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Fire - caribou - winter range relationships in northern Canada

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Abstract: We needed data on temporal changes in caribou forages after fire and relative use of age-classes of forests by caribou to help devise a fire suppression priority strategy for caribou winter range in north-central Canada. Consequently, from 1983 through 1986, we estimated the abundance of vegetation and relative use by caribou at 197 sites in western and eastern study areas on the winter range of the Beverly herd of caribou (*Rangifer tarandus*). Species of lichens attained peak biomass at different periods after fire - as early as 40-60 years for *Cladonia* spp. to >150 years for *Cladina rangiferina* and *Cetraria nivalis*. Biomass ofi the primary "caribou lichen", *Cladina mitis*, increased rapidly from 21-30 years after fire to 41-50 years and attained maximum biomass at 81-90 yeats in the west and 41-60 years in the east. However, total lichen biomass increased with age of forest to 100-150 years because biomass of *Stereocaulon* spp. did not peak until after 100 years. The biomass ofi "caribou lichens" (*Cladina* spp. and *Cetraria nivalis*) stabilized after 61-80 years in the west and 41-60 years in the east. The biomass of terrestrial lichen species can be predicted from their cover. Caribou lichen abundance apparently was only one of several factors that caused caribou to use stands 151-250 years after fire more than othet age classes.

Key words: burns, habitat, lichens, *Rangifer tarandus,* succession.

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Introduction

Large fires in 1979 burned 1.4 million ha of caribou winter range northeast of Fort Smith, Northwest Territories (NWT). Consequently, aboriginal hunters requested more fire suppression on forested winter range of caribou. Previous studies of the effects of natural fires on forested winter ranges of caribou (*Rangifer tarandus groenlandicus*) in this part of Canada (e.g. Scotter, 1970; Johnson & Rowe, 1975; Johnson, 1979; Miller, 1980) had produced divergent views. Therefore, a fire review panel concluded that more information was needed on the effects of fires on caribou and their winter range (Murphy *et al.*, 1980).

Results from studies in 1980 and 1981 on caribou diet (Thomas & Barry, 1991) and digestibility of forages (Thomas *et al.*, 1984) compelled us to focus primarily on lichens as winter forage. This report provides results of the third phase of fire-caribou studies from 1982 through 1988 - the relationship between time since fire and the quantity of caribou forage and its use by caribou.

Our objectives were: (1) To measure the abundance (cover, biomass, and frequency of occurrence) of caribou forages relative to time since fire; (2) To assess the relationship between cover and biomass of caribou forages; and (3) To obtain information on relative use of forest types and ages by caribou.

Associations among flora and their relationship to caribou use will be reported separately.

Characteristics of the study areas were detailed by Bradley *et al.* (1982). The terrain is Precambrian Shield overlain by various amounts of glacial till. Jack pine (*Pinus contorta*) germinates within 1-5 years of stand-replacing crown fires, whereas spruce (*Picea* spp.) arise continuously. West of about 107°30'W in the NWT, pine dominated xeric sites after fire, grading to dominance by black spruce (*P. mariana*) in lowland sites. Pine persisted to age class 150-200 years at rocky and sandy sites in the west but did not occur in forests >100 years in the east. Spruce usually was most numerous even where pine dominated the canopy. East of about 107°30'W in the NWT pine failed to regenerates after fire except on the most-favorable southern exposures near 60°N. White spruce (*P. glauca*) occurs throughout the forested region but only in favorable locations characterized by sandy or gravelly alluvial soil.

In March 1982 through 1988, snow was deeper in the eastern block than in the west, averaging 64 cm and 56 cm, respectively (Thomas, 1991). Snow and the regional burn pattern influenced caribou distribution, though caribou readily travelled through individual burns of all ages and sizes.

Methods

Five study areas were selected in the core of the winter range, where large lakes provided access by boat. We sampled 139 sites west of 107°W ("west block") and 58 east of 107°W ("east block"). The western sites were clustered around Porter, Nonacho, and Thekulthili lakes; the eastern ones around Beauvais and Selwyn lakes (Fig. 1).

