated independently for each season)

SCALE-DEPENDENT ANALYSIS DESIGN

Our analysis design conformed to Thomas and Taylor's (1990) study design 2, with inferences relevant at the population level. We considered the study animals a representative sample of the population, and we pooled location data among caribou, as is appropriate where few locations are obtained from many animals (Manly et al. 2002).

We employed a scale-dependent analysis design following methods previously described (Apps et al. 2001). Spatial scale in ecology is characterized by the geographic extent of analysis and the spatial resolution of data. We analyzed caribou-habitat associations at 3 spatial scales, corresponding to successively smaller landscapes of used and available habitat. At each analysis level, we adjusted the resolution of habitat variables by aggregating data (Bian 1997) using a GIS moving-window routine. Pixels thus reflected each variable's mean value or proportional composition within a surrounding circular landscape. Landscape composition was sampled at each caribou location and at a paired location of fixed distance but random azimuth from each caribou location (Figure 5). At level 1, the broadest scale of analysis, caribou and paired random locations were separated by 13.70 km (Figure 6). This parameter is consistent with previous scale-dependent analyses of mountain caribou habitat selection, and corresponds to the distance beyond which 5% of resident caribou movements occurred within a 1 – 2 week sampling interval (Apps and Kinley 2000a, Apps et al. 2001). Because, at this scale, we expected that radiolocations obtained within 7 days would not be independent samples, we weighted them such that they collectively influenced the analysis as would a single location. By applying a 0.295 multiplier to the 13.70 km distance, we defined a 4.04 km radius of circular landscapes within which we measured habitat composition at caribou and random locations. At levels 2 and 3, random locations were generated at distances equivalent to the landscape radius at the previous level, and habitat composition was again measured within a radius of 0.295 of this distance. Although this multiplier was arbitrary, it ensured that the radius used to scale habitat composition at level 3, the finest scale of analysis, encompassed what we expect to be 95% of the spatial error of radiolocations (350 m[1]) within the pooled dataset. Although the true location of some data may fall outside this error zone, we chose to accept the lower statistical power to detect habitat selection, relative to sample size, that will result from a random misassignment of habitat attributes for these data. Moreover, habitat selection may still be detected from data falling outside the expected error zone given that random locations occurred at a markedly greater fixed distance of 1.19 km. The proportion of used landscape to available area was equal at all levels, and used landscapes did not overlap with paired random landscapes. Lands for which any of the habitat data sources were not available, and major water bodies (i.e., Priest Lake), were not considered part of the landscape when aggregating data using the moving-window routine.

[1] Using similar methods, tests in the North Columbia Mountains study showed the recorded locations of 95% of test collars to be within ±364 m of their true location, although mean error was substantially smaller (Apps et al. 2001).

At each analysis level, we extracted attributes associated with caribou and random landscapes to a database. As described previously (see Data Subsampling), data were subsampled at 7-day intervals for analysis at all levels.

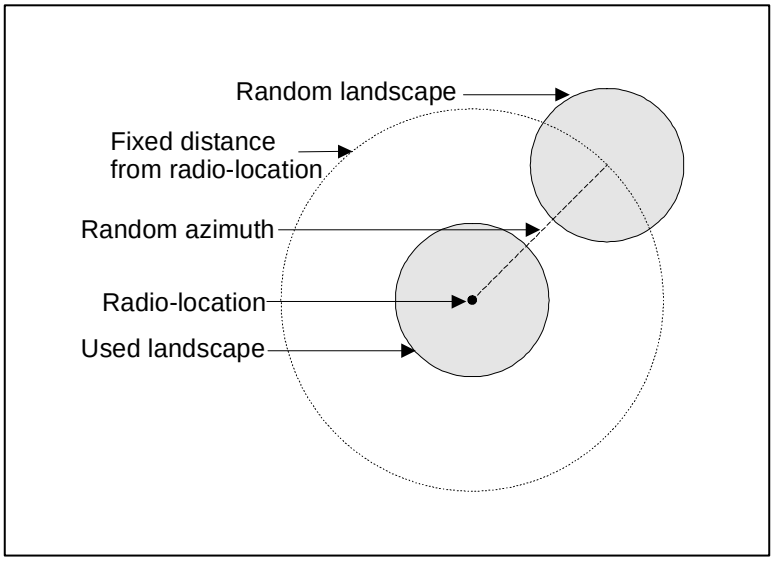

Figure 5. Scale-dependent design for analyzing caribou habitat selection in the South Selkirk Ecosystem, Idaho, Washington, and British Columbia.

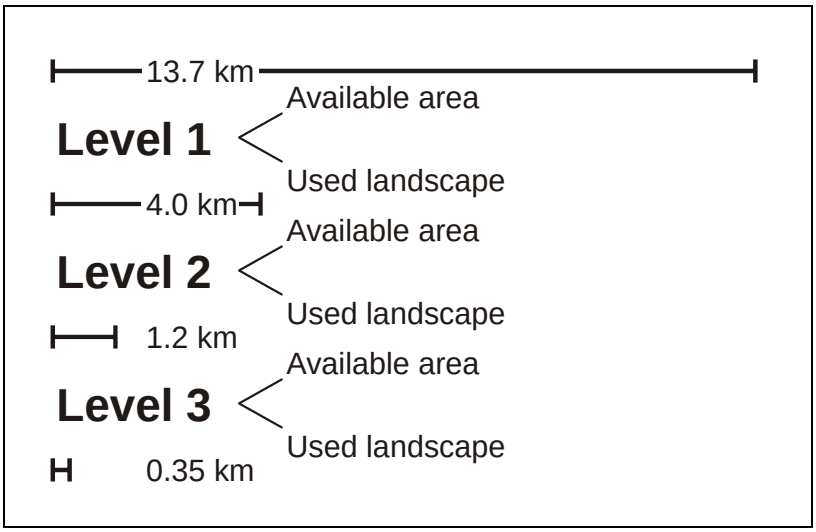

Figure 6. Hierarchical scales considered in analyzing caribou habitat selection in the South Selkirk Ecosystem, Idaho, Washington, and British Columbia. Scales were defined by radii of available areas and landscape composition. The radius of "available area" was the distance from caribou radiolocations at which landscapes were randomly sampled. The "landscape" radius was that within which habitat composition was defined.

STATISTICAL ANALYSES

As described previously, caribou radiolocation data were stratified according to season, and data obtained within the first month of sampling were excluded to ensure that the data represented only independent choices of habitats and landscapes by caribou.

We analyzed caribou habitat selection for each original variable, at each spatial scale, using univariate techniques. For each analysis season, we used t tests to compare mean composition of landscapes at caribou locations to that of paired random locations. Due to the number of variables and levels considered, all univariate tests were appropriately conservative ($\alpha = 0.0001$). These analyses were descriptive, and although we were not testing conventional hypotheses, we considered the sign and strength of univariate statistics in describing relationships of individual variables with caribou habitat selection.

We developed multivariate habitat selection models for each season. Variables were entered into multiple logistic regression (MLR) to derive probabilistic resource selection functions (Manly et al. 2002) across all 3 spatial scales. Our goal was to identify a minimum linear combination of variables that best predict caribou habitat selection across spatial scales during each season. We considered only variables exhibiting at least marginal univariate relationships ($P < 0.1$). Landscapes used by caribou and random landscapes represented the dichotomous dependent variable. However, the design differed from the scale-dependent univariate analyses in that paired random locations occurred at distances ranging from 1.19 – 13.70 km, spanning the 3 spatial scales. We employed forward stepwise selection using the likelihood-ratio test (Hosmer and Lemeshow 1989) to derive the most parsimonious variable combinations that best discriminated caribou used landscapes from random landscapes. We evaluated the improvement of fitted models over null models according to the reduction in (-2)loglikelihood ratios, and we evaluated the significance of variable coefficients using chi-square tests of Wald statistics (Ibid.). Variables included in best-fit models were examined for multicollinearity using linear regression tolerance statistics (Menard 1995). Where problematic collinearity occurred (tolerance < 0.2; Ibid.), we inspected correlation coefficients to identify offending variables. Of highly correlated pairs, variables that were less significant in univariate analyses were excluded from the next iteration of model selection. We continued this iterative process until tolerance values associated with best-fit models were ≥ 0.2. We further evaluated goodness of fit and predictive power of each model by calculating the Nagelkerke R^2, Hosmer-Lemeshow statistic, and c statistic (Norusis 1999). All analyses employed the software SPSS 12.0 (SPSS Inc. 2003).

Using the Manly et al. (2002) resource selection function equation, we applied each seasonal MLR habitat model to the study area using algebraic raster overlays. We then reclassed the resulting probability surfaces into 3 habitat classes.

RESULTS

Habitat selection by caribou in the South Selkirk Ecosystem was significant among most variables, seasons, and scales, although some variables were significant only at broader scales (Table 3). Relationships varied somewhat across scales, with differences in the sign (direction) of the relationship for certain variables.

During early winter, caribou were associated with landscapes dominated by spruce and subalpine fir stands across scales. Although, at the broadest scale, these were relatively high elevation landscapes associated with alpine and open habitat conditions, there was, at the finest scale, no association with elevation, strong negative relationships with alpine and non-forest habitats, and a strong positive relationship with forest canopy closure of 26-50%. Across scales, preferred habitats were strongly related to old forests, while the “stand reinitiation” seral stage was apparently avoided across scales. Caribou were associated with relatively steep and concave terrain conditions at the broadest scale, but strong selection for relatively gentle slopes and convex (valley bottom) terrain was apparent at the mid and finest scales.

During late winter, caribou were associated with high-elevation landscapes dominated by spruce and subalpine fir across scales. As compared to early winter, a negative association with cedar and hemlock stands was apparent at the finest scale. Also, at finer scales, there was a strong negative association with the “mixed-mesic” overstory type and a stronger positive association with alpine than in early winter. While landscapes used by caribou were related to non-forest conditions at broader scales, there was still a positive association with 26-50% forest canopy across scales. Caribou were again associated with older forests at the broadest scale, but this correlation was weaker at finer scales as compared to early winter. Preferred terrain was again rugged at the broadest scale but gentle at the finer scales, whereas relationships with slope curvature suggests that caribou were mostly at higher slope positions especially at broader scales and clearly not in valley bottoms. Broad-scale association with northern aspects was also apparent.

During spring, the association with spruce and subalpine fir stands was again positive across scales. Like previous seasons, relationships with other overstory composition variables were negative at broader scales, but there was also an apparent avoidance of Douglas-fir stands at the finest scale. Results for alpine and non-forested conditions were similar to previous seasons but were more neutral at mid to fine scales, and forests used by caribou were apparently more open. Although caribou may have shifted to lower mean elevations during spring, they were still high relative to the “available area” at all scales. One of the most notable results for this season is the strong association with solar insolation apparent across scales, in contrast to the very minor importance of this variable in other seasons.

During summer, caribou were again associated with high-elevation spruce- and subalpine fir-dominated landscapes. Terrain associations were similar to other seasons, but caribou exhibited stronger preferences for valleys at the finest scale. Northern aspects were also preferred at finer scales.

Preferred canopy closure was similar to previous seasons, while there was a clear avoidance of alpine and non-forest conditions at the finest scale.

During the calving season (females only), the positive relationship with spruce- and subalpine fir-dominated landscapes became neutral at the finest scale. Relationships with other overstory composition variables remained negative or, at the finest scale, neutral. The negative fine-scale association with alpine apparent during summer became positive, and while there was still a positive affinity for old forests at broader scales, caribou no longer avoided non-forested conditions at the finest scale. Across scales, there was clear affinity for high elevations and high slope positions (e.g., ridgetops) that were moderately gentle only at the finest scale.

