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Development of a preliminary habitat assessment and planning tool for mountain caribou in southeast British Columbia

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Abstract: The Purcell Mountains of southeast British Columbia support a population of mountain caribou near the southernmost extension of their range. This ecotype is dependent upon late-successional forests, largely because such stands provide arboreal lichen for winter forage. Recent provincial forest practices legislation and land-use planning initiatives have provided the impetus for developing an interim caribou habitat assessment model for use as a planning tool. We applied an HSI (habitat suitability index) model developed for a nearby population as a testable hypothesis of caribou habitat selection in the southern Purcells. In a study area of about 6000 km^2, 512 radiolocations were obtained for 22 animals from 1993 through 1995. Seasonal selectivity was assessed for the following model variables: elevation, slope, habitat type/current cover type, overstory size class, canopy closure, and age of dominant overstory. Caribou were most selective for stand age, which the model also defined as the greatest determinant of habitat suitability. However, we did not judge overall model output to be an adequate predictor of habitat selection by southern Purcell caribou. Seasonal ratings for each variable were therefore modified to better reflect selection patterns by animals in this study, and subjectively adjusted to ensure that potentially limiting habitat types were rated highly. An evaluation of the adjusted model established its efficacy as an interim decision-support tool. Selection analyses of spatial habitat distribution levels indicated a preference by caribou for landscapes with at least 40% suitable habitat per 250 ha and per 5000 ha. From this, it is apparent that suitable habitat is highly fragmented in this study area.

Key words: GIS, Habitat Suitability Index, HSI, Purcell Mountains, model, landscape, stand.

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Introduction

The ecotype of woodland caribou found in wet coniferous forests of southeastern British Columbia is referred to as mountain caribou (Stevenson & Hatler, 1985). This ecotype is strongly associated with late-successional forests (Simpson *et al.*, 1994; Stevenson *et al.* 1994), largely because such stands provide arboreal lichen for winter forage (Freddy, 1973; Antifeau, 1987; Simpson & Woods, 1987; Rominger & Oldemeyer, 1989; Seip, 1990; Seip, 1992). These habitats also tend to be associated with high timber value.

The southern Purcell Mountains support a remnant population of less than 100 mountain caribou (Kinley, unpubl. data) occurring near the southern limit of their range. Caribou are provincially listed as "vulnerable", and provincial forest practices legislation directs that their requirements be integrated with forest management. However, little ecological information exists for the southern Purcell population from which to develop prescriptive guidelines at strategic or operational planning levels. A long-term research program established in 1992 to improve baseline information is still underway. However, given mounting demands on this landbase and the impetus of a regional land-use planning process, an interim tool was required to integrate the best available knowledge of caribou requirements with ongoing planning initiatives in a timely fashion. In this paper we present the evaluation and adaptation of an existing mountain caribou Habitat Suitability Index (HSI) model for a nearby population (Allen-Johnson 1993), and its application at both stand and landscape levels.

Study area

The study area encompasses roughly 6000 km^2 near the southern end of the Purcell mountain range of southeastern B.C. (Fig. 1). This area is coincident with the known distribution of the southern Purcell montain caribou population, and also defines the area searched in the process of capturing study animals. Elevations range from 530 to 2850 m. Vegetation patterns are affected by elevation and a west to east gradient of decreasing precipitation. Climax communities are dominated by western redcedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) in moist areas at lower elevations, Douglas-fir (*Pseudotsuga menziesii*) in dry areas at low elevation, and Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) at mid to high elevations, although fire-successional stands of lodgepole pine (*Pinus contorta*) are common throughout. Alpine tundra occurs at the highest elevations.