The basic design was to sample two ages across a fire boundary and compare floral abundance and caribou use. The paired sites had the same landform, surface materials, elevation, etc. In this way, physical variables that could affect vegetative characteristics were "controlled". Representative xeric sites were chosen on ridge tops or on gentle slopes where caribou tended to feed. Our samples were restricted to canopy openings, as the vegetation differed under the drip areas of trees.

A site was selected at the first location along a burn boundary where the terrain was relatively flat and uniform. At 100-200 m from the boundary, a stake was thrown >5 m over a shoulder to mark the southwest corner of a 10 m x 10 m plot. Then quadrats (inside dimensions 25 cm x 50 cm) were tossed laterally 3-5 m while looking upward and slow-

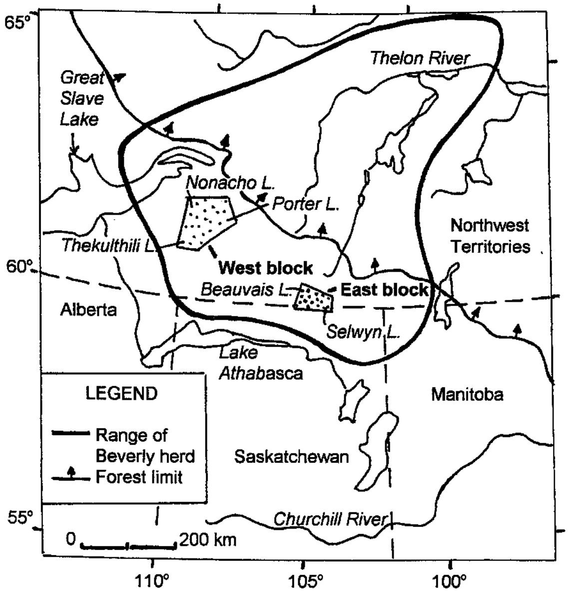

Fig. 1. Location of west (W) and east (E) block study areas within forested winter range of the Beverly herd of barren-ground caribou in northern Canada.

ly walking in and near the plot. Those landing under trees with low branches or on grazed lichen mats were tossed again until a standard number of 10 quadrats was established. In stands <50 years old, 15 to 25 quadrats were sampled because of greater variation in lichen distribution. Arboreal lichen abundance to 2 m above ground was rated visually on an ordinal scale of 0 to 4 (1=sparse, 2=light, 3=moderately abundant, and 4=abundant).

Diameter at breast height (DBH) of all trees in the plot was measured with a vernier caliper. A minimum of two of the tallest trees of each species were felled and measured for height and DBH. Several sections cut 25 cm above the ground were saved for counts of annulations. Fire scars were obtained from several pine and, failing that, from spruce. Lacking fire scars, we estimated forest age by adding 5 and 10 years to the maximum number of annulations in pine (preferred) and spruce, respectively. In ancient stands, the estimated time since death of the oldest fallen "mother" spruce was added to the estimated age of the oldest spruce in the associated layered clone. Time since death was based on subjective evaluation of the degree of rot without benchmarks.

Pellet groups of caribou and other species were counted in two belt transects 4 m x 100 m and restricted to the habitat type that was sampled. Starting points of each transect was one corner of the plot and direction was arbitrary yet remain in the habitat type. Winter-type pellets survived about 2-3 years in mesic habitats and 4½-6 years on xeric sites (Thomas & Kiliaan, 1994). About 50% of the groups would be detectible in fecal surveys at 2½ and 4½ years, respectively, after deposition of the pellets.

The cover of plant species within each quadrat was estimated visually to the nearest 1%. Personnel were trained using paper cutouts of various shapes and percent cover. Biomass was obtained by first mist wetting the vegetation using a plastic spray "bottle". Otherwise the dry lichens fractured when handled. All live vegetation produced in previous seasons, except moss, was removed from within each quadrat. Sorting entire samples was too time consuming (2-4 hours) so we sorted a subsample of one-third or more by weight. The initial sorting was checked in the laboratory before drying samples at 55°C for 3 days and weighing them on a microbalance.