The best-fit MLR models for each of the 5 analysis strata were significant ($\chi^2 > 154.6$, df ≥ 10, $P < 0.001$). For each stratum, models predict the probability that any given site represents the broad- and fine-scale landscape conditions that characterize caribou habitat. The derived models achieved a classification success of used and random locations (cutpoint $P = 0.5$) ranging from 71% to 78% and explained approximately 31 to 45% of the variation within each dataset, while other tests indicated that the models fit the data well and carried significant predictive power (Table 4). For each model, the predictive subset of variables represented all 3 scales (Table 5). Model performance across cutpoint probability values suggested that optimal discrimination occurred at approximately $P = 0.5$ for each stratum (Figure 7). Within the GIS, the application of each model to its representative area is portrayed in Appendix 1.

Table 3. Univariate analysis results of scale-dependent caribou habitat selection by season in the South Selkirk Ecosystem, Idaho, Washington, and British Columbia, 1987 – 2004. Results are based on univariate t tests.[a] Variables are defined in Table 2.

	EARLY WINTER			LATE WINTER			SPRING			SUMMER			CALVING		
Variable	1[b]	2	3	1	2	3	1	2	3	1	2	3	1	2	3
FC_S-F	+++	+++	+++	+++	++	+++	+++	+++	++	+++	+++	+++	+++	+++	o
FC_C-H	- - -	- - -	o	- - -	- - -	- -	- - -	- - -	-	- - -	- - -	- - -	- - -	- - -	-
FC_GF	- - -	+	o	-	o	o	- - -	-	o	- - -	o	o	o	o	o
FC_P-L	- - -	-	o	- - -	- -	o	- - -	- - -	o	- - -	- - -	- -	- - -	- -	o
FC_DF	- - -	- - -	o	- - -	- - -	o	- - -	- - -	- -	- - -	- - -	o	- - -	- - -	o
FC_WP	- - -	-	o	- - -	-	o	- - -	-	-	- - -	- - -	o	- - -	o	o
FC_MD	- - -	- - -	- -	-	- -	-	- -	- - -	o	- - -	- - -	- - -	- - -	- - -	-
FC_MM	+	o	o	-	- - -	- - -	- - -	- -	-	- - -	- - -	-	-	- - -	-
FC_ALP	+++	++	- - -	+++	+++	+	+++	+++	o	+++	+++	- - -	+++	+++	+
FC_SHB	-	- - -	o	o	- - -	-	- - -	- - -	-	- - -	- - -	- -	- -	- - -	-
FC_NF	+++	- -	- - -	+++	+++	- - -	+++	o	-	+++	- -	- - -	+++	o	o
SERAL_1	+++	- - -	- - -	+++	+++	- - -	+++	o	- - -	+++	- - -	- - -	+++	+	-
SERAL_2	- - -	- - -	- - -	- - -	- - -	-	-	- - -	- - -	- -	- - -	- -	- - -	- - -	o
SERAL_3	-	o	o	o	o	o	++	o	+	+++	++	o	+	o	o
SERAL_4	o	+++	++	- -	o	+	- - -	+	o	- - -	o	+	- - -	o	o
SERAL_5	+++	+++	+++	+++	+	+	+++	+++	++	+++	+++	+++	+++	++	+
CANOPY	- - -	o	+++	- - -	- -	o	- - -	-	o	- - -	-	+++	- - -	- - -	o
CANOPY_1	+++	- - -	- - -	+++	- -	- - -	+++	-	- -	+++	- - -	- - -	+++	o	-
CANOPY_2	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	++
CANOPY_3	- - -	-	o	- - -	- - -	o	- - -	- - -	o	- - -	- - -	+	- - -	-	o
CANOPY_4	- - -	- -	o	- - -	- - -	- - -	- - -	- - -	-	- - -	- - -	- - -	- - -	- - -	- -
ELEV	+++	+++	o	+++	+++	+++	+++	+++	+++	+++	+++	++	+++	+++	+++
SLOPE	+++	- - -	- - -	+++	- - -	- - -	+++	- -	- - -	+++	- - -	- - -	+++	+	- -
CURVA	+++	o	- - -	+++	+++	o	+++	+++	+	+++	+	- - -	+++	+++	+++
SOUTH	-	- -	o	- - -	-	o	- -	o	o	+	- - -	- -	o	- - -	-
WEST	+++	+++	++	o	o	o	- - -	o	-	-	o	- -	o	o	-
SOLAR[c]	o	- -	o	o	o	o	+++	+++	+++	+++	-	-	+++	o	+

[a] Preference/avoidance (t-tests) is indicated by +++/- - - ($P < 0.00001$), ++/- - ($P < 0.001$), +/- ($P < 0.1$), or "0" ($P \geq 0.1$).

[b] Analysis level: broad (1) to fine (3) spatial scales.

[c] Solar energy variable was calculated specific to each season.

Table 4. Significance and fit of predictive multivariate caribou habitat models for each season.

Stratum	χ^2 *P* [a]	CS [b]	R^2 [c]	*c* Stat [d]
EARLY WINTER	< 0.001	71.6	0.31	0.78
LATE WINTER	< 0.001	77.7	0.45	0.84
SPRING	< 0.001	70.9	0.30	0.77
SUMMER	< 0.001	73.0	0.35	0.79
CALVING	< 0.001	71.3	0.32	0.78

[a] Model chi-square statistic, testing the null hypothesis that coefficients for all model terms are 0.

[b] Model classification success at cutpoint probability $p = 0.5$.

[c] Nagelkerke R^2: the approximate variation in the dataset explained by the model.

[d] The proportion of pairs of caribou and random locations for which the model results in a higher habitat probability for the caribou location. A value of 0.5 would indicate a model that is no better than a random guess.

Table 5. Variables and parameters associated with best-fit multiple logistic regression models of seasonal caribou habitat selection in the South Selkirk Ecosystem, Idaho, Washington, and British Columbia, 1987 – 2004.

Season	Variable	Level [a]	β [b]	SE	*P* [c]	Exp(B) [d]	Tolerance [e]
EARLY WINTER	FCT_ALP	1	2.213	0.349	0.0000	9.1394	0.59
	FCT_LP-WL	1	-3.715	0.635	0.0000	0.0244	0.84
	ELEV	2	0.003	0.000	0.0000	1.0033	0.67
	SOLAR_EW	2	0.000	0.000	0.0001	0.9996	0.94
	CANOPY_2	2	0.701	0.254	0.0057	2.0162	0.62
	SERAL_4	2	1.061	0.184	0.0000	2.8884	0.67
	SLOPE	3	-0.044	0.004	0.0000	0.9568	0.88
	CANOPY_1	3	-1.078	0.205	0.0000	0.3404	0.67
	SERAL_1	3	-1.262	0.218	0.0000	0.2831	0.69
	SERAL_2	3	-1.810	0.347	0.0000	0.1637	0.74
	Constant	0	-3.532	0.569	0.0000	0.0292	

LATE WINTER	SOUTH	1	-0.110	0.022	0.0000	0.8954	0.85
	CANOPY_4	1	4.203	0.769	0.0000	66.8907	0.52
	FCT_LP-WL	1	-4.341	0.842	0.0000	0.0130	0.66
	FCT_NF	1	3.215	0.790	0.0000	24.9107	0.46
	FCT_ALP	2	2.623	0.349	0.0000	13.7779	0.53
	ELEV	3	0.006	0.000	0.0000	1.0058	0.73
	SLOPE	3	-0.081	0.006	0.0000	0.9219	0.80
	CANOPY_1	3	-0.618	0.203	0.0023	0.5390	0.76
	CANOPY_4	3	-1.654	0.563	0.0033	0.1913	0.61
	SERAL_1	3	-1.096	0.249	0.0000	0.3344	0.70
	SERAL_4	3	0.590	0.181	0.0011	1.8035	0.78
	Constant	0	-2.813	1.332	0.0346	0.0600	
SPRING	ELEV	1	-0.004	0.001	0.0000	0.9960	0.60
	SLOPE	1	0.051	0.013	0.0002	1.0521	0.71
	WEST	1	-0.072	0.011	0.0000	0.9304	0.70
	SOUTH	1	-0.071	0.014	0.0000	0.9314	0.86
	CANOPY_2	1	1.843	0.434	0.0000	6.3141	0.71
	FCT_ALP	1	2.243	0.458	0.0000	9.4262	0.36
	SERAL_3	1	1.751	0.336	0.0000	5.7579	0.37
	FCT_DF	2	-5.813	1.220	0.0000	0.0030	0.73
	FCT_LP-WL	2	-3.940	0.536	0.0000	0.0194	0.77
	FCT_SHRUB	2	-1.546	0.519	0.0029	0.2131	0.85
	SERAL_4	2	1.936	0.273	0.0000	6.9311	0.40
	SERAL_5	2	1.938	0.398	0.0000	6.9451	0.41
	ELEV	3	0.004	0.000	0.0000	1.0041	0.60
	SLOPE	3	-0.046	0.005	0.0000	0.9547	0.84
	SOLAR_SP	3	0.000	0.000	0.0007	1.0003	0.90
	CANOPY_1	3	-0.599	0.149	0.0001	0.5496	0.74
	Constant	0	1.909	1.385	0.1683	6.7461	

SUMMER	ELEV	1	-0.004	0.001	0.0000	0.9960	0.60
	SLOPE	1	0.051	0.013	0.0002	1.0521	0.84
	WEST	1	-0.072	0.011	0.0000	0.9304	0.71
	SOUTH	1	-0.071	0.014	0.0000	0.9314	0.86
	CANOPY_2	1	1.843	0.434	0.0000	6.3141	0.71
	FCT_ALP	1	2.243	0.458	0.0000	9.4262	0.36
	SERAL_3	1	1.751	0.336	0.0000	5.7579	0.37
	FCT_DF	2	-5.813	1.220	0.0000	0.0030	0.73
	FCT_LP-WL	2	-3.940	0.536	0.0000	0.0194	0.77
	FCT_SHRUB	2	-1.546	0.519	0.0029	0.2131	0.85
	SERAL_4	2	1.936	0.273	0.0000	6.9311	0.40
	SERAL_5	2	1.938	0.398	0.0000	6.9451	0.41
	ELEV	3	0.004	0.000	0.0000	1.0041	0.60
	SLOPE	3	-0.046	0.005	0.0000	0.9547	0.84
	SOLAR_SP	3	0.000	0.000	0.0007	1.0003	0.90
	CANOPY_1	3	-0.599	0.149	0.0001	0.5496	0.74
	Constant	0	1.909	1.385	0.1683	6.7461	
CALVING	ELEV	1	-0.003	0.001	0.0000	0.9973	0.34
	WEST	1	-0.034	0.013	0.0106	0.9666	0.74
	FCT_DF	1	-7.749	2.291	0.0007	0.0004	0.41
	FCT_LP-WL	1	-3.390	0.609	0.0000	0.0337	0.78
	SOUTH	2	0.024	0.012	0.0538	1.0238	0.53
	SERAL_2	2	-1.657	0.473	0.0005	0.1908	0.73
	ELEV	3	0.008	0.000	0.0000	1.0076	0.41
	SLOPE	3	-0.041	0.006	0.0000	0.9601	0.75
	WEST	3	-0.007	0.003	0.0038	0.9928	0.90
	CANOPY_1	3	-0.606	0.199	0.0023	0.5458	0.68
	FCT_DF	3	3.385	0.928	0.0003	29.5297	0.58
	SERAL_1	3	-1.172	0.254	0.0000	0.3099	0.59
	SERAL_3	3	-0.608	0.176	0.0006	0.5444	0.63
	SOLAR_CA	2	-0.003	0.001	0.0000	0.9971	0.44
	Constant	0	18.612	4.356	0.0000	6.7461	

[a] Indicates spatial scale of variable, from broadest (1) to finest (3).

[b] Predictive coefficient.

[c] Significance of Wald chi-square statistic.