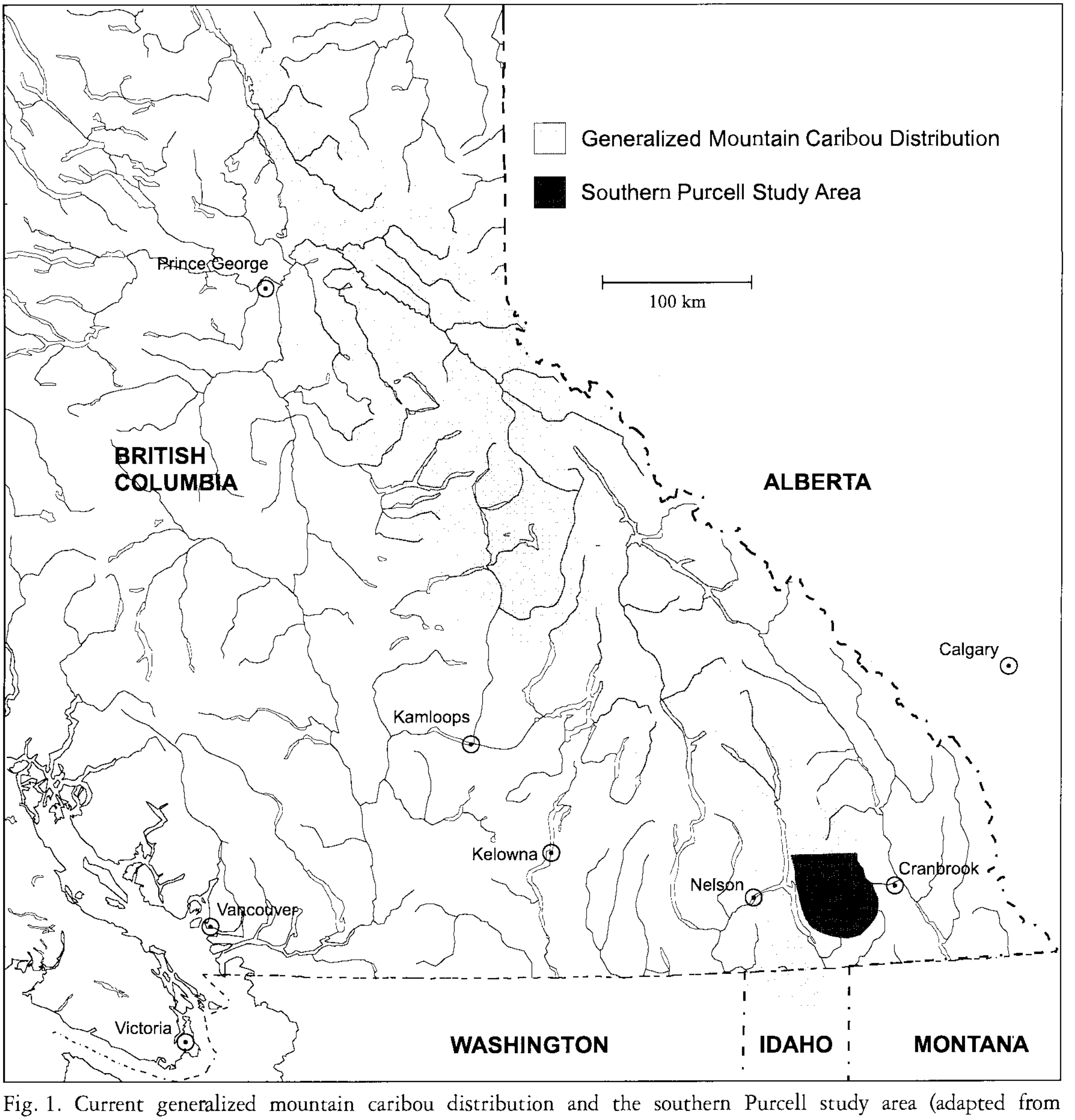


Fig. 1. Current generalized mountain caribou distribution and the southern Purcell study area (adapted from Stevenson & Hatler, 1985).

Methods

Data

Between 1993 and 1995, 22 caribou were radiocollared and monitored using standard aircraft telemetry techniques (White & Garrott, 1990). From semi-monthly sampling, 512 radiolocations were obtained and referenced to the nearest 100 m. (Because the majority of radiolocations were associated with visual sightings, they are considered acccurate to within 100 m). Data points from animals traveling together were deleted such that we could be certain that all radiolocations represented independent habitat choices.

A digital habitat database was assembled for the study area. Polygon data of forest cover attributes as well as topographic and planimetric data originally mapped at 1:20 000 scale were compiled as GIS raster coverages with a resolution of 100 m. From this, model variables were derived.

Analyses

An unvalidated HSI model was developed by Allen-Johnson (1993) for the Idaho Panhandle National Forest (Fig. 2). This area supports a herd of mountain caribou in the Selkirk Mountains, approximately 50 km from the Purcell study area. Using a GIS (Eastman, 1993), we applied this Idaho model as a testable hypothesis of habitat selection by southern Purcell mountain caribou. For each of four caribou seasons (spring, April 1 to June 15; summer, June 16 to October 22; early winter, October 23 to January 15; late winter, January 16 to March 31), model performance was evaluated by comparing observed caribou selection to four suitability classes as predicted by the Idaho model. To improve our understanding of mountain caribou habitat relationships, and to provide a basis for model improvement, we also analyzed caribou selection for each of the six model variables independently.

Data were pooled among years and individual study animals. The land area considered to be collectively available to all study animals was determined as the composite 100% minimum convex polygon of all radiolocations. For each analysis, a *G*-statistic (Sokal & Rohlf, 1981) tested the goodness of fit of habitat use versus availability for pooled radiolocations, and indicated whether selection was evident considering all habitat classes simultaneously. Habitat classes with expected use values of less than three were excluded from analysis (ibid.). Confidence intervals for "selection" or "avoidance" of each habitat class were then established using Bonferroni *Z*-statistics (Neu *et al.*, 1974; Byers *et al.*, 1984).

While retaining the original model structure, we adjusted Idaho HSI coefficients to improve model performance with respect to observed habitat selection by southern Purcell caribou. At the same time, we maintained relatively high ratings for habitats that, although were not selected according to our limited data, have been established by other research as being at least seasonally important. Thus, although our adjustments do utilize habitat selection results for each model variable, they are largely subjective.

Adjustment of model coefficients

Based on past research (Simpson *et al.*, 1994; Stevenson *et al.*, 1994), we felt that the Idaho HSI model included macro-habitat variables that contribute to stand suitability for mountain caribou. We therefore restricted our analyses to only these variables. Also, because we employed univariate analysis techniques, we chose not to modify the original algebraic structure of the model.

Recognizing the limitations to direct inference of habitat requirements from selection analyses (Manly *et al.*, 1993), we adopted a four-stage approach to assigning suitability coefficients. Given the potential consequences of disregarding important habitats due to a limited data set, our methods were intentionally conservative from the perspective of caribou conservation. In the first stage, we assumed that the importance of a habitat attribute is proportional to its observed degree of selection by caribou as indicated by its selection ratio (use/availability). For "avoided" habitat classes, selection ratios (0.0 - 0.99) were stratified into five groups and assigned coefficients from 0.0 to 0.4. For "selected" habitat classes, we identified the point where the array of selection ratios began to increase exponentially (>3.2), and selection ratios above this point were assigned a coefficient of 1.0. The range of remaining selection

V_1	stand elevation
V_2	stand slope
V_3	stand habitat type and current cover type
V_4	stand overstory size class
V_5	percent stand canopy closure
V_6	age of dominant stand overstory

$$\text{Stand HSI} = (V_1^2 \times V_2 \times V_3 \times V_4 \times V_5)^{1/6} \times V_6$$

Fig. 2. HSI model variables and equation structure.

ratios (1.01 - 3.2) was stratified and assigned coefficients from 0.6 to 1.0. In the second stage, we assigned additional suitability coefficients based on the level of significance at which each variable class was either "selected" or "avoided". This allowed for the effect of sample size and the number of habitat classes within each variable to be accounted for in the interpretation of selection ratios. Selected habitats were rated as 1.0, 0.9, 0.8, 0.7 or 0.6 depending on whether selection occurred at the 95, 75, 50, 25 or 5% confidence levels respectively. Following these same confidence levels, avoided habitats were assigned ratings from 0.0 to 0.4. In both cases, confidence levels of < 5% were assigned ratings of 0.5. In the third stage, we compared these two suitability ratings for each habirat class and, where discrepancies occurred, adopted that which was closest to 0.5. To ensure that trends in suitability coefficients for each model variable were biologically meaningful, we reviewed the assigned ratings for each variable as the fourth stage. Given the limited time over which our data were collected and the variability in habitat use that may occur among years, we applied subjective adjustments to ensure that coefficients of certain habitat elements, found by other studies to be important and potentially limiting, were not underrated.

