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Attributes of Woodland Caribou Migration Habitat in West-Central British Columbia

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Abstract: We examined sites used by 73 caribou located by radio-tracking during spring migration through a forested travel corridor. The physical and botanical characteristics of these sites were described to find what features (if any) distinguished them from the forest at large. Raised and open aspect, sparse tree cover, free-draining soils, and a simple flora with abundant lichens were features common to all the sites, but were lacking in the denser forest around. Scores for these attributes were ordinated by multidimensional scaling of similarities and differences from site to site. Separate scalings for (i) terrain features, (ii) tree cover attributes, and (iii) floristic content each yielded a single cluster of points with few outliers and no particular pattern or trend. The inference is that the sites conformed to a single type with limited variation. A profile of the distinguishing characteristics was compiled and then applied to transects through the general migration area by persons unfamiliar with it beforehand. Sites which matched the profile proved easy to identify, even though they comprised only a small proportion of the area. Sites with high scores for the most distinctive attributes had more caribou at the time of radio-tracking.

Key words: habitat descriptors, ordination, lichens, radio-tracking, forest management, *Rangifer tarandus*

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Introduction

The Tweedsmuir-Entiako woodland caribou herd contains about 500 animals (Cichowski & Banner, 1993). Until recently, these were some of the least studied caribou in British Columbia. In the mid-1980s, using radio-tracking, Marshall (1986) defined the range of the herd and its seasonal pattern of use. The animals summer in northern Tweedsmuir Park, and winter in the Entiako drainage south-east of Tetachuck Lake (Fig. 1). The Chelaslie River drainage serves as a connecting travel route, and in certain years part of the herd may winter within that route, rather than continuing on to the Entiako (Steventon, 1994).

Cichowski (1989) described habitat preferences on the Entiako range, but site selection during migration was not well understood. As logging and other land uses begin to encroach on the range of this herd, the need to know more about habitat usage was becoming urgent.

We examined a sample of sites used by the herd during spring migration in 1993, and compared their physical and botanical characteristics. The aim was to find what features, if any, were shared amongst these sites, and distinguished them from other parts of the travel corridor. The study was done as part of a forest management plan for the area.

Study area

The Chelaslie corridor (61 000 ha) is a gently sloping plateau with undulating terrain, from 850 m elevation at Tetachuck Lake to 1430 m at the Tweedsmuir Park boundary. It lies within the driest part (subzone *dk*) of the Sub-boreal Spruce (SBS) biogeoclimatic zone of British Columbia. Treeline (westward within Tweedsmuir Park) is about 1600 m. The forest cover is mostly lodgepole pine (*Pinus contorta*) and hybrid white spruce (*Picea glauca* x *engelmannii*). Small raised periglacial features (drumlins, eskers, and fluvial terraces) are scattered throughout the area. These alternate with numerous meandering sedge meadows and willow swamps, fringed with black spruce (*Picea mariana*). The forest cover has a long history of wildfires, resulting in a patchwork of even-aged stands at various stages of maturity.

Methods

Sample sites

In April and May 1993, 42 radio-collared cow caribou were tracked from the air, approximately twice weekly by the BC Forest Service and BC Parks. Most of the