[d] Odds ratio: change in odds of habitat use with a one-unit increase in the value of the variable.

[e] Values <0.2 indicate problematic collinearity (Menard 1995).

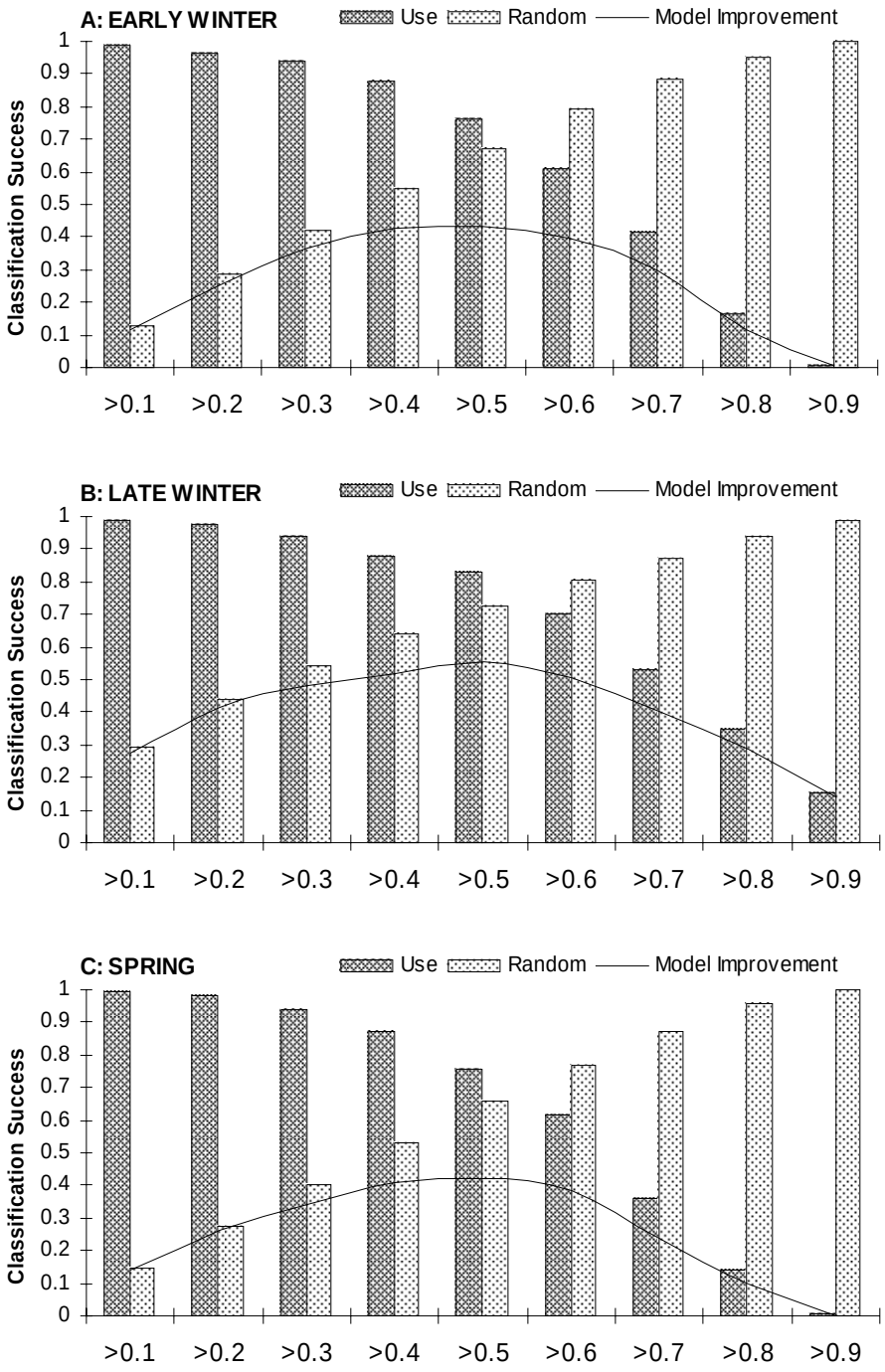

Figure 7. Predictive efficiency of season-specific caribou habitat models across cutpoint probability levels in the South Selkirk Ecosystem, Idaho, Washington, and British Columbia, 1987 – 2004. Model improvement (correctly classified caribou minus incorrectly classified random) indicates the optimal classification cutpoint in discriminating caribou from random locations.

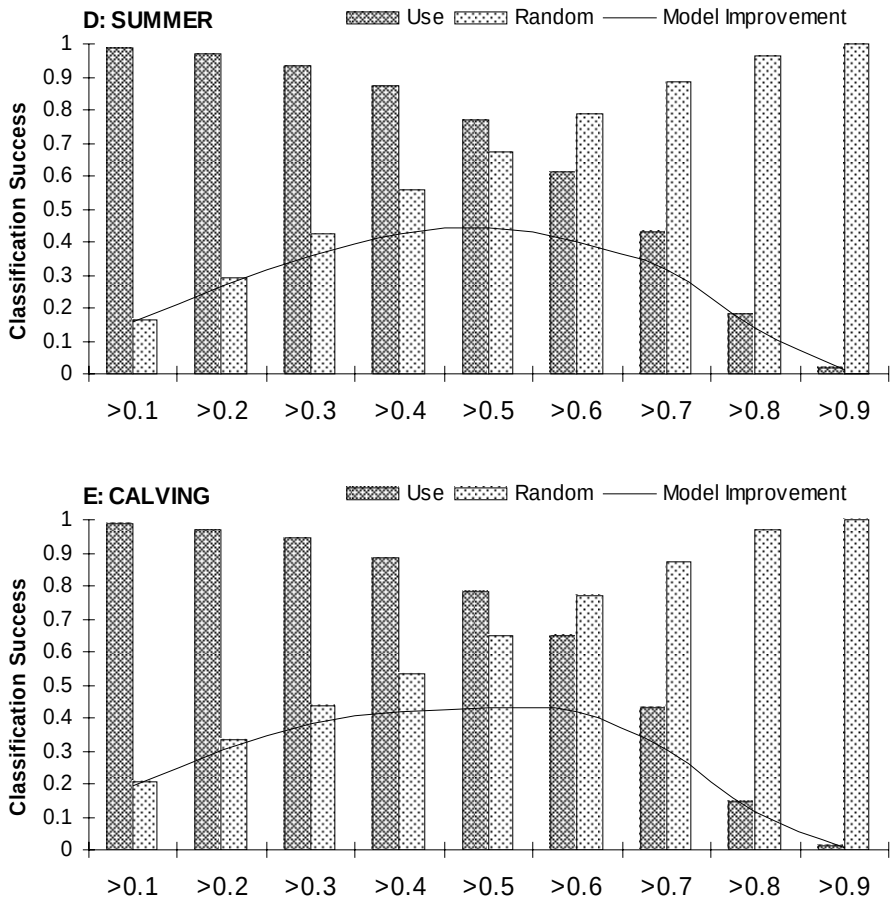

Figure 7. Continued.

DISCUSSION

Including the results reported here, mountain caribou habitat has now been modeled using spatially explicit (map-based) techniques for all but 1 of the 18 subpopulations described by Wittmer et al. (2005). Almost identical methods were applied to the Purcells-South and Purcells-Central (Apps and Kinley 2000a), Nakusp and Duncan (Hamilton et al. 2000), Frisby-Boulder, Columbia-South, Columbia-North and Kinbasket-South (Apps et al. 2001), and Wells Gray, Groundhog, Allan Creek and Barkerville (Apps and Kinley 2000a) subpopulations. An information-theoretic approach was used in a winter model for the George Mountain, Narrow Lake, North Cariboo Mountains and Hart Ranges subpopulations (Johnson et al. 2004). Patterns observed for the South Selkirk subpopulation are within the range of results from these previous analyses. For example, the seasonal shifts in elevation reported here were associated with distinct seasonal habitat relationships. This seasonal variation was considerably more evident than in the nearby South Purcells, yet less pronounced than in the Central Selkirks and Revelstoke. Preferred habitat for each season in the South Selkirk Ecosystem is typically associated with old, open-canopied spruce-subalpine fir forests located in the upper half of the available elevation range. However, at the finest scale of analysis, caribou neither select for higher elevations nor against cedar-hemlock stands during early winter. As a result, preferred habitats occur noticeably lower during early winter than during other seasons, extending in places downslope to at least the recovery zone boundary (Appendix 1). This approximates the transition between areas broadly having climax stands of spruce and subalpine fir to those of cedar and hemlock. Within the overall ecosystem, most areas identified by models as lower-elevation early-winter habitat are on PLEL. Within the portion of PLEL below the recovery line, the lack of GIS-based vegetation data comparable to that available for the rest of the ecosystem prevented us from mapping preferred habitats. However, the presence of high-suitability early-winter habitats immediately above the recovery line in some portions of PLEL suggests that early-winter habitat may extend somewhat below that line in places (see Chapter 4 for field-based assessments).

CHAPTER 3: ECOSYSTEM – LEVEL HABITAT PRIORITY AREAS

METHODS

One of the objectives of this project was to determine the overall habitat value to caribou of PLEL within the context of the greater South Selkirk Ecosystem. This would indicate the relative priority of IDL holdings in relation to the rest of the recovery area. The seasonal models described in the previous section and mapped in Appendix 1 do indicate presumed habitat suitability for any site across the ecosystem, including most of PLEL. However, due to the number of seasons and the disjunct pattern of high-suitability areas within each model, the overall priority of PLEL or portions of it may not be immediately obvious from those maps. Therefore, we wished to delineate priority ratings across the landscape based on the juxtaposition and coincidence of seasonally important caribou habitat.

The first step was to generalize each seasonal habitat model such that each site (pixel) reflected the median habitat probability value in a surrounding circular landscape of 50 km^2. This area is equivalent to the "used landscape" at level 1, our broadest analysis scale. We then considered all 5 of these generalized seasonal models together and derived a single image that reflected the minimum habitat probability value for each pixel across all 5 caribou seasons. We then determined the probability values from this image that encompassed 50, 75, and 92% of caribou radiolocations considered for analysis, and we mapped the outer bounds of these probability values (Figure 8). Finally, for areas for which seasonal habitat probability values could not be derived because we did not have the data to derive all habitat variables, we interpolated the boundaries within a maximum distance of 1.0 km. The area encompassed by the probability value corresponding to the 50th percentile of locations was considered to be Priority 1, with Priority 2 and 3 corresponding to the 75th and 92nd percentiles respectively.

RESULTS AND DISCUSSION

The use of 50th, 75th and 92nd percentiles is somewhat arbitrary, but allows a comparison across the ecosystem and over a range of habitat values. Priority 1 – 3 habitats are almost entirely contained within the identified caribou recovery area (Figure 8). The largest polygon of Priority 1 habitat is within British Columbia but extends into Idaho and Washington, and there are several disjunct polygons of Priority 1 habitat in Idaho, including within and adjacent to PLEL. Most of the portion of PLEL for which vegetation data were available falls within Priority 1 – 3 areas, with the exceptions being the extreme northwest. Overall, PLEL does significantly contribute to caribou habitat within the South Selkirk Ecosystem.

Due to the nature of the method used in identifying priority habitat nodes, its utility is greatest at the ecosystem scale. The boundaries are unlikely to translate to features readily identifiable at the field level or on detailed forest-cover or topographic maps. It should also be noted that locations important for caribou conservation may not be entirely circumscribed by Priority 1, 2 and 3 areas. Considerable

suitable habitat and 8% of radiotelemetry locations, including both travel routes and sites of more prolonged residence, fall outside of the bounds of the Priority 3 polygon.