To evaluate the overall veracity of the adjusted model, HSI output was stratified into four suitability classes in the GIS, and caribou selection was assessed using the above described univariate techniques.

Landscape-level habitat distribution analysis

Mountain caribou populations appear to be influenced by the availability of suitable habitat over large areas, which may be a function of predator avoidance (Stevenson *et al.*, 1994). We therefore assessed caribou selection for habitat distributions at two broad scales. Because it is a scale commonly used in local wildlife habitat management guidelines, we initially assessed caribou selection for the proportion of suitable habitat distributed per 250 ha. We also analyzed caribou selection for the proportion of habitat distributed per 5000 ha, roughly corresponding to the average area of a core caribou home range in this study area. (Mean 75% harmonic contour home range size for 12 study animals (4M, 8F) with a minimum 24 locations sampled over at least one year = 4869 ha (Kinley & Apps, unpubl. data)).

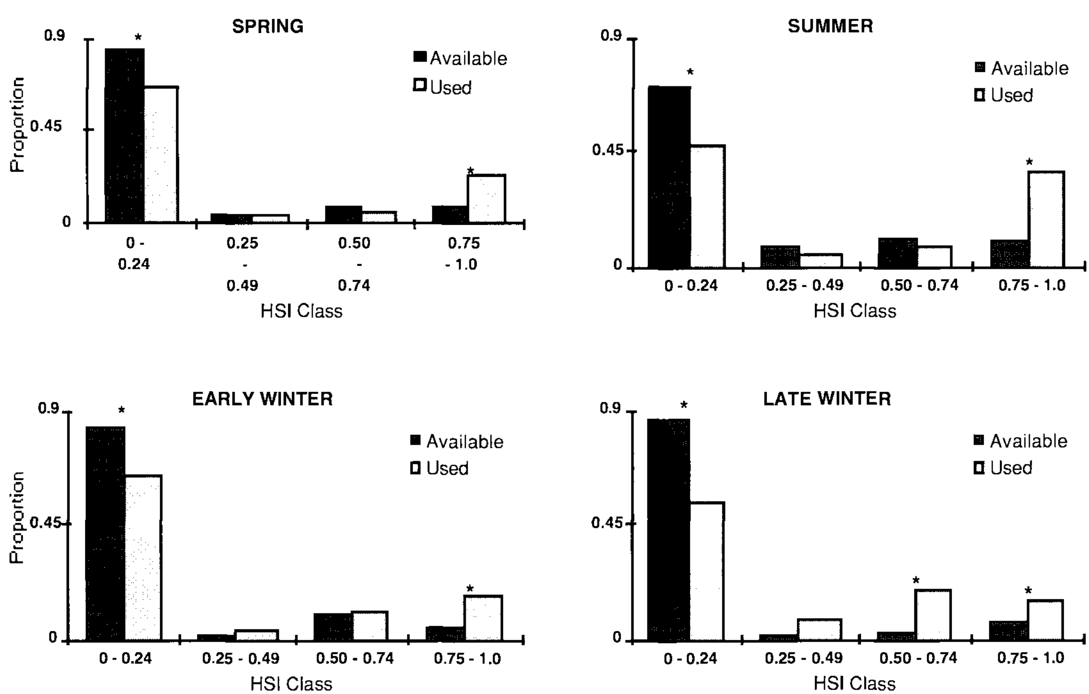


Fig. 3. Caribou selection for habitat suitability classes as defined by the Idaho HSI model. * indicates significance ($P < 0.05$) based on Bonferroni Z-statistics.

Table 1. *G*-test results for each model variable by season. Selection is evident at the probability levels indicated.

Season	Var.	G-Stat.	d.f.	*P*<
Spring	V_1	79.4	9	0.001
	V_2	14.8	3	0.005
	V_3	74.9	7	0.001
	V_4	99.0	4	0.001
	V_5	78.0	4	0.001
	V_6	168.6	2	0.001
Summer	V_1	79.7	9	0.001
	V_2	20.3	3	0.001
	V_3	69.3	7	0.001
	V_4	90.0	4	0.001
	V_5	49.6	4	0.001
	V_6	103.7	2	0.001
E. Winter	V_1	13.7	9	0.25
	V_2	7.4	3	0.10
	V_3	40.9	6	0.001
	V_4	27.5	3	0.001
	V_5	18.0	4	0.001
	V_6	22.4	2	0.001
L. Winter	V_1	50.5	9	0.001
	V_2	8.8	3	0.05
	V_3	38.1	7	0.001
	V_4	85.0	4	0.001
	V_5	40.5	4	0.001
	V_6	33.8	2	0.001

This may also approximate the broadest level at which individual caribou perceive the larger landscape.

For this landscape-level analysis, "suitable habitat" was defined as those HSI classes selected by caribou. A GIS "moving window" procedure was then carried out to determine habitat distribution per 250 ha and per 5000 ha. That is, a value indicating the proportion of suitable habitat in the surrounding landscape (either 250 ha or 5000 ha) was assigned to each 100 m-pixel. The resulting maps were then stratified into six habitat distribution classes and use/availability analyses carried out as described above.