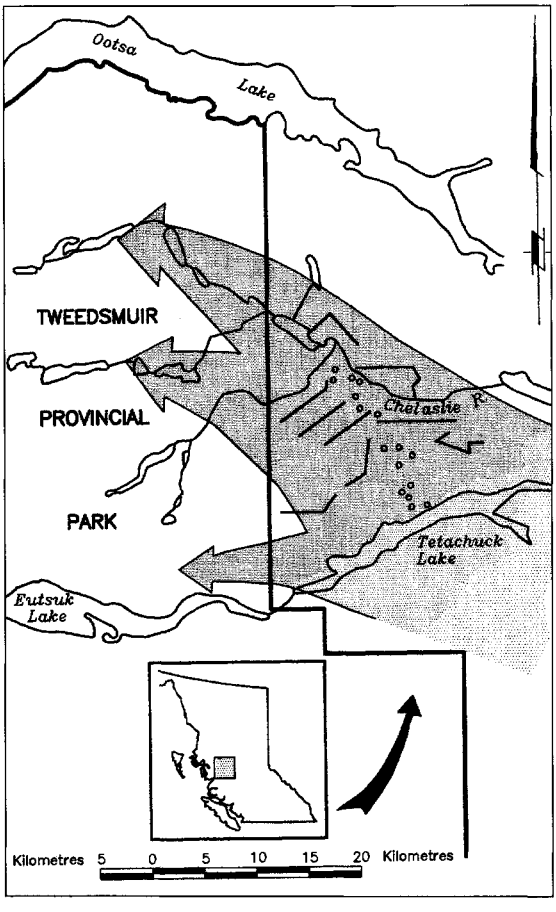

Fig. 1. Project area adjoining the northeast portion of Tweedsmuir Park, west-central British Columbia, showing the general spring migration route of the caribou (arrowed band). Redrawn from Marshall (1986). Circles show the approximate location of 16 habitat sampling sites; zig-zag lines represent 10 habitat survey transects.

herd travelled in small groups, usually less than 10 animals per group but sometimes up to 20. Radio-locations were recorded either as Global Positioning System readings, or Universal Transverse Mercator coordinates. All were considered accurate to within 200 m, and many were confirmed by direct sighting.

From the full set of 153 radio-locations (Steventon, 1994), we chose a sample of 16 to visit on the ground. These were chosen without regard to location-date, identity of the caribou concerned, or any site attribute except that all 16 were from places considered to he within the main path of migration through the corridor (Ministry of Forests, 1992).

Some of the 16 sites had more than 1 radio-collared caribou at the time the site was radio-located. Other sites were occupied more than once by different collared individuals at different dates. Together they represented the locations of 23 collared caribou. A further 50 uncollared ones were sighted along with these, bringing the total up to 73. Others which were screened by trees may well have been missed, however, and so this total was a minimum.

When migration ended, the 16 sites were plotted onto forest cover maps and located on the ground by compass. Each was described by terrain, soil, and floristic criteria, with special attention given to the terrestrial lichen flora. Physical and floristic descriptors (Tables 1 and 3) were from the list by Luttmerding *et al.* (1990) for assigning sites to ecosystem type within the biogeoclimatic classification of British Columbia. The flora for each site was compiled by walking the length and breadth of the site, recording the species present and estimating their percentage ground-cover. Species represented by just a few scattered plants were given a cover score of 1. A few species with scant cover may have been overlooked, and a few plants lacking flowers could not be identified with certainty. The list in Table 3 is thus conservative. However, common species tended to be common at most sites, and species with sparse cover were consistently sparse at each site where they were found.

Tree descriptors (Table 2) were as used by the BC Forest Service (Ministry of Forests, 1994). Mean height, crown closure, and live crown percentage were estimated visually for the stand as a whole. Diameters were tape-measured at 1 or 2 large trees and 1 or 2 small trees according to the range of sizes in the stand. Stem density and merchantable volume (a function of tree numbers and size) were estimated by standard timber cruising methods (Ministry of Forests, 1994). Ages were taken by increment bore and ring count for 1-3 trees in the stand. As most stands were of fire-origin, most of the trees within them were of the same age-*class* (defined in the Notes below Table 2). One sample tree was usually enough to determine age-class.

Signs of caribou use of the sites (tracks, trails, droppings etc.) were noted as they occurred, as was the general context of the site itself (adjoining forest types; other habitats nearby). 'Beard lichen' loadings (*Bryoria* and *Alectoria* spp.) on trees at the site were scored on a scale of 0-5 by the method of Armleder *et al.* (1992).

Data analysis (sample sites)

The data in Tables 1-3 (for all tables, see Appendix) were converted to standardized scores expressing the similarity or difference in each attribute, site by site. Scores were compiled separately for the three types of attribute (soil and terrain, tree cover, and flora). For soil and terrain: a pair of sites with the

same attribute scored 1, or zero if the two sites differed. Summing these scores over all attributes gave the net difference in soil and terrain for that site-pair. Tree attributes were scored the same way as for soil and terrain. For the rest of the flora, the species list for all 16 sites combined was compared to the lists for each site-pair. A species which was present at both sites scored 1. Likewise a species absent from both sites. A species which was present at one but absent at the other scored zero. These scores were then summed to express the net difference in flora, in the same way as for soil/terrain and trees. For each of Tables 1-3, these steps generated a matrix of net differences for all possible site-pairings (120 pairs).