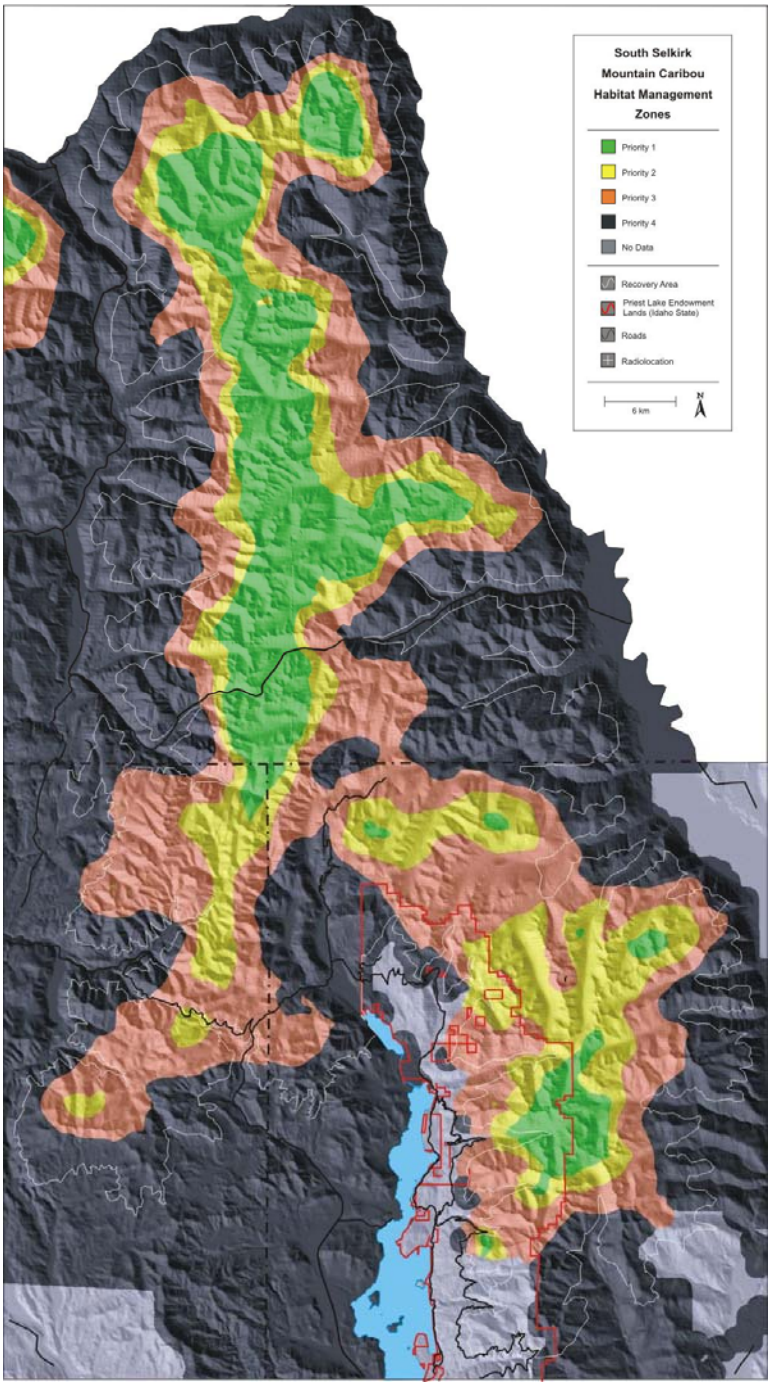

Figure 8. Ecosystem-level habitat priority areas for the South Selkirk Ecosystem in Idaho, Washington and British Columbia as defined by generalized and seasonally-combined habitat models. Priority 1, 2 and 3 areas represent habitat value cut-points that encompass 50, 75 and 92% respectively of independent telemetry locations. Refer to the text for details of methods.

CHAPTER 4: FIELD ASSESSMENTS FOR PLEL

METHODS

We conducted field inspections to (1) familiarize ourselves with the potential habitat available to caribou; (2) ensure that the range of forest stand conditions was similar to areas with which we had previous field experience; (3) determine whether seasonal locations of caribou and seasonal habitat ratings derived from modeling were consistent with conditions observed in the field; and (4) gather evidence to interpret seasonal foraging patterns, particularly with reference to early winter. We therefore selected 10 locations covering a range of elevations, stand conditions and predicted habitat values. Walking routes through each location ranged from about 0.5 to 10 miles. Along the routes, we periodically noted characteristics relevant to caribou habitat value, particularly for early winter and late winter, such as:

- relative abundance of lichen, using Armleder et al. (1992) as a guide;
- dominance of *Bryoria* versus *Alectoria* lichen;
- height above ground level at which lichen was available;
- indications of lichen being available other than on standing trees (windthrown branches on ground, brittle or dead branches with lichen in canopy, recently windthrown trees, clumps of lichen on ground);
- presence of ground-based wintergreen foods suitable for early-winter forage, such as falsebox (*Pachystima myrsinites*);
- presence of forbs suitable for spring and summer forage;
- whether terrain, shrub density, windthrow or other factors were sufficiently significant to potentially impair movement or line-of-sight;
- potential connections between the site visited and nearby habitat areas.

In addition, we conducted a 1-hour overflight of PLEL with a fixed-wing aircraft.

DATA SOURCES

In addition to notes taken during field inspections, available data included:

- Generalized vegetation data for most of the South Selkirk Ecosystem (with the exception of those portions of PLEL below the recovery zone and south of Soldier Creek). The classification included overstory tree species or species group, non-forested type, seral stage, and canopy closure class. Data were provided as GIS files.
- Results of the USDA Forest Service's Priest Lake Geographical Analysis (provided by Tim Layser, Idaho Panhandle National Forests, Priest Lake) covering PLEL. The classification scheme included overstory species group, height class, size class, canopy-closure class, age and non-forested type. Data were provided as GIS files.

- Timber type mapping completed by IDL staff for PLEL. Categories included tree size class, stocking class, and designations for non-stocked and non-forested land. Data were provided as 1:24,000 paper mapping overlaid on monochrome orthophotos (provided by M. Shanilec, IDL, Coolin) and GIS files (provided by W. Koski, IDL, Coeur d'Alene). We also made limited use of recent color orthophotos of PLEL in the Coeur d'Alene IDL office.
- Roads, streams, waterbodies, and recovery zone boundaries provided as GIS files by Tim Layser, Idaho Panhandle National Forests, Priest Lake.
- GIS files of PLEL boundaries provided by M. Shanilec, IDL, Coolin.
- GIS files of the primary and secondary land timber landbase and non-forested or noncommercial land within PLEL provided by T. McManus, IDL, Boise.
- Paper copies of 1:24,000 federal topographic maps.
- Caribou radiolocations and seasonal habitat models, as reported in Chapter 2.

RESULTS AND DISCUSSION

We visited 10 sites or general locations and drove many of the main roads in PLEL between 22 September and 8 October, 2004 (Figure 9, Table 6). We therefore conducted at least cursory ground inspections of all major drainages within the recovery zone except South Fork Hunt Creek, North Fork Indian Creek and the Abandon Creek/upper Caribou Creek area. Regardless of the level of actual caribou use recorded through telemetry studies, there was generally a strong correlation between habitat values as modeled and as determined in the field. Exceptions tended to be:

(a) patches of apparently suitable habitat observed in the field that were too small or had too little of their area within the available GIS database to influence habitat modeling results (or vice-versa); and
(b) limited areas with atypically poor lichen loads relative to stand structure and elevation.

One significant shortcoming was the lack of vegetation data (in the GIS dataset used for modeling) below the recovery zone boundary and at the southern end of PLEL. This limited our ability to identify potential habitat at low elevations and in several drainages, and prevented us from comparing modeled to observed habitat values.

Based on characteristics of sites used by caribou in PLEL during early winter, our experience trailing caribou in other areas (Terry et al. 2000, Kinley et al. 2003, Serrouya et al. 2007), and published reports from the elsewhere in the South Selkirk Ecosystem (Rominger and Oldemeyer 1989, Servheen and Lyon 1989), foraging in that season appears to involve a combination of (1) lichen from standing trees and windthrow, typically within subalpine fir or spruce-dominated stands at relatively high elevations, and (2) lichen as litterfall and ground-based forbs and shrubs in hemlock- and spruce-dominated stands at lower elevations. This is surmised from characteristics at sites used by caribou in that season; ground-trailing of caribou would be required to confirm this.

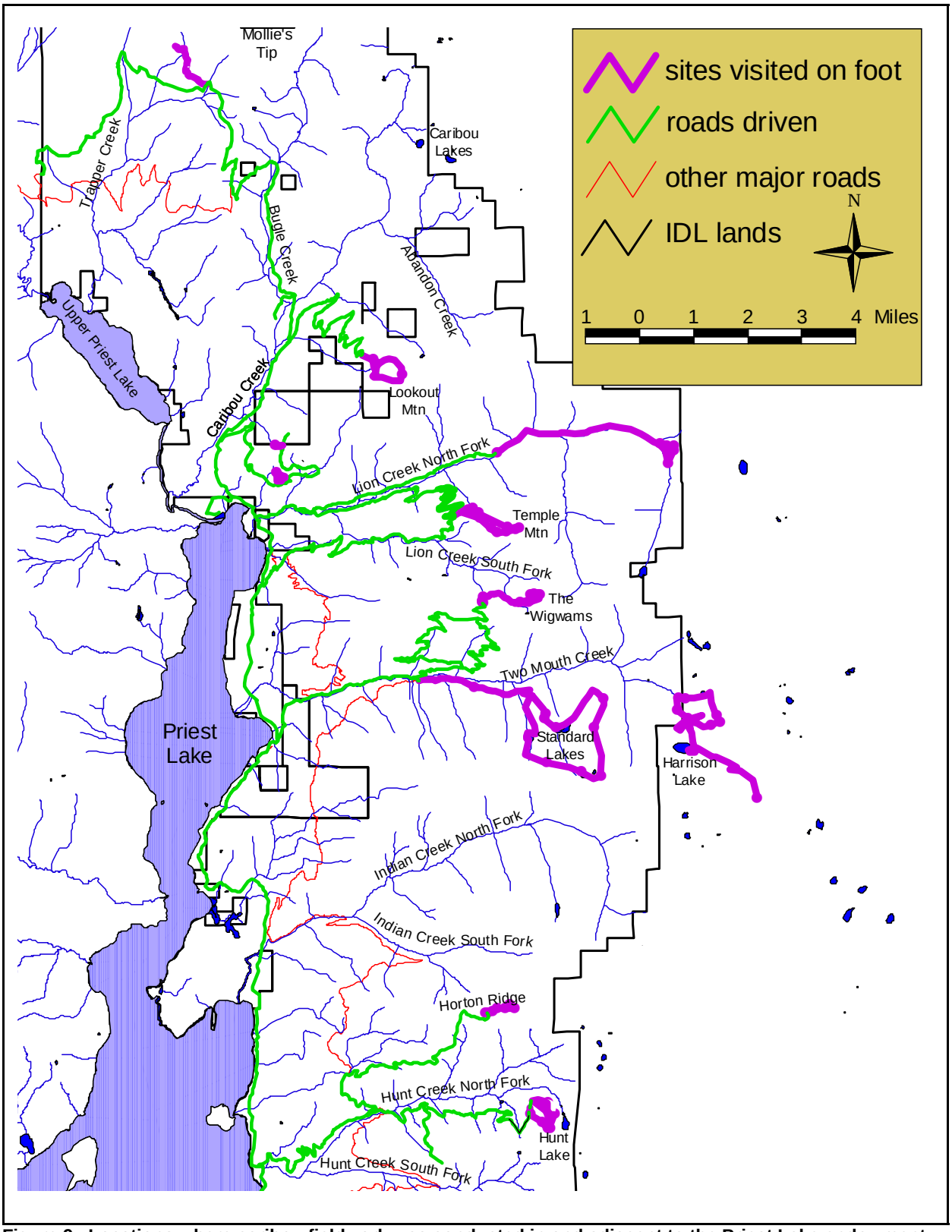

Figure 9. Locations where caribou fieldwork was conducted in and adjacent to the Priest Lake endowment lands.