Results

Stand-level suitability

Based on results of caribou selection for associated HSI classes (Fig. 3), we judged the original Idaho model to be inadequate as a useful planning tool for our study area. Thus, we assessed caribou selection for each model variable independently. Within each season, results indicate that caribou are selective for model variables and habitat classes within each (Table 1 & Fig. 4), with the greatest selectivity being associated with age class. New suitability coefficients determined for each model variable are presented in Table 2. Evaluation of the modified HSI model confirms its improved performance relative to our data (Fig. 5). Selection is evident for HSI ratings greater than 0.25, which are therefore considered to provide "suitable" habitat.

Landscape-level suitability

Caribou appeared to be selective for both 250 ha and 5000 ha habitat distribution classes (Fig. 6). In both cases, selection began to occur where the distribution of suitable habitat in the surrounding landscape achieved 30 - 50%.

Discussion

Results of analysing HSI variables were generally consistent with our understanding of mountain caribou ecology, as indicared by research carried our on other populations (Simpson *et al.*, 1994; Stevenson *et al* , 1994). This was particularly true with respect to caribou selection for subalpine fir and Engelmann spruce stands dominated by old, large-diameter trees. However, we did observe several anomalies. Our data indicated an avoidance of moist, low-elevation forests of western redcedar and western hemlock on gentle slopes, even in early winter and spring when such habitats are often heavily used by other mountain caribou populations. Conversely, there was general selection for lodgepole pine-dominated stands, particularly in early winter, which has not been previously reported for this ecotype. These differences may relate to the location of this study area at the extreme southeast corner of mountain caribou distribution, an area with a drier climate than elsewhere in mountain caribou range. Thus, there may have historically been less western redcedar and western hemlock, and more fire-successional lodgepole pine available than elsewhere in mountain caribou range, causing animals in the southern Purcells to adapt to slightly different habitats. Alternatively, the observed pattern may occur in years with near-normal winter weather, but in years of more inclement weather conditions, habitat use may be similar to patterns found elsewhere in their range. A third possibility is that habitat disturbances, such as wildfires, logging, road construc-