The three sets of differences were ordinated by monotonic multidimensional scaling (MDS) for indications of clustering or segregation into site-groups, or evidence of a linear or other gradational trend. Scaling was done first in two dimensions and then in three (where each dimension represents a different combination of variables in the dataset - here, the matrix of net-difference scores among the 16 sites). Dimensions beyond 3 or 4 seldom account for much of the variation in a dataset (Wilkinson, 1990). In the present case, adding the third dimension explained only 5% more of the variation in scores. Therefore, only the first two dimensions are plotted in Figs 2-4.

Transect strips

Attributes which best defined the 16 sample sites were then checked for consistency and occurrence in the area at large. Ten transects (Fig. 1) totalling 65.4 km were run through places having a mixture of merchantable and non-merchantable timber types, so that value as timber and value to caribou could be compared. When a site was found which fit the profile of the sample sites, its size, tree density, crown closure, and lichen cover and moss cover were scored in classes of 1 to 4, corresponding to quartiles of the range of values shown by the 16 sample sites. One of us (BM) surveyed 2 of the transects and supervised the other 8, which were done by three people with no previous knowledge of the sample sites or the rest of the area. This allowed us to test the criteria in Table 4 for their ability to indicate habitat sites without needing prior experience or data on caribou themselves. The surveys also allowed us to roughly estimate the extent and distribution of such sites throughout the migration corridor.

Number of caribou at the 16 sample sites

The number of caribou seen per site during the radio-tracking period ranged from 1 (5 sites) to 20 (one site). Numbers per site were compared with site attributes singly and in combination, under the assumption that numbers at a site were a measure of caribou use of that site, and that level of use was a reflection of site suitability - specifically, the state of the forest cover and lichen supply. The analysis was therefore confined to six variables: (1) lichen abundance (all spp.), (2) percentage *Cladina* spp., (3) stem density, (4) tree size (merchantable volume), (5) crown closure, and (6) percentage slash. These were compared by step-down multiple regression. There was no *a priori* reason to reduce these variables in any particular sequence, and so they were deleted by size of effect in simple regression, largest first. As well as to find whether caribou numbers did vary with these attributes, the aim was see which of them had most potential for ranking sites in value to caribou.

Results

Sample sites

Each of the 16 sample sites differed distinctly from its surrounds. This was apparent as soon as the site was located on the ground. Their similarity to each other was obvious as well. Raised and open aspect, coarse free-draining soils, sparse tree cover, little or no large woody debris, and a simple ground flora with abundant lichens were characteristics shared by all. Most of the sites were small and narrow (less than 100 m in width), but some extended for more than 1 km atop eskers and glaciofluvial terraces next to sedge meadows and willow swamps. Tables 1-3 show the attributes of each site. Together, these attributes contrasted sharply with the denser forest around. Indeed: just the combined presence of juniper, *Arctostaphylos uva-ursi*, *Shepherdia canadensis*, and a *Cladina*-dominant lichen flora beneath a sparse cover of lodgepole pine, is sufficient to distinguish these sites from all other types within the *SBSdk* biogeoclimatic subzone (DeLong *et al.*, 1993).

The results of multidimensional scaling confirmed the similarity of the sites. Separate sealings for (i) terrain features, (ii) tree cover attributes, and (iii) ground flora each yielded a single cluster of points with few outliers and no linear or other systematic trend (Figs. 2-4). The inference is that the 16 sites conformed to a single type with limited variation. A composite profile of the sites is shown in Table 4.

Numbers of caribou at the sites

Total lichen cover, percentage *Cladina*, tree density, canopy closure, merchantable volume, and debris cover, together explained nearly 60% of the difference in caribou numbers from site to site (Table 5). Fig. 5 compares numbers seen and numbers predicted from these attributes combined as an

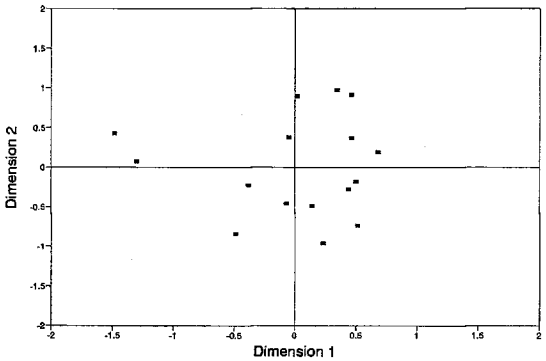

Fig. 2. Multidimensional scaling (MDS) of soil and terrain attributes at the 16 sample sites. Dimensions 1 and 2 represent combinations of attribute scores which account for the largest and the next largest amount of variation among the sites.