We expressed terrestrial lichen biomass as total biomass and as weighted biomass where *Cladonia* spp., including *Cl. uncialis*, was reduced 50% and *Stereocaulon* spp. was reduced 75% for reasons discussed later. *Cladina mitis*, *C. rangiferina*, and *Cetraria nivalis* were totalled as "caribou lichens." Reindeer lichens were defined as *Cladina* and *Cetraria* by Russell *et al.* (1993).

Forest ages generally were grouped into eight classes to describe changes in forage at the site level, with 20-year intervals to 100 years and 50 thereafter. The classes were a compromise between the need to characterize rapid changes in abundance up to 100 years and maintaining reasonable sample sizes in older classes. Quadrat data were grouped in 10-year age classes to 100 years to better define vegetation dynamics and to display frequency of occurrence data.

A tree biomass index was calculated as the cumulative sum of products of the number of trees in each 5 cm DBH class and the median value of each class (e.g., 8 cm for class 6-10 cm).

Snow depth was measured periodically, 1982 through 1988, in forest openings at several locations in each block as explained in Thomas (1991).

Frequency of occurrence of species was extracted from biomass data for each quadrat. Site means were used for most analyses of relationships. We categorized the data measures as interval (biomass, number of pellet groups, number of trees, DBH classes), ratio (cover, frequencies), and ordinal (arboreal lichen biomass) and then selected tests accordingly using SYSTAT (1992) and BMDP software. Data normality was checked with normal probability plots. Unaltered cover values produced results similar to percentages transformed by arcsine. Results from Pearson and Spearman correlations were almost identical. Alpha was 0.05 for all tests.

Herein, age refers to post-fire age, *C.* is *Cladina*, *Cl.* is *Cladonia*, and *Cet.* is *Cetraria*. *Cladina stellaris* was included with much more abundant *C. mitis*.

Results

Terrestrial lichen biomass in relation to time since fire

In west and east blocks, biomass of lichen species and groups varied significantly (Kruskal-Wallis 1-way ANOVA) with forest age. For most species/groups this difference was caused by significant increases in biomass between classes 21-40 and 41-60 years. Consequently, means for age classes 1-20 years did not differ from those for 21-40 years and means for age classes 41-60 years and older did

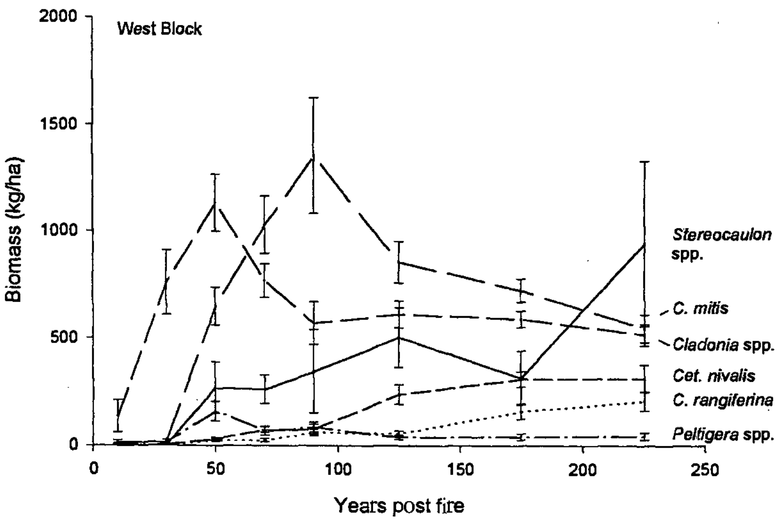

Fig. 2. Post-fire biomass of lichen species at 20-yeat intervals to 100 years, and 50 years thereafter, in the west block of foresred winter range of the Beverly herd of caribou. The bars are standard errors about mid-point means.