Table 6. Field inspections conducted on Idaho Department of Lands' Priest Lake endowment lands, September-October 2004.

Site	Caribou Use and Predicted Habitat Values[a]	Field Observations	Conclusions/Comments
1. Two-Mouth Creek south side (Standard Lakes)	• from Standard Lakes through Goblin Knob, models predict high value for EW (down into valley) and LW (restricted to basins) • values overall lower and more patchy for SP, CA and SU • headwaters of Two-Mouth (i.e. east of Standard Lakes) generally predicted to be of limited value; better for EW on valley floor • telemetry records throughout, including larger cluster on NE face of Goblin Knob	• did not visit Goblin knob or headwaters • moderate EW suitability in older hemlock stands on lower slopes (litterfall of *Alectoria*, some ground forage), and at lower end of spruce-subalpine fir forest (low-moderate *Bryoria* loads – Fig. 10) • much of area (especially headwater of Two-Mouth) has talus or exposed bedrock (Fig. 11) • *Bryoria* abundance in upper basins is moderate (Fig. 12) to locally good and available 2.5/2.8 m[b] above ground; some pockets of dense cover (Fig. 12) that might impede movement	Although movement into the area surveyed is likely affected by the amount of talus in the surrounding terrain, it does occur. Difficult terrain here and elsewhere in PLEL may offer some advantage to females during CA by enhancing separation from other species. *Bryoria* is available but not especially abundant. Maturing to old stands at slightly lower elevations (possible EW habitat) are contiguous with upper basins. Overall, the area appears to be good (not excellent) habitat for caribou (Fig. 12).
2. Harrison Peak area (Harrison Lake in Kaniksu NF and east side of upper Two-Mouth Creek in PLEL)	• greatest concentration of caribou locations in/near PLEL (all seasons); falls along Selkirk Crest (main ridge connecting PLEL and Kaniksu NF) • predicted high value in all seasons, especially LW	• *Bryoria* loads good to excellent, both in PLEL (Fig. 13) and in Kaniksu NF • some stands with good SP/SU/EW ground-foraging opportunities adjacent to abundant *Bryoria* (Fig. 14), providing all-season habitat	Observed characteristics are consistent with high values predicted by habitat model for all seasons. This area straddles PLEL and Kaniksu NF and appears to be one of the most valuable locations for caribou within the study area.

[a] from habitat models in Chapter 4; CA = calving, EW = early winter, LW = late winter, SP = spring, SU = summer

[b] first number is average height above ground of any attached and growing *Bryoria*; second number is average height where *Bryoria* becomes more abundant and > 10 cm long; measurements in metric to facilitate comparisons with other research

Site	Caribou Use and Predicted Habitat Values	Field Observations	Conclusions/Comments
3. Klootch Mountain - The Wigwams-upper South Fork Lion Creek	• caribou use and predicted habitat values moderately high to high for all seasons • notably large patch of predicted EW habitat extending well downslope from ridge between the 2 mountains	• between about 5600' and 6000', lichen availability line very low in canopy (mean heights 1.7/2.0 m^b) so excellent availability of lichen when snow shallow or absent in EW (Fig. 15) • shifts to open stands of subalpine fir with heavy *Bryoria* loads at 2.4/2.7 m^b above about 6000' (Fig. 15); excellent LW habitat • below 5600' on south side of ridge, stands of lodgepole pine and maturing hemlock also provide possible EW habitat (primarily through Alectoria windthrow) that will likely improve over next few decades	Observed characteristics are consistent with high values predicted by habitat model for all seasons that extend north across South Fork Lion Creek through Mount Temple area. EW habitat occurs at high elevations due to lichen line low in canopy but extends downslope through remaining patches of older forest, which have been used by caribou.
4. Horton Ridge	• at edge of habitat modeling area • predicted habitat values moderately high to high for all seasons • no telemetry records on ridge (a few in South Fork Indian Creek to north)	• ridgeline (> 6000') has good to excellent Bryoria or mixed Bryoria/Alectoria loads at an average of 2.3/2.7 m^b (Fig. 16) • some areas downslope (5500-5600') have lichen lower in canopy so offer some EW potential • upper south slope of Horton Ridge is grassy (Fig. 17: top, middle); more suited to deer and elk than caribou • area outside modeling area to south (upper Hunt Creek) appears to have good caribou habitat, and area to north (upper South Fork Indian Creek) also appears to have suitable stand structure (Fig. 17, bottom)	Access by caribou to Horton Ridge and South Fork Indian Creek via PLEL is likely limited by rugged terrain (Seven Sisters, Chimney Rock, Mount Roothaan) between there and caribou activity areas to the north, and by the low predicted habitat values in North Fork Indian Creek. Access is more likely from the southeast through Kaniksu NF. Local habitat values on Horton Ridge and the adjacent upper South Fork Indian Creek area are high, and those in upper Hunt Creek just south of Horton Ridge also appear to be good (see also next entry).

Site	Caribou Use and Predicted Habitat Values	Field Observations	Conclusions/Comments
5. Hunt Lake area	• outside of habitat modeling area • some telemetry records for EW and LW on ridge and slope west of Hunt Lake • telemetry records for CA along Gunsight Peak and adjoining ridge to NE of Hunt Lake (Fig. 18) • these represent the southernmost extent of concentrated caribou telemetry records in the South Selkirk Ecosystem	• area used by caribou in EW and LW is along steep ridge and hillside west of Hunt Lake; moderate *Bryoria* and mixed *Bryoria*/*Alectoria* loads • most forest in upper Hunt Creek is below normal LW elevations • much of Hunt Creek has been harvested but there are some significant stands of older hemlock at mid elevations that could provide good EW habitat (Fig. 18; see also foreground of top photo in Fig. 17)	While used to some extent by caribou, the higher-elevation stands of subalpine fir and spruce we inspected are of only moderate value for EW or LW habitat. Values are higher for calving (along Selkirk Crest, to east) and probably for EW habitat in older hemlock stands closer to the valley floor. The main limiting factors for use of this area appear to be its southern location and the somewhat limited extent of LW habitat.
6. Temple Mountain	• part of same patches of seasonal habitat noted for Klootch Mtn – The Wigwams – upper South Fork Lion Creek (above) • many telemetry records, particularly for EW	• our route covered 5000' to 6600' and followed the transition from stands with predominantly *Alectoria* in canopy to those with almost all *Bryoria* (Figs. 19-21) • some hemlock immediately above old logging at 5000'; rapid transition to spruce, lodgepole pine and subalpine fir • some trees with very heavy lichen loads, but most only moderate; lichen availability at about 1.5 m at lower elevations • generally open ground on gentle slopes	With no single outstanding habitat feature noted in the field, the main value of this site is that there is reasonably good habitat in a large block spanning a wide range of elevations and connected to other areas over easily-traveled ground. Of note is the easy connection to the high-quality habitats in South Fork Lion Creek between Klootch Mountain and The Wigwams. This situation appears to be significant to caribou, given the number of telemetry records there.

Site	Caribou Use and Predicted Habitat Values	Field Observations	Conclusions/Comments
7. Upper Lion Creek	• portion of valley bottom within modeling area has high habitat model ratings for EW, moderate for SP and SU, low for CA and LW • telemetry locations on valley bottom almost all EW (down to 4400') and SU (down to 4800')	• old, mainly cedar-dominated stands between road closure and end of old road (3600-4200') are old partial cuts so are generally quite dense with limited forage (no telemetry records there) • past end of old road the valley bottom is almost entirely open, old stands: first spruce-subalpine fir, then a large patch of old hemlock forest (Fig. 22) near the bend in Lion Creek, then more spruce-fir (Fig. 22) • evidence in hemlock stands of abundant litterfall (lichen clumps and broken branches; Figs. 22, 23) and ground-based forage for EW (falsebox, mitrewort, other wintergreen shrubs and forbs; Fig. 23) • relatively good connection to Selkirk Crest, Smith Creek and other areas in Kaniksu NF , but somewhat limited connections to ridges bounding Lion Creek farther downstream (Fig. 24)	There is very good EW habitat on the valley bottom of Lion Creek beyond the end of the road, occurring in old, open hemlock stands and some spruce-fir stands. This is unusually low elevation for caribou use in PLEL, and represents a locally uncommon habitat type.

Site	Caribou Use and Predicted Habitat Values	Field Observations	Conclusions/Comments
8. Lower Caribou Creek	• several records of SP use here (3700-4000') and nearby (as low as 2400') at elevations much below most caribou activity • outside habitat modeling area (no data were available below recovery zone line in PLEL)	• we were not able to access 2 SP records in what appears to be old-growth forest (possibly cedar-hemlock) within PLEL just east of Upper Priest Lake • the 1st site we visited was in a stand that appears to have had 2 entries of partial cutting, so has an open canopy and an abundance of forbs (Fig. 25) • the 2nd site was on the boundary between a small, closed-canopy stand of older hemlock (Fig. 25) and a more open mixed species stand with a west aspect; there was partial-cut logging nearby • at this site little vegetation suitable for spring foraging was evident right on site, but nearby slopes and cutblock would lose snowcover early in SP, and there was abundant foliose-type lichen on the ground which (if accumulating on snow over winter) would be available and still fresh as snow melted in spring	It was not completely clear which habitat features caribou that used these and nearby sites during SP were targeting. Forage plants would be available earlier in SP here than they would be at higher elevations, particularly on the 1st site with its relatively open canopy and high insolation, but also at openings in the vicinity of (though not right at) the 2nd site and the sites not visited. Overall, these sites were representative of a small proportion of the SP locations. Whether they are particularly important under specific climatic or physiological conditions is not known.

Site	Caribou Use and Predicted Habitat Values	Field Observations	Conclusions/Comments
9. Lookout Lake	• habitat values are high both above and below Lookout Lake in SP, SU and especially EW, moderately high above the lake in CA, and very limited (and at upper elevations) in LW • this is at the western end of a ridge with lower elevations all around • no telemetry records	• just above the strip logging (below the lake), there is some potential EW habitat due to lichen availability being 1.8-2.0 m above ground • lichen availability line moves to > 2 m at lake elevation (5600') and 3.5-4.5 m in upper basin above lake (6000-6200'; Fig. 26); in addition, *Bryoria* is generally close to trunk with little on branch ends (inconsistency and great height of lichen line suggests possibility of recent abnormal snow event) • stand above lake appears to be relatively young • despite open stand structure, travel in area west of Lookout Lake would be difficult when snow cover lacking due to abundance of rock	This appears to be a site where gross-level vegetative and terrain characteristics suggest habitat values (i.e. model indicates some habitat values to be high) but this prediction is not supported by current conditions evident on the ground. There may be value for CA around upper perimeter of basin and there is some value for EW below lake, but this generally does not appear to be a high-quality year-round site for caribou, and is somewhat isolated from other caribou habitat.