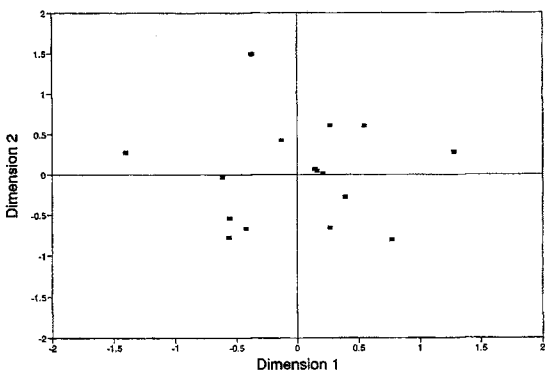

Fig. 4. Multidimensional scaling (MDS) of floristic attributes at the 16 sample sites. See note below Fig. 2.

index of the 'habitat value' of the site. With only 9 degrees of freedom available, the index was not statistically significant. Individually, however, crown closure and merchantable volume had a quite substantial effect: when these two factors were dropped from the index, R^2 fell by more than half. Stem density and lichen cover appeared to have only a small effect, and slash cover none at all, even though caribou tend to avoid dense timber clogged with slash, and lichens are their dietary mainstay. However, all but one of the 16 sites had stem densities less than 2000 per ha, and none of the sites had much slash (Table 1). Lichen cover varies with crown closure and stem density (next Section).

Transect strips

The 10 transects through the wider study area identified 64 sites which fit the general profile in Table 4. Every transect had at least 2 such sites; the most was

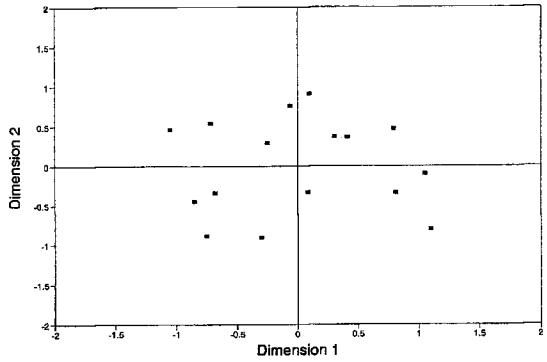

Fig. 3. Multidimensional scaling (MDS) of tree attributes at the 16 sample sites. See note below Fig. 2.

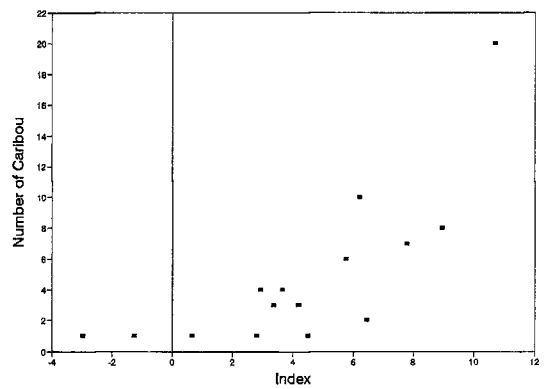

Fig. 5. Index of site attributes I versus number of caribou seen at the sites.
$I = 11 + .11TL - .06Cl\% + 4\text{EXP}3SD - .04MV - .49CC\% + .41S\%$,
by multiple linear regression. TL = total lichen cover, $CL\%$ = percent *Cladina* spp., SD = stem density (ha^{-1}), MV = merchantable timber volume (m^3), $CC\%$ = percent crown closure, and $S\%$ = percent cover of large woody debris (as in Tables 2 and 3).

11 (Table 6). All but one of the 64 sites were in forest cover composed of mature semi-open lodgepole pine, mostly less than 2000 trees per ha - the density used by the BC Forest Service to define a stand of timber which was 'passable' for travel by this caribou herd (Ministry of Forests, 1992). All but three sites had densities less than 1500 trees per ha, and ninety percent had a canopy closure of 25% or less.