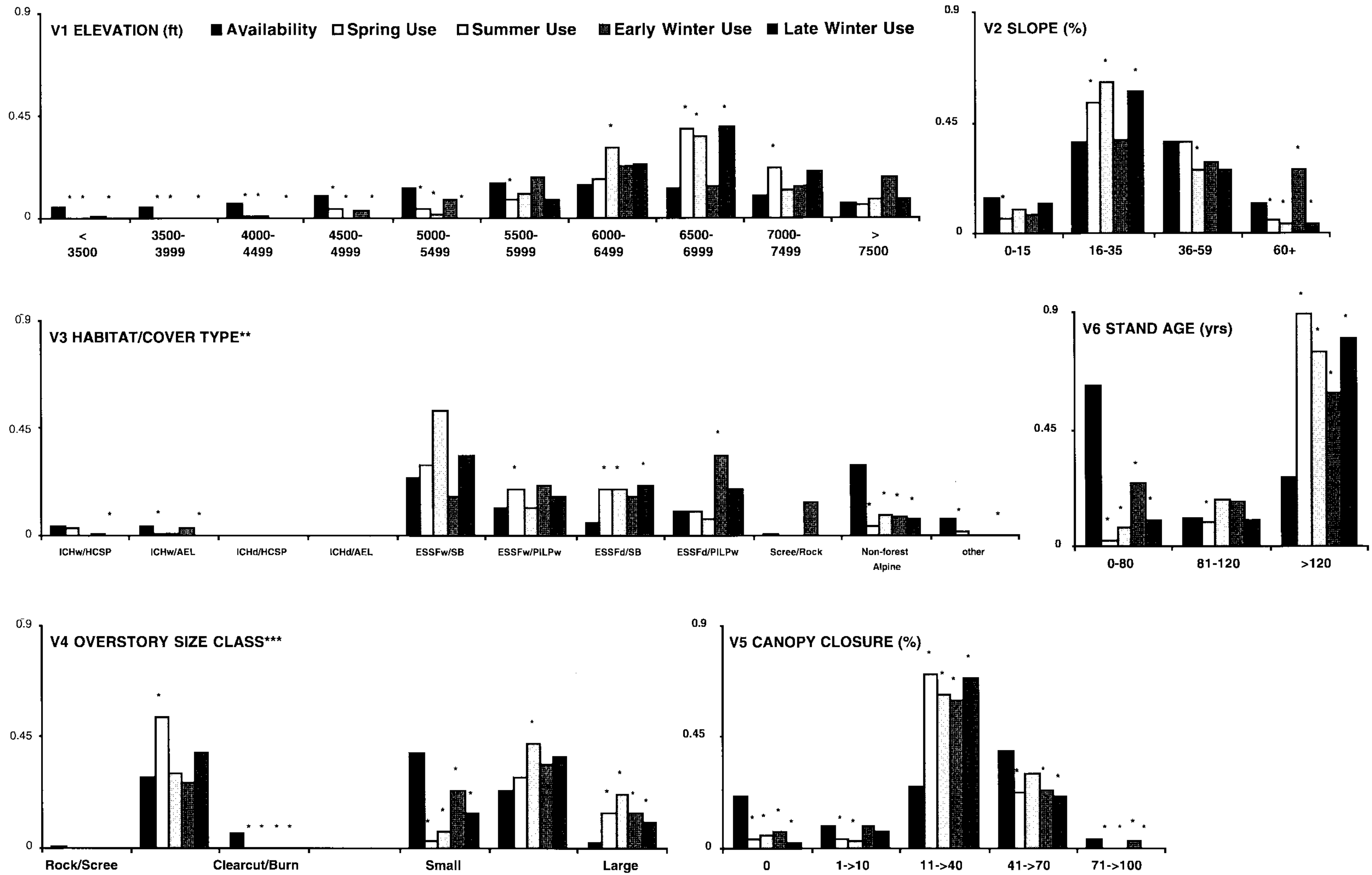


Fig. 4. Results of caribou selection for individual variable classes by season. * indicates significance ($P < 0.05$) based on Bonferroni Z-statistics. ** ICH=Interior Cedar Hemlock zone (Meidinger & Pojar, 1991)); ESSF=Engelmann Spruce/Subalpine Fir zone (ibid.); d=dry variants; w=wet variants; H=hemlock; C=cedar; S=spruce; B=balsam fir; A=aspen; E=birch; L=larch; Pl=lodgepole pine; Pw=whitebark pine. *** sapling=dbh 0.3–12.7 cm; small=dbh 12.7–22.9 cm; medium=dbh 22.9–35.6 cm; large=dbh>35.6 cm.

Table 2. Adjusted habitat suitability coefficients.

V_1 Elevation (ft)	Spring	Summer	Early Winter	Late Winter
<3500	0.0	0.0	0.1	0.0
3500-3999	0.0	0.0	0.1	0.0
4000-4499	0.0	0.0	0.7	0.0
4500-4999	0.5	0.0	0.7	0.0
5000-5499	0.7	0.0	0.7	0.0
5500-5999	0.7	0.3	0.7	0.2
6000-6499	0.7	0.8	0.7	0.7
6500-6999	1.0	0.9	0.5	1.0
7000-7499	0.8	0.5	0.5	0.6
>7500	0.5	0.5	0.9	0.5
V_2 Slope (%)				
0 - 15	0.7	0.7	0.7	0.7
16 - 35	0.7	0.7	0.7	0.7
36 - 59	0.5	0.3	0.3	0.3
60 +	0.2	0.1	0.8	0.1
V_3 Habitat/Cover Type*				
ICH wet / H, C, S, B	0.5	0.1	0.5	0.
1ICH wet / A, E, L	0.0	0.0	0.5	0.1
ICH dry / H, C, S, B	0.2	0.2	1.0	0.0
ICH dry / A, E, L	0.0	0.0	0.0	0.0
ESSF wet / S, B	0.6	0.8	0.3	0.6
ESSF wet / PI, L, Pw	0.7	0.5	0.7	0.5
ESSF dry / S, B	1.0	1.0	0.9	1.0
ESSF dry / Pl, L, Pw	0.6	0.3	1.0	0.8
Scree/Rock	0.0	0.2	0.0	0.2
Non-forested Alpine	0.0	0.1	0.1	0.1
All other habitat types	0.1	0.0	0.0	0.0
V_4 Overstory Size Class				
Rock/Scree0.0	0.1	0.0	0.1	
Non-forest (A,M,NP,NC)	0.7	0.5	0.5	0.6
Clearcut/Burn	0.0	0.0	0.1	0.1
Sapling (dbh 0.3-12.7 cm)	0.2	0.1	0.0	0.1
mall (dbh 12.7-22.9 cm)	0.0	0.1	0.2	0.1
Medium (dbh 22.9-35.6 cm)	0.7	0.8	0.7	0.6
Large (dbh >35.6 cm)	1.0	1.0	1.0	1.0
V_5 Canopy Closure (%)				
0	0.0	0.5	0.1	0.0
1 - 10	0.1	0.1	0.5	0.3
11 - 40	0.9	0.9	0.9	0.9
41 - 70	0.2	0.3	0.9	0.2
71 - 100	0.1	0.0	0.9	0.1
V_6 Overstory Stand Age				
0 - 80	0.1	0.1	0.1	0.1
81 - 120	0.7	0.7	0.7	0.7
> 120	1.0	1.0	1.0	1.0

*ICH=Interior Cedar Hemlock zone (Meidinger & Pojar, 1991); ESSF = Engelmann Spruce/Subalpine Fir zone (ibid.); d = dry variants; w = wet variants; H = hemlock; C = cedar; S = spruce; B = balsam fir; A = aspen; E = birch; L = larch; Pl = lodgepole pine; Pw = whitebark pine.