Site	Caribou Use and Predicted Habitat Values[a]	Field Observations	Conclusions/Comments
10. Upper east side of Trapper Creek	• northwest corner of PLEL (west of about Bugle Creek) has overall low predicted values for caribou in all seasons (with small patches of higher value for EW and SU) • very few telemetry locations (all SP and SU)	• land falling within the elevations at which most caribou activity normally occurs on an annual basis makes up a small proportion of the landscape in this area (many ridges are low), and a large part of what exists at higher elevations is either rock or has burned (Fig. 27, top); exceptions to this (ex. Fig. 27, bottom) are limited in size and relatively rare • there are some stands of older spruce-fir forest remaining at slightly lower elevations, but much of it has a tall, dense understory (Fig. 28) • small, scattered stands of old, large-diameter hemlock and cedar occur throughout the northwest corner, both above and below the recovery zone boundary	There is considerable variability in elevations used by caribou in the South Selkirk Ecosystem between and even within seasons, but most lies above about 5800-6000'. In this portion of PLEL, habitat values are limited by the low mean elevation and the high percentage of burned land or exposed rock where elevations are higher. The burned land not only provides little caribou forage (except in SP), it may also act as an attractant to other ungulates and therefore their predators. However, while there is little here to attract prolonged activity by caribou, current conditions likely do not provide a major impediment to travel, and this area is an obvious link between nodes of more concentrated activity lying to the southeast and the northwest. Continued movement through this area in the future will depend in part on whether forest regenerating in the burn becomes excessively dense, and whether pockets of remaining old forest along the northern boundary remain intact.

Figure 10. Top: older hemlock stand (298 years[a]) in Two-Mouth Creek provides potential early-winter habitat due to some ground forage and windthrown trees and branches with lichen. Bottom: just above the transition from hemlock to spruce-subalpine fir forests (198 years), *Bryoria* loads are moderate and found relatively low in canopy, offering some potential early-winter foraging opportunities.

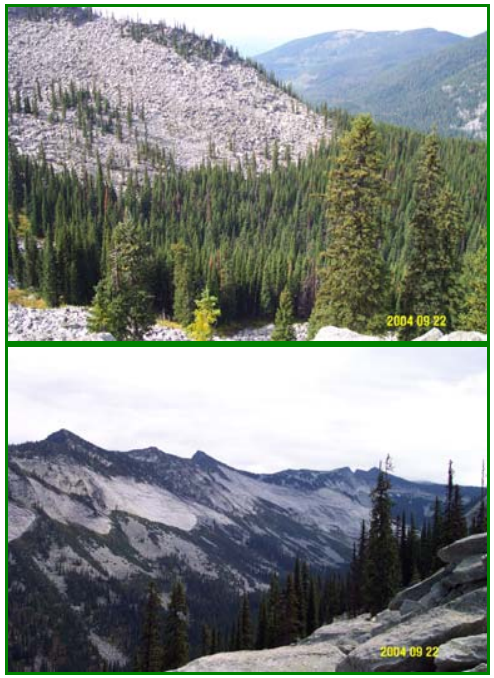

Figure 11. Extensive exposed bedrock and talus in many parts of PLEL may affect the ability of caribou to travel and forage efficiently. Top: northeast of Upper Standard Lake (88 years). Bottom: headwaters of Two-Mouth Creek. However, such terrain may aid calving caribou by allowing greater isolation from other species. Habitat is generally better connected within than between forested patches.

Figure 12. Partial range of conditions within the Standard Lakes area. Top: moderate *Bryoria* loads. Bottom: thickets with limited visibility and impediments to travel near Lower Standard Lake. Both sites typed as 198 years; bottom site in patch of younger forest within the generally older stand.

[a] All ages listed in Figures 10-28 are taken from forest cover classification done as part of the Priest Lake Geographical Analysis and provided by Tim Layser, USDA Forest Service.

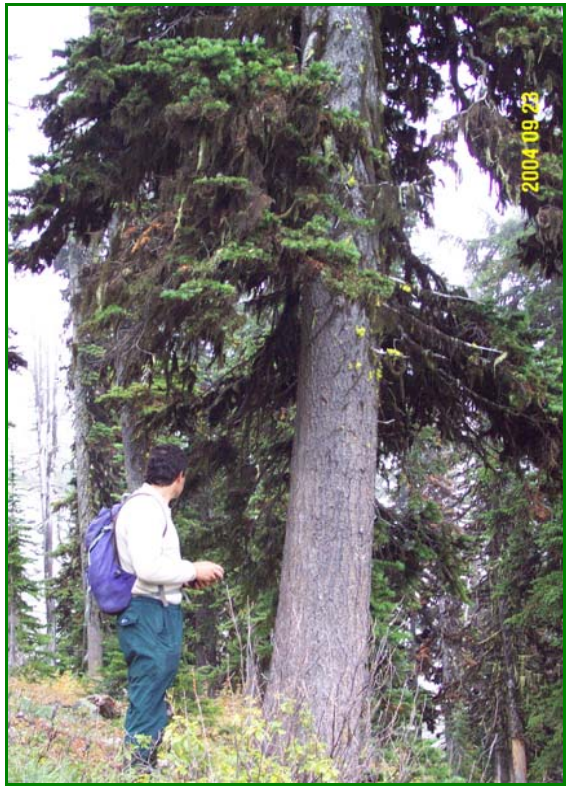

Figure 13. Heavy Bryoria loads were observed through much of the area near Harrison Peak, providing excellent late-winter foraging opportunities (stand age 248 years). Photo from the upper east side of Two-Mouth Creek in PLEL.

Figure 14. Old parkland stand near Harrison Peak illustrating open stand structure that results in habitat for all seasons due to long sight lines, ease of movement, relatively abundant *Bryoria* and availability of ground forage used in spring, summer and potentially early winter (mainly wood-rush [*Luzula* sp.] in this location).

Figure 15. Top: heavy loads of *Alectoria* and *Bryoria* lichen starting 1.5 m above ground at 5700' near The Wigwams trailhead (stand age 148 years). Bottom: Subalpine fir stand (268 years) with heavy lichen loads, mainly *Bryoria* (note darkness of trees in foreground), at 6200' near The Wigwams trail in upper end of South Fork Lion Creek.

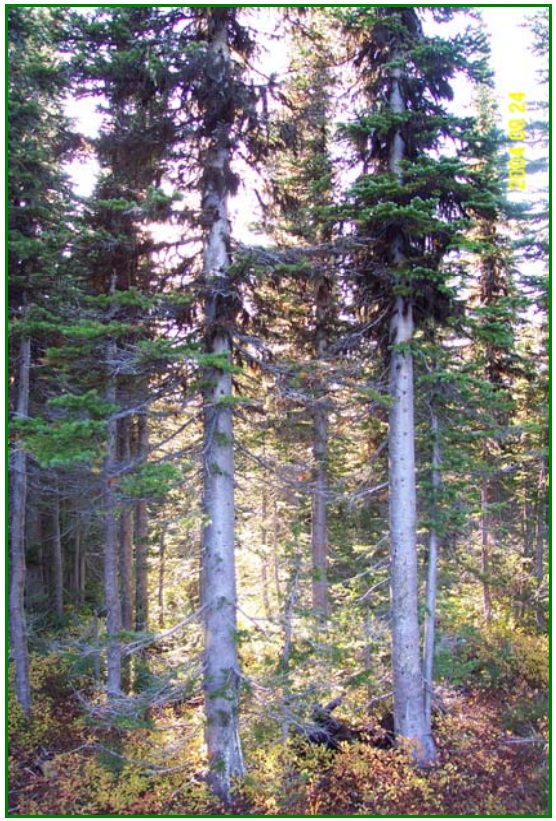

Figure 16. ***Bryoria*** **on subalpine fir (stand age 188 years) along crest of Horton Ridge. Lichen relatively abundant; most trees with more than this. Note bottom end of lichen availability line in canopy, about 2 m above ground.**

Figure 17. Top: view toward Horton Ridge (mid-ground on right) from southeast. Note open, grassy slopes just below ridgeline on part of ridge. Middle: view from Horton Ridge looking southeast toward Hunt Lake. Bottom: view from Horton Ridge to north into upper South Fork Indian Creek (stand age 188 years).

Figure 18. Some habitat features in vicinity of Hunt Lake. Top: ridge extending north from Gunsight Peak having telemetry records during calving. PLEL boundary lies about 2/3 of way up slope. Bottom: View from road in Hunt Creek at about 4400' showing old hemlock stand in foreground (potential early-winter habitat), with younger, mixed-species stand in background (lower habitat value). Area used by caribou during early and late winter in Hunt Creek not shown in photos.

Figure 19. *Alectoria*-dominated stand of spruce (268 years) in draw at about 5600' on west side of Temple Mountain. Open stands of spruce, lodgepole pine, subalpine fir and hemlock with *Alectoria* rather than *Bryoria* extend down to about 5000' nearby. The lowest lichen in this area can be reached by caribou from the ground, without any snowpack, so provides opportunities for EW foraging.

Figure 20. Stand (268 years) transitional between *Alectoria*- and *Bryoria*-dominated stands, about 5800'. Note open stand structure and relative lack of tall understory, providing ease of travel and good lines of sight.

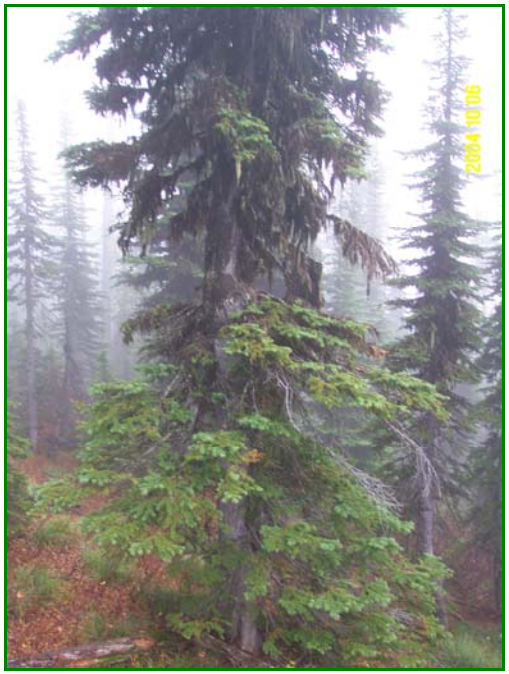

Figure 21. *Bryoria*-dominated stand (268 years) of subalpine fir at 6400' near top of Temple Mountain. Most nearby trees had somewhat less lichen. Line below which lichen not present in tree indicates snowpack depth (about 2.5 m here).

Figure 22. Stands on the valley floor of upper Lion Creek used by caribou during early winter. Top: stand of old hemlock (168 years) with very open understory and excellent visibility on gentle slope at 4700'. Bottom: spruce stand (168 years) at 4800'; openness probably due to cold air pooling. Both stands have abundant branches, broken tops and trees on forest floor, and this should increase as stands get older.

Figure 23. Early-winter foraging features present in old hemlock stand in Lion Creek. Top: broken branches originating in forest canopy, indicative of windthrown lichen availability, and wintergreen forbs such as mitrewort. Bottom: falsebox, often used as an early-winter forage.

Figure 24. Relative permeability of landscape to travel by caribou into and out of upper Lion Creek. Top: view east toward Selkirk Crest, indicating contiguous mature to old forest (168 years). Bottom: view to northwest toward The Lions Head and Lions Head Ridge showing exposed bedrock resulting in reduced foraging possibilities and more difficult travel along the mid slope.

Figure 25. Two sites used by caribou during spring near the lower reaches of Caribou Creek. Top: mixed stand (mainly cedar and hemlock) that appears to have had 2 high-grade or partial logging entries in past, and has an open canopy (stand age 74 years). Bottom: small stand of older, closed-canopy hemlock (248 years) adjacent to more open forest to left of photo.