Lichen ground coverage ranged from 5% to 50%, with most sites having 5-25%. Moss cover (mostly *Pleurozium schreberi*) varied inversely with this (Kendall τ = -0.57). The sparser the timber and the more open its canopy overhead, the higher was the ground-coverage by lichens underneath (Kendall τ = -0.36 and -0.35 respectively) and the lower was the

cover by moss (all τ values significant at $p < 0.001$). Lichen:moss ratios showed no relationship to site size, and so the sites were merely summed rather than weighted by size when calculating the extent of 'lichen habitat' on the transect strips.

The sum of the widths of the 64 sites where they intercepted the transects was 4700 m. This was 7.2% of the total transect length. Most of the sites were roughly 2.5 times longer than wide; hence the sum of the lengths was at least 11 600 m (17.7%, ignoring very elongated sites whose total length was unknown (pursuing these sites to their full length would have required long deviations from the transect route)). By simple division, the mean of these two percentages was 12.5.

Associations with other habitat types

Eleven of the 16 radio-sample sites were within 200 m of treeless lakeshores, meadows, or swamps. Most of these openings were crossed by game-trails with caribou tracks or droppings. Some trails led from one dry lichen site, through a nearby meadow, to another lichen site nearby. Along the 10 transect strips, sites with lichens tended to occur in scattered groups interspersed with low-density timber and meadows or swamps. The pattern as a whole appeared to consist of series or clusters of feeding sites linked by trails through semi-open timber and treeless ground.

Discussion

The 16 sample sites resembled each other and differed distinctly from their surrounds. When being approached through the surrounding timber, most of the sites were readily visible some distance ahead as openings in the forest with little or no understorey and a carpet of lichens on the ground.

Assuming that their extent on the transects reflected proportion by area, sites of this type comprised at least 12.5% of the migration corridor - probably more, since the unknown length of very long sites was ignored. Thus, any one of the 23 radio-collared caribou had at least a 12.5% chance of finding such a site at random. However, the chances of all 23 doing so were less than 1 in 2^{21} (ie, 0.125^{23}). This degree of consistency was not likely accidental. (Four sites had more than one radio-collared caribou. If these are treated as just one location per site, the likelihood is still only 1 in 3^{14} that caribou found all 16 sites by chance (ie, 0.125^{16})).

State of the tree cover was better than lichen cover at predicting the number of caribou seen at a site. However, the estimates of lichen cover were rather crude, were correlated with the tree cover, and were made after the caribou had already grazed the site. Also, the caribou seen at a site were not necessarily all of the caribou present at the time. Thus, the coefficients in Fig. 5 do not necessarily express the actual relationship between caribou numbers and site attributes. Nonetheless, a trend was apparent, and was strong enough to suggest that the degree of site usage does vary with differences in these attributes. (The presence of some caribou at a site might have attracted others to it. However, if 'herd behavior' instead of site attributes determined the size of the group, Fig. 5 should not have shown a trend).

The floristic features in Table 3 resemble the 'dry lichen' and mixed 'lichen/moss' vegetation types which Cichowski & Banner (1993) described as important to this caribou herd on the winter range. Among the sites studied by us, lichen cover and moss cover alternated with each other in a gradational way rather than discretely, and the sites as a whole suggested a continuum of differences rather than a set of disjunct types (Fig. 4). Level of use by caribou appears to vary likewise.

After this study had ended, Steventon (1994) plotted the full set of 153 radio-locations onto forest cover maps which rated each part of the area in timber-production terms. He found that the percentage of locations on sites rated 'low' or 'poor' exceeded the extent of these sites on the area. The opposite held for sites rated 'medium' or 'good'. The apparent preference of the caribou for less-productive forest may lower the risk from logging within their range. On poor dry sites with approximately 2000 stems per ha or less, the timber becomes sparse enough for lichens to occur, but is usually too low in volume for logging to be worthwhile.