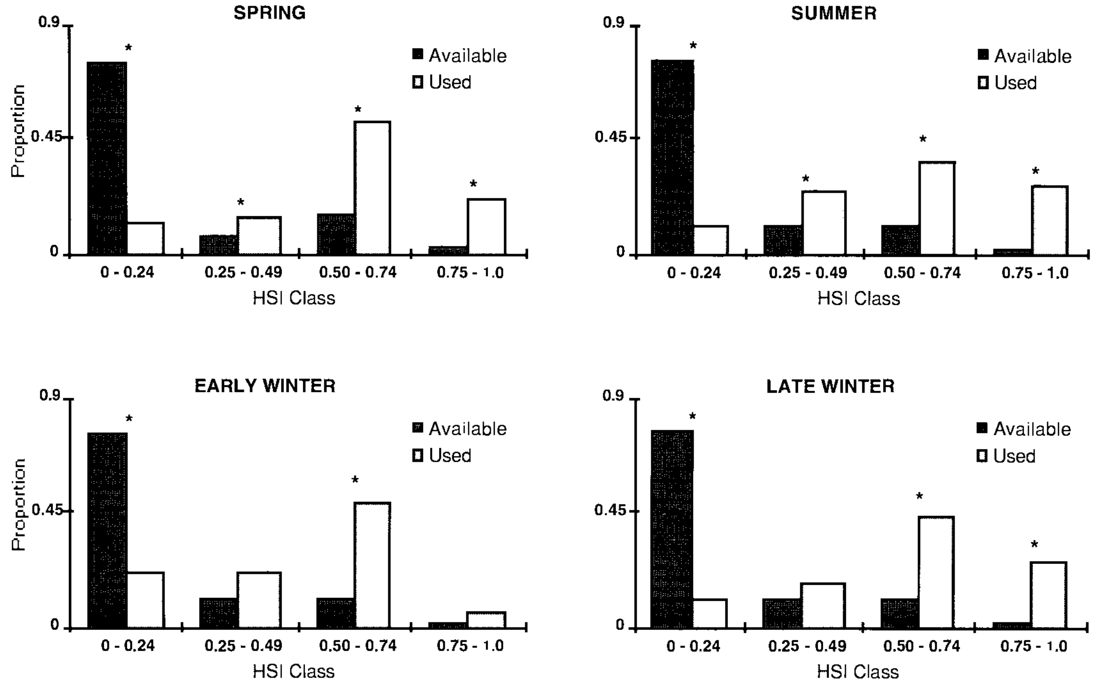


Fig. 5. Caribou selection for habitat suitable classed as definded by the adjusted HSI model. * indicates significance ($P < 0.05$) based on Bonferroni Z-statistics.

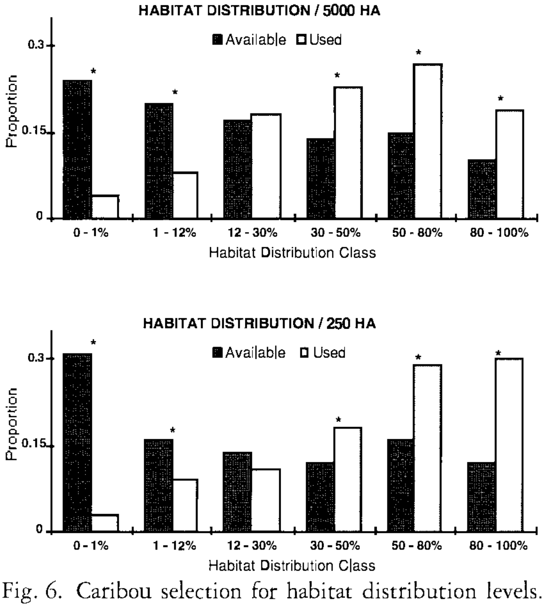
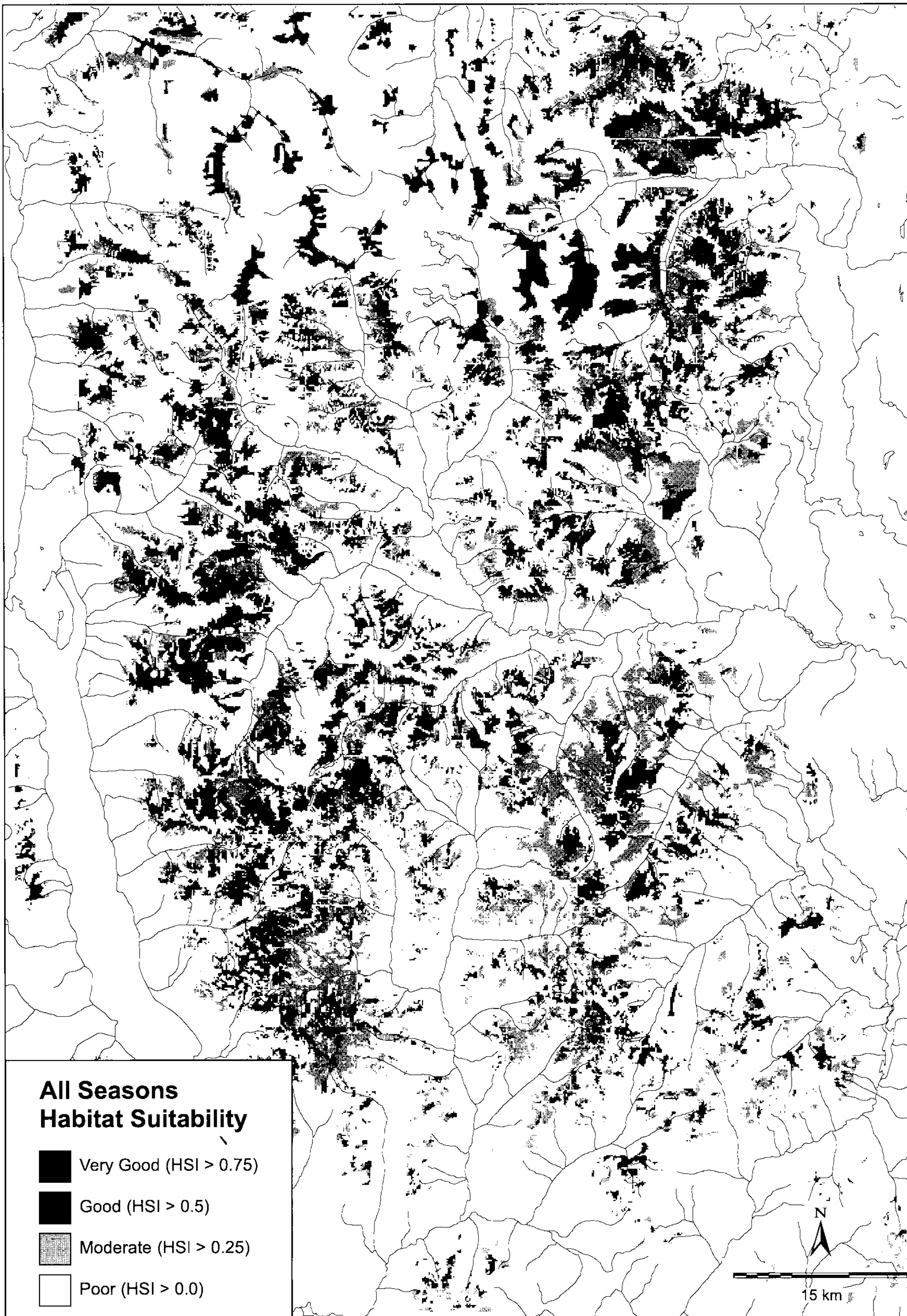


Fig. 6. Caribou selection for habitat distribution levels. Distribution classed reflect the proportion of suitable habitat (HSI>0.25) at two landscape scales. * indicates significance ($P < 0.05$) based on Bonferroni Z-statistics.

tion and human habitation, that have occurred disproportionately at lower elevations, may have caused mountain caribou in the Purcells to make much less use of low-elevation cedar and hemlock forests than in the past, such that the observed pattern may represent a recent shift. The correct explanation is far from clear, but having suitable low-elevation habitats into which caribou may move in early winter and spring is potentially critical and limiting, even if such habitats are used only occasionally or for short periods. It is by this rationale that we subjectively increased model coefficients for lower elevation classes, cedar and hemlock cover types, higher canopy closures and gentle slopes, to parallel those of the Idaho model.