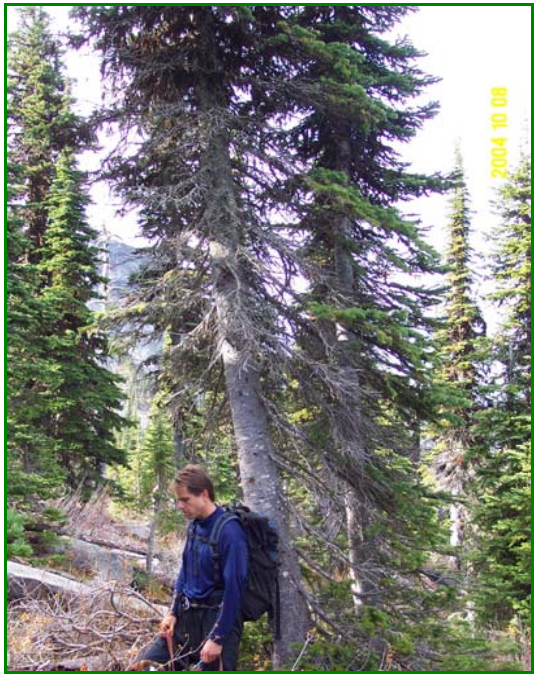

Figure 26. Subalpine fir (248 years) in basin above Lookout Lake (about 6100'). Bryoria loads at this elevation on this site are only moderate on most trees and currently occur 3.5 – 4.5 m above ground level so would be unavailable for most of the winter.

Figure 27. Upper elevations in northwest corner of PLEL. Top: looking NNW from Lookout Mountain to Bugle Ridge (forested ridge in right foreground); Caribou Hill (low forested ridge, center-left); Mollie's Tip with Phoebe Tip just visible (rocky peaks at center right); Trapper Peak (burned; obscured by middle tree); and Green Bonnet Mountain (left background; also burned). Mountains in far background outside of PLEL. Bottom: West side of ridge south of Mollie's Tip, showing terrain limitations even where old forest (168 years) does occur at higher elevations in this area (top of ridge at 6500').

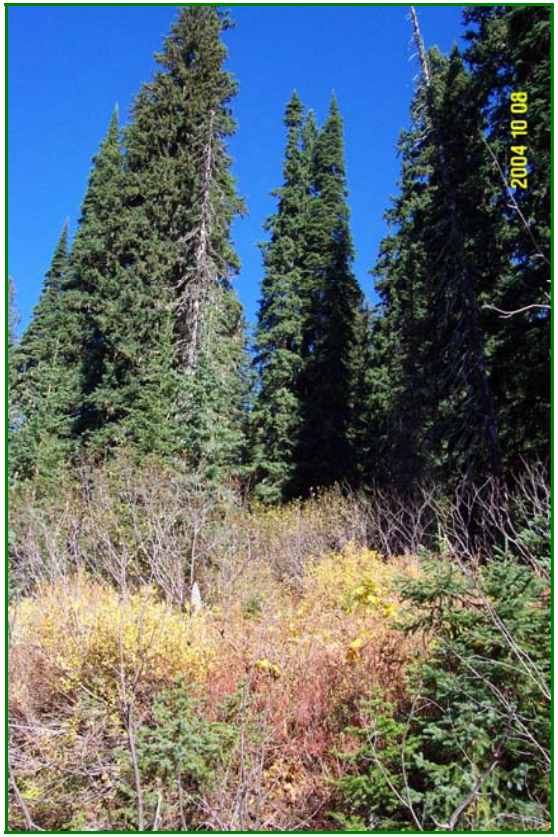

Figure 28. Stand of Engelmann spruce (168 years) at 4800' beside Road 461. The stand is superficially suitable for early-winter habitat (open stand of old trees), but the tall, dense understory and paucity of lichen near ground level limit its value.

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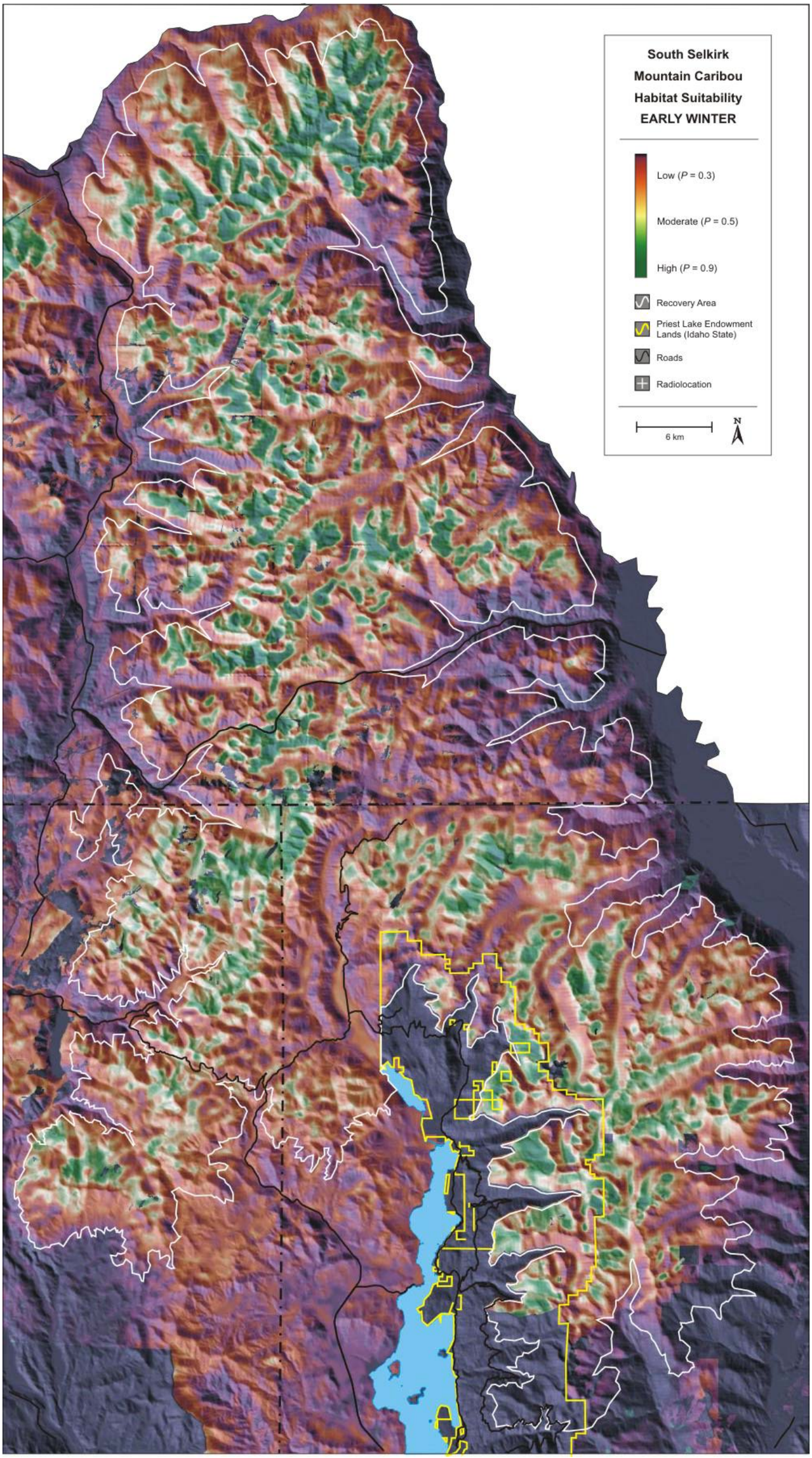
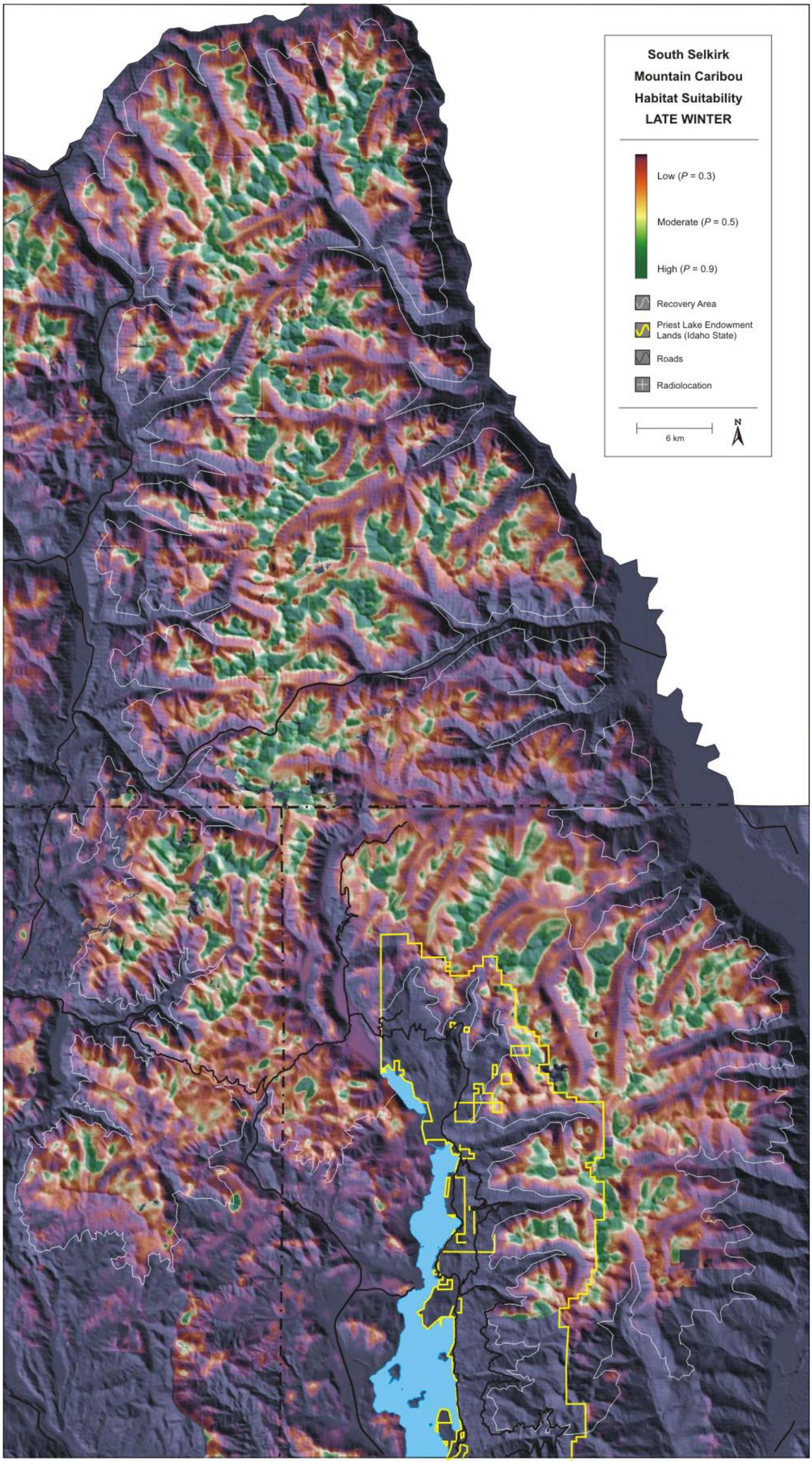
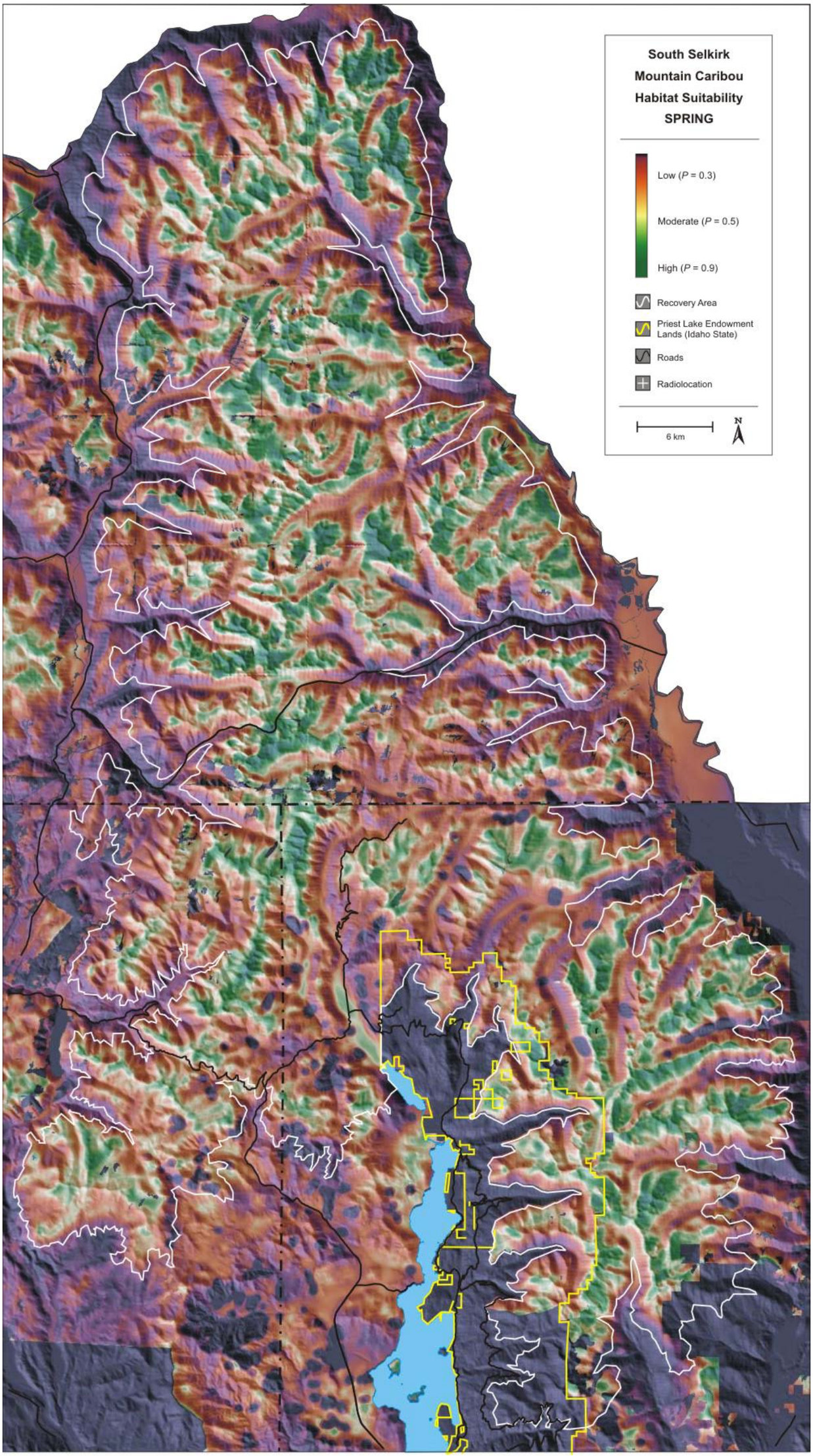
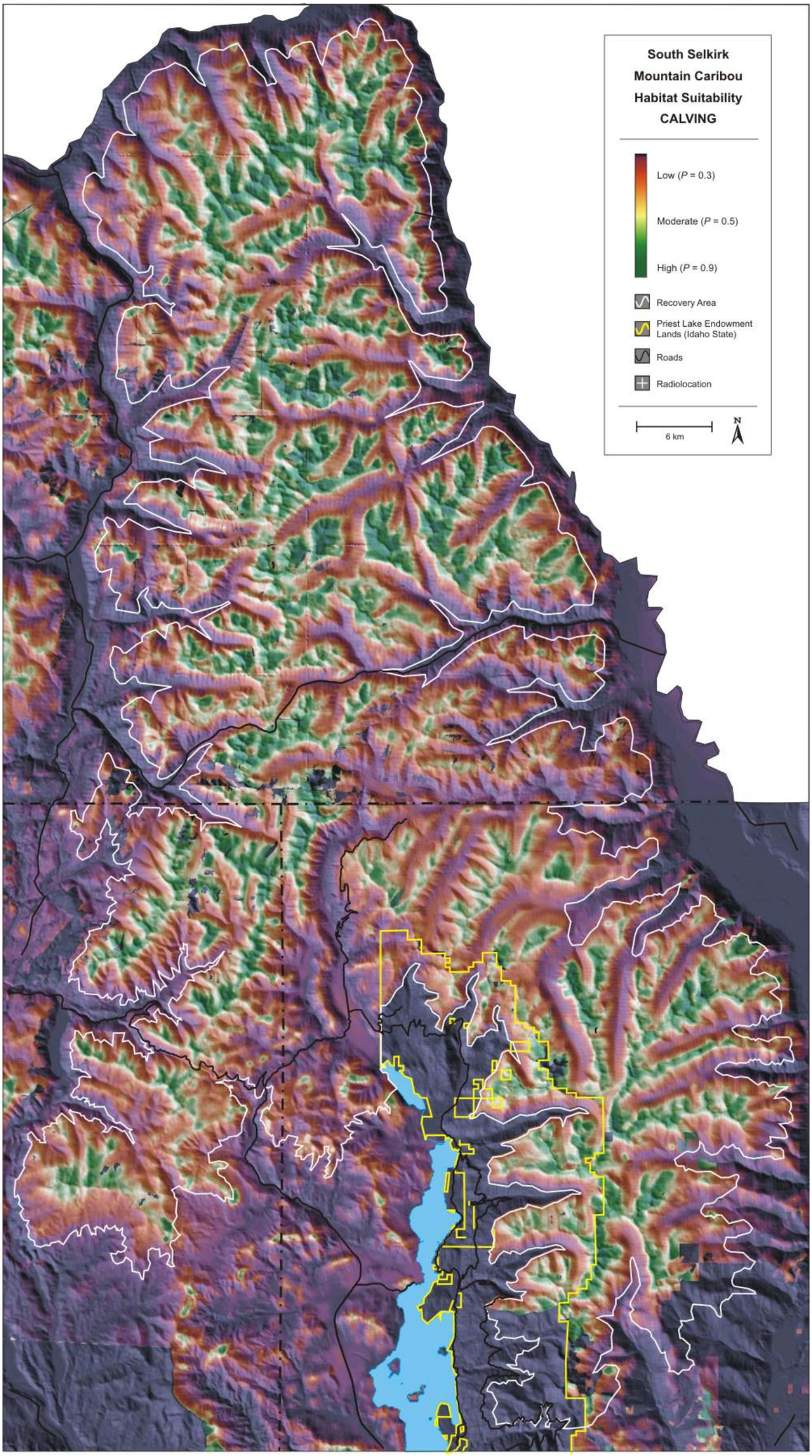
APPENDIX 1