Acknowledgements

Staff of BC Environment, BC Parks, and various volunteers, caught and marked most of the radio-collared caribou during the 1980s. J.D. Steventon (BC Forest Service) and D.B. Cichowski (BC Parks) did the radio-tracking in spring 1993, accompanied by one of us (ANL) during an early flight. We thank them for the use of these data for choosing the sample sites. B.Barry, A.Jankowski, & D.Routledge (Industrial Forestry Service) did most of the fieldwork at the ten transects. George Danilec re-drew Fig. 1. The BC Forest Service, Burns Lake, funded the flights for radio-tracking, and Fraser Lake Sawmills Ltd funded the fieldwork.

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Appendix: Tables 1-6

Table 1. Terrain and soil attributes of the sample sites.

Attribute	Site															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
landform[a]	FG	M	M	FG	M	MR	M	FGM	FG	M	M	MFG	FGM	M	M	FG
edatope[b]	B2	B3	B2	B2	B2	B3	B3	B1	B1	B2	B2	B1	B3	B2	B2	B2
slopeclass[c]	G	G	G	G	G	G	M	S	G	M	G	5	G	M	G	G
aspect	S	S	S	S	S	S	N	S	S	S	N	S	S	N	S	S
slope position[d]	M	M	M	U	C	C	C	C	C	C	C	C	M	C	C	C
soil group[e]	B	P	B	B	P	B	B	P	B	B	B	B	P	B	B	B
soil type[f]	G	G	G		G	GC	G	G	G	G	G	GC	G	G	G	G
soil texture[g]	LS	SCL	SCL	S	SL	SL	SL	SL	LS	LS	SL	SL	Si	SL	SL	5
coarse fragment content[h]	M	M	H	L	M	M	H	H	H	H	H	M	L	M	M	L
duff type[i]	X	H	X	X	X	X	H	X	X	X	X	X	H	X	X	X
duff depth (cm)[j]	3.5	5	2	2	4	3.5	3	3	3	4	2	2	3	3		
% woody debris cover[k]	0	1	1	3	2	5	5	1	3	6	1	0	4	1	1	2
woody debris depth (cm)[l]	0	10	20	20	10	20	30	10	20	30	10	0	40	30	10	20

Notes: (categories from Luttmerding *et al.*, 1990).

[a] F fluvial; G glacial; M morainal; R ridge.

[b] B nutrient-poor (A very poor; E very rich); Moisture regime: 1 xeric; 3 submesic (6 hygric).

[c] G gentle; M moderate; S steep.

[d] M midslope; U upper slope; C crest.

[e] B brunisol; P podzol.

[f] G gravel; C cobble.

[g] L loam; S sand; C clay; Si silt.

[h] H high; M moderate; L low.

[i] X xeromor; H hemimor.

[j] Depth to first mineralized horizon.

[k] Logs, dead branches etc.

[l] Size (diameter) of debris, or height elevated above ground surface (whichever was greater).

Table 2. Tree attributes at the sample sites.

Attribute*		Site															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Leading species[a]		Pl	Pl	Pl	Pl	Pl	PlSx	Pl	PlSx	Pl	Pl	PlSx	Pl	Pl	Pl	PlSx	Pl
Ageclass[b]		5	5	3	5	8	8	8	8	8	8	6	7	4	6	3	4
Mean DBH[c]	(cm)	20	25	15	20	25	25	25	20	25	30	15	20	15	25	15	30
Range DBH[d]	(cm)	10	15	5	15	10	20	10	20	10	20	15	20	10	10	10	10
Mean Height[e]	(m)	15	20	10	15	20	20	20	15	15	20	20	15	15	15	15	10
Crown closure[f]	(%)	15	5	5	5	15	10	15	10	5	10	10	15	20	10	5	5
Live crown[g]	(%)	40	50	60	70	30	50	50	80	60	50	80	60	40	50	80	80
Stem density[h]		850	330	1000	1600	900	600	300	1750	430	450	370	1500	2700	600	1800	150
Merchantable volume[i]	(m^3)	150	105	110	100	225	120	90	180	140	150	60	200	170	220	115	70

* Sample size (n) varied with attribute and site. Age, DBH, and height were determined from 1-3 trees which typified most trees in the stand. Crown closure, Live crown %, Stem density, and Merchantable volume were visual estimates for the entire stand.

[a] The dominant/co-dominant tree species at the site. Pl = lodgepole pine (*Pinus contorta*); Sx = hybrid white spruce (*Picea glauca* x *engelmannii*).