Linked to a GIS database of habitat attributes at the appropriate scale and resolution, we consider the performance of the adjusted HSI model to be adequate as an interim habitat assessment and planning tool (e.g. Fig. 7). From the consistent observed selection against the lowest (0 - 0.24) HSI class, we infer a relative lack of importance of these habitats to southern Purcell caribou. The lack of significant selection for the next HSI class (0.25 - 0.49) suggests that these habitats may be "suitable" but are

Fig. 7. Combined habitat suitability for the southern Purcell study area. The maximum suitability value over each of four caribou seasons is indicated.



All Seasons
Habitat Suitability
Very Good (HSI > 0.75)
Good (HSI > 0.5)
Moderate (HSI > 0.25)
Poor (HSI > 0.0)
N
15 km

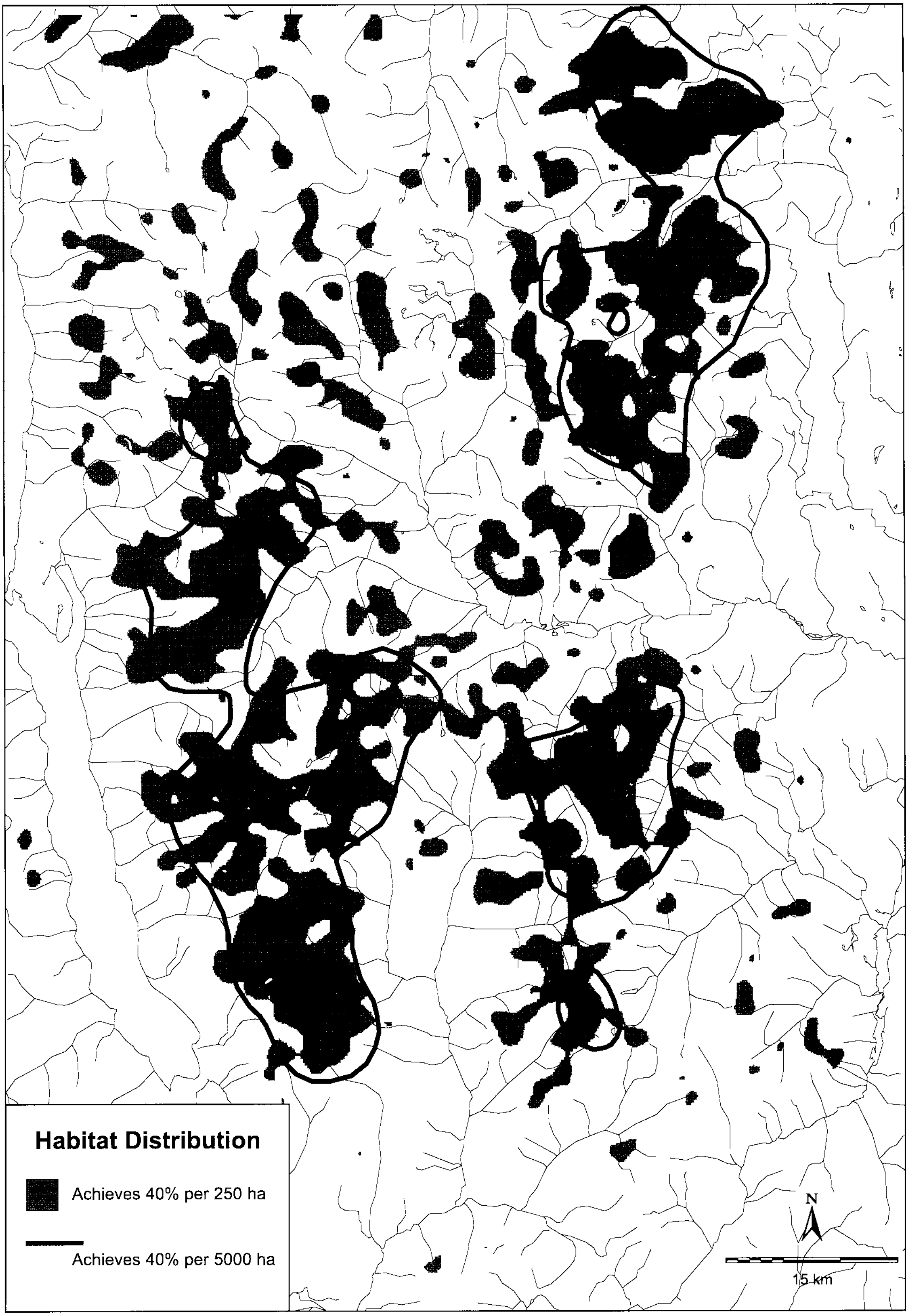


Fig. 8. Lands within the southern Purcell Montains that achieve at least 40 % suitable habitat distributed per 5000 ha and 250 ha.

not of exceptionally high quality. Consistent selection across all seasons for HSI class 0.5 - 0.74 illustrates the relative importance of these habitats, while we consider the strong selection for HSI class 0.74 - 1.0 during every season except early winter as indicative of exceptional importance to caribou. The lack of apparent selection for the highest HSI class during early winter reflects subjective adjustments to early winter suitability ratings.