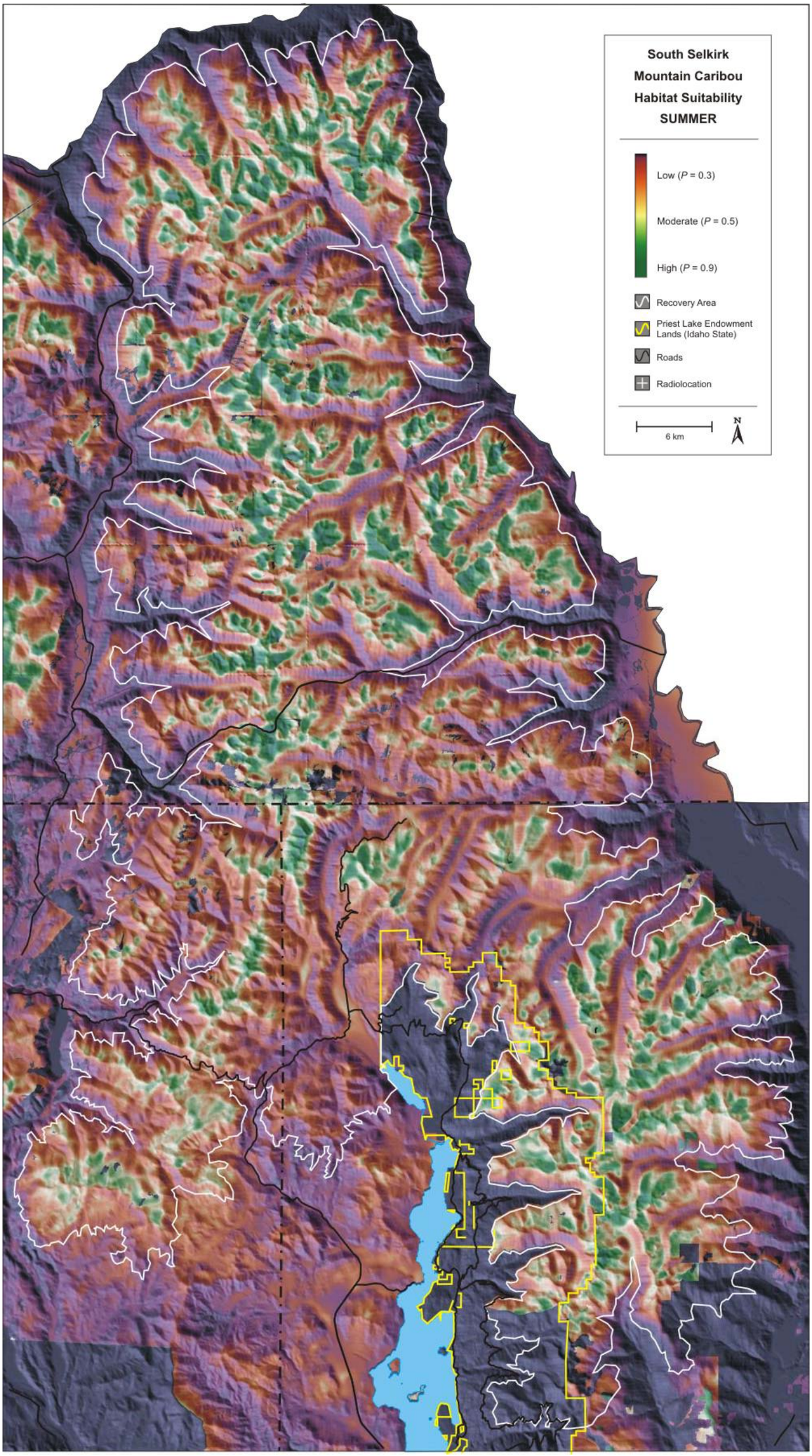
Predicted seasonal habitat suitability for mountain caribou in the South Selkirk Ecosystem of Idaho, Washington and British Columbia. Images depict a continuum of values reflecting caribou habitat selection probability.


South Selkirk
Mountain Caribou
Habitat Suitability
EARLY WINTER
Low (P = 0.3)
Moderate (P = 0.5)
High (P = 0.9)
Recovery Area
Priest Lake Endowment Lands (Idaho State)
Roads
Radiolocation
6 km
N


South Selkirk
Mountain Caribou
Habitat Suitability
LATE WINTER
Low (P = 0.3)
Moderate (P = 0.5)
High (P = 0.9)
Recovery Area
Priest Lake Endowment Lands (Idaho State)
Roads
Radiolocation
6 km
N


South Selkirk
Mountain Caribou
Habitat Suitability
SPRING
Low (P = 0.3)
Moderate (P = 0.5)
High (P = 0.9)
Recovery Area
Priest Lake Endowment Lands (Idaho State)
Roads
Radiolocation
6 km
N


South Selkirk
Mountain Caribou
Habitat Suitability
CALVING
Low (P = 0.3)
Moderate (P = 0.5)
High (P = 0.9)
Recovery Area
Priest Lake Endowment Lands (Idaho State)
Roads
Radiolocation
6 km
N


South Selkirk
Mountain Caribou
Habitat Suitability
SUMMER
Low (P = 0.3)
Moderate (P = 0.5)
High (P = 0.9)
Recovery Area
Priest Lake Endowment Lands (Idaho State)
Roads
Radiolocation
6 km
N