[b] BC Forest Service age-classes: 3 = 41-60 yrs; 4 = 61-80; 5 = 81-100; 6 = 101-120; 7 = 121-140; 8 = 141-250.

[c] DBH = diameter at breast height, to the nearest 5cm.

[d] Max. minus Min. for the sample trees, to the nearest 5cm.

[e] Visual estimate for the sample trees, to the nearest 5%.

[f] Percent ground cover, to the nearest 5%.

[g] Proportion of total stand height comprised of live tree crowns, to the nearest 10%

[h] Number of live trees per hectare.

[i] Volume of timber available (m^3 per ha) from sound trees of commercially harvestable size and age.

Table 3. Plant species content (percentage cover) of the sample sites.

Species[a]	Site 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	All sites	% of sites
Arboreal lichen																		
Total arboreal lichen[b]	0	2	0	0	2	1	1	1	0	1	2	2	0	1	1	1		
Terrestial lichen																		
Cladina mitis	30	5	20	10	14	20	5	13	60	15	7	50	4	5	4	2	16	100
Cladina rangiferina	1					1		1	1	1		15	1	2		1	9	100
Cladonia cornuta	1		3	7	1	2	1	1	2	5	4	1	1	1			13	81
Cladonia pixidata															1	1	2	13
Cladonia bellidiflora				1												1	2	13
Peltigera apthosa	6	3	1	2	2	5		1	10	1	3	1		10	1	3	14	88
Stereocaulon spp.	1	1	1		1	1		1	2	1	1	1	1	1	1	1	14	88
Total terrestrial lichen	39	9	25	20	18	29	6	17	75	23	15	68	7	19	7	9		
% *Cladina*	80	56	80	50	78	72	83	82	81	70	47	96	71	37	57	33		
Mosses																		
Pleurozium schreberi	1	80			5	15	50		1	60	30	2	10	20			11	69
Polytrichmn spp.																1	1	6
Dicranum fuscescens	1											1					2	13
Total moss	2	80	0	0	5	15	50	0	1	60	30	3	10	20	0	1		
% *Pleurozium*	50	100			100	100	100		100	100	100	67	100	100		0		
Vascular plants																		
Shepherdia canadensis	1	2	3	3	1	1	3	2	1	2	2	1	10	15	5	8	16	100
Arctostaphylos uva-ursi	20	5	5	30	1	1	10	25	5	3	3	1	3	20	15	5	16	100
Rosa acicularis	1	1	1	3	1	1		1		1	1	1	1	1	1	1	14	88
Juniperus communis	3		3	2			1	20		5	4	3		1	1		10	63
Spiraea betulifloria	1	2	2	2	1		1						1	1	1		9	56
Oryzopsis pungens	1	1			1			1	1			1					6	38
Arnica cordifolia							2	1		1	1	1	1				6	38
Cornus canadensis					1	1			1		1	1				1	6	38
Lycopdium complanatum		1				1					1			1	1		5	31
Vaccinium membranaceum						1	1			1			1	1			5	31
Linnea borealis					1							1	1		1	1	5	31
Empetrum nigrum		1				1					1			1			4	25
Calamagrostis rubescens				2							1	1			1		4	25
Geocaulon lividum									1				1		1		3	19
Vaccinium caespitosum			1							1					1		3	19
Chimaphila umbellata			1								1						2	13
Pyrola asarifolia				1							1						2	13
Achillea millefolium			1								1						2	13
Salix spp.		1												1			2	13
Petasites palmatus							1										1	6
Fragaria virginiana															1		1	6
Vaccinium vitis-idaea														1			1	6
Aster conspicuous													1				1	6
Calamagrostis canadensis																1	1	6
Epilobium angustifolium													1				1	6
No. of vascular species	6	8	8	7	7	7	7	6	5	7	12	9	10	10	11	6	25	
Total ground flora	13	12	12	11	12	13	10	11	11	13	17	16	15	16	15	13		

[a] Species represented by >1 individual at a site. Species occuring as a few scattered individuals were given a score of 1.

[b] Virtually all *Bryoria* spp. ('horsehair lichen'), but occasionally with small amounts of *Alectoria sarmentosa* ('witch's hair lichen'). Scored on a geometric scale of 0 to 5, after Armleder *et al.* (1992). Plant names after MacKinnon *et al.* (1992).