Based on results of these analyses, it is apparent that landscape attributes need to be considered in habitat planning, particularly because suitably-distributed habitats appear to be highly fragmented. From our analysis, we consider the mid-point of our selected habitat distribution range (40%) as a minimum target in the maintenance of southern Purcell mountain caribou habitat (Fig. 8). Considering the large home ranges typically used by mountain caribou, lands which achieve 40% suitable habitat distributed per 5000 ha may approximate core habitat areas in which long-term use by caribou may be possible. Lands that fall much below the limits of this distribution may receive periodic use, but are unlikely to be used consistently unless they provide seasonally important attributes. Two qualifications to this are that the model does not account for the influence of apparently "unsuitable" but barrier-free movement routes, such as alpine tundra, nor does it account for habitat that is not within a suitably distributed matrix but is contiguous with one. Conversely, there are lands within the 5000 ha contour that do not meet the minimum distribution requirements at the 250 ha level and thus may not contribute to core habitat.

We recognize that numerous assumptions are at play in our approach to the adaptation of this model. Our intent was to provide an interim tool to integrate our best understanding of caribou-habitat relationships with ongoing forest planning until further information comes available. As long-term research continues, a strictly empirical, multivariate approach will be taken in model development at the stand level. Similarly, we cannot yet be certain that our identified core habitat areas represent habitat distribution levels required to maintain a viable population over the long term, but this may also change as data comes available and our understanding of the relationship between habitat distribution, road access, and mortality risk improves. However, the exercise of HSI evaluation and adaptation: 1) illustrates the potentially large differences in habitat use between adjacent populations of a single ecotype, 2) indicates that there may be important seasonal differences within the population, 3) highlights the need to manage for habitat values at a landscape level, and 4) demonstrates that interim management tools can be developed and put into use with relatively limited data. Obviously, a conservative approach to forest management is desired where our understanding of habitat relationships is uncertain. In ecosystems that are being rapidly altered through primary management for timber values, interim models based on limited data and informed conjecture may provide essential tools for maintaining habitat integrity until more complete data becomes available.

References

Allen-Johnson, L. 1993. *Woodland caribou habitat suitability index.* Working draft. United States Department of Agriculture, Forest Service, Bonners Ferry, Idaho. 15 pp.

Antifeau, T. D. 1987. *The significance of snow and arboreal lichen in the winter ecology of mountain caribou (Rangifer tarandus caribou) in the North Thompson watershed of British Columbia.* M.Sc. Thesis, University of British Columbia, Vancouver. 142 pp.

Byers, C. R., Steinhorst, R. K. & Krausman, P. R. 1984. Clarification of a technique for analysis of utilization-availability data. – *J. Wildl. Manage.* 48 (3): 1050–1053.

Eastman, J. R. 1993. IDRISI 4.1 *User's Guide.* Clark University Graduate School of Geography. Worcester, Massachusetts. 178 pp.

Freddy, D. J. 1973. *Status and management of the Selkirk caribou herd, 1973.* M.S. Thesis, University of Idaho, Moscow. 132 pp.

Manly, B. F. J., McDonald, L L. & Thomas, D. L. 1993. *Resource Selection by Animals: statistical design and analysis for field studies.* Chapman and Hall. New York. 177 pp.

Meidinger, D. V. & Pojar, J. 1991. *Ecosystems of British Columbia.* Special report series no. 4. British Columbia Ministry of Forests, Victoria. 29 pp.

Neu, C. W., Byers, C. R., Peek, J. M. & Boy, V. 1974. A technique for analysis of utilization-availability data. – *J. Wildl. Manage.* 38: 541–545.

Rominger E. M. & Oldemeyer, J. L. 1989. Early-winter habitat of woodland caribou, Selkirk Mountains, British Columbia. – *J. Wildl. Manage.* 53 (1): 238–243.

Seip, D. R. 1990. *Ecology of woodland caribou in Wells Gray Provincial Park.* Wildlife Bulletin No. B-68. Ministry of Environment, Victoria, British Columbia, and Ministry of Parks, Kamloops, British Columbia. 50 pp.

Seip, D. R. 1992. *Habitat use and population status of woodland caribou in the Quesnel Highlands, British Columbia.* Wildlife Bulletin No. B-71. Ministry of Environment, Lands and Parks, Williams Lake, British Columbia. 50 pp.

Simpson, K., Kelsall, J. P. & Leung, M. 1994. *Integrated management of mountain caribou and forestry in southern British Columbia.* Report prepared for Ministry of Environment, Lands and Parks, Victoria, British Columbia, by Keystone Wildlife Research, White Rock, British Columbia. 99 pp.

Simpson, K. & Woods, G. P. 1987. *Movements and habitats of caribou in the mountains of southern British Columbia.* Wildlife Bulletin No. B-57. Ministry of Environment and Parks, Victoria, British Columbia. 36 pp.

Sokal, R. R. & Rohlf, F. J. 1981. *Biometry: the principles and practice of statistics in biological research.* Second edition. W.H. Freeman and Company, New York. 859 pp.

Stevenson, S. K., Armleder, H. M., Jull, M. J., King, D. G., Terry, E. L., Watts, G. S., McLellan, B. N. & Child, K. N. 1994. *Mountain caribou in managed forests: preliminary recommendations for managers.* Report to Ministry of Forests, Victoria, British Columbia. 33 pp.

Stevenson, S. K. & Hatler, D. F. 1985. *Woodland caribou and their habitat in southern and central British Columbia.* Volume 1. Land Management Report No. 23. Ministry of Forests, Victoria, British Columbia. 355 pp.

White, G. C. & Garrott, R. A. 1990. *Analysis of wildlife radio-tracking data. Chapter 8: habitat analysis.* Academic Press, Toronto, Ontario. 383 pp.