Table 4. Key-feature summary of the sample sites.

Feature	Attribute	Criteria
Landform	**Glacial deposition**	**Fluve, moraine, esker, or mounded blanket till**
	Terrain	Hummocky, undulating, ridge or bench
		Sloping or raised, giving an outlook over surrounds
	Aspect	Variable, but most often SE, S, SW
	Slope position	Midslope & upward
Substrate	**Mineral soil**	**Free-draining** sandy clay loam
		Coarse fragment content (gravel or cobble) 20% or more
	Duff layer	**Xeromor** <5cm thick (occasionally hemimor)
Tree Cover	**Dominant species**	***Pinus contorta***
	Sub-dominant species	*Picea glauca* x *engelmannii*
	Age	Variable between (and within) sites, but usually >60 years
	Crown closure	**<20% (usually <15%)**
	Height	Variable between (and within) sites, but seldom <15m
	Stem density	**<1600/ha** (rarely >2000)
	Dead woody debris	**Sparse to nil** (usually <5% ground cover)
Flora	**Terrestrial lichens**	**>10% total ground cover** (may be less if site has been grazed)
	***Cladina* spp.**	**>50% of total lichen cover**
	Arboreal lichen	*Bryoria* Spp. usually present, but sparse
	Mosses	Variable (0 - 90% cover); inversely related to Lichen Cover
		Pleurozium schreberi dominant
	Vasculars	**Simple flora:** Max. No.of species = 25
		Number* at any one site is usually 12 or less
	constants:	*Shepherdia canadensis*
		Arctostaphylos uva-ursi
	present at most sites:	*Rosa acicularis*
		Juniperus communis
		Spiraea betulifolia
	cover-dominants:	*Arctostaphylos* (up to 30%)
		Juniper (up to 20%)
		Shepherdia (up to 15%)

Boldface type denotes the most characteristic attributes.
* Number of species with significant ground cover (1% or more). Other definitions: see Tables 1-3 and text.

Table 5. Percentage of variance explained by the site attributes in Fig. 5.

Regression	Crown closure	Merch. volume	Stem Density	Cladina%	Total lichen	Slash%
simple[a]	31.7*	11.9	3.6	3.7	1.5	0
multiple[b]	14.4	20.4	11.9	9.3	1.5	0

[a] The variance explained by each attribute in simple regression with caribou numbers.
[b] The reduction in explained variance when the attribute was deleted during step-down multiple regression.
* $p<0.05$.

Table 6. Score-frequencies of four main site attributes on 10 survey transects.

Strip	Strip length (m)	No.of sites	Tree density				Lichen cover				Moss cover				Canopy closure			
		Score[a]:	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	5000	11	8	3	0	0	1	10	0	0	1	9	1	0	8	3	0	0
2	5640	2	0	1	1	0	2	0	0	0	0	0	2	0	2	0	0	0
3	7600	7	1	0	6	0	5	1	1	0	1	1	5	0	1	5	1	0
4	6366	3	1	2	0	0	0	2	1	0	1	2	0	0	1	2	0	0
5	6360	5	5	0	0	0	2	3	0	0	2	3	0	0	1	4	0	0
6	5740	4	4	0	0	0	4	0	0	0	4	0	0	0	1	2	1	0
7	6950	11	1	8	2	0	1	8	2	0	8	2	1	0	2	9	0	0
8	8600	5	0	2	3	0	2	3	0	0	1	1	3	0	1	3	1	0
9	6923	9	4	5	0	0	2	5	2	0	3	3	3	0	5	4	0	0
10	6220	7	1	5	1	0	2	4	1	0	0	2	3	2	0	5	2	0
All	65399	64																
% All[b]			39	41	20	0	33	56	11	0	33	36	28	3	34	58	8	0

[b] % All = percent of the 64 sites.

		Tree density (stems/ha)	Lichen cover (%)	Moss cover (%)	Canopy closure (%)
[a] Score-classes	1	< 1000	< 5	< 5	< 10
	2	1000-1500	5-25	5-25	10-25
	3	1500-2000	25-50	25-50	25-50
	4	>2000	>50	>50	>50