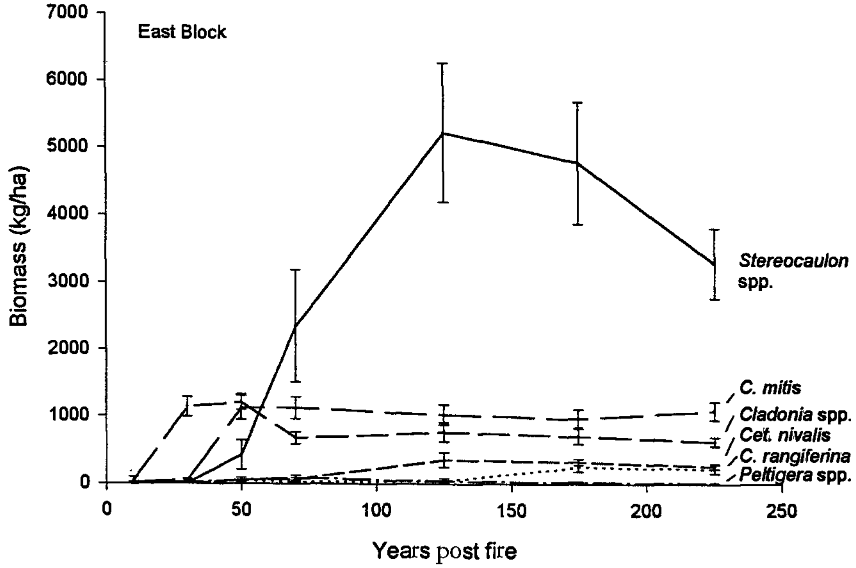

Fig. 3. Post-fire biomass of lichen species at 20-yeat intervals to 100 years, and 50 years thereafter, in the east block of forested winter range of the Beverly herd of caribou. The bars are standard errors about mid-point means.

not differ. Exceptions were *Cet. nivalis*, where significant differences occurred either side of 100 years, and *Cladonia* spp. where year classes 21-40 and 41-60 did not differ.

In the west block, mean biomass of lichens based on site data was low in the 1-20 and 21-40 year classes except for *Cladonia* spp. (less *Cl. uncialis*) in the 21-40 year class (Fig. 2). The mean biomass of *Peltigera* spp. and *Cladonia* spp. peaked in class 41-60 years. The mean biomass of *C. rangiferina, Cet. nivalis,* and *Stereocaulon* spp. peaked after 150 years.

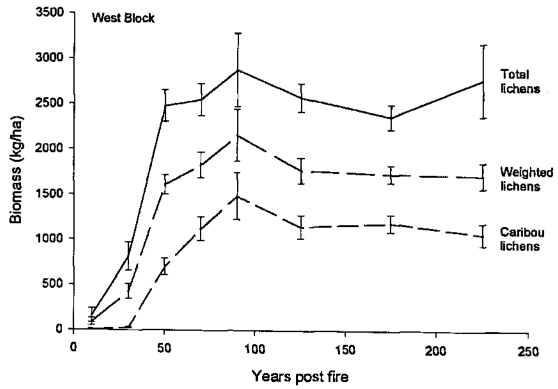

Fig. 4. Post-fire biomass of total, weighted, and "caribou lichens" at 20-year intervals to 100 years, and 50 years thereafter, in the west block of forested winter range of the Beverly herd of caribou. The bars are standard errors about mid-point means.

The mean biomass of *Cet. islandica/arenaria* (not shown) peaked in the 61-80 year class and *Cl. uncialis* in the 81-100 year class (Thomas & Kiliaan, 1994).

Biomass of *Stereocaulon* spp. in age group 100-200 years was over 10 fold higher in the east than in the west (Fig. 2 & 3). The biomass of *C. mitis* was maintained in older sites in the east but declined after 80-100 years in the west.

In the west block, there was little change in total and weighted lichen biomass after class 21-40 years (Fig. 4). The high biomass of *Stereocaulon* spp. in the east block (Fig. 5) caused total and weighted lichens to peak in classes >100 years. The biomass of caribou lichens remained about constant after 20-40 years in the east block and 40-60 years in the west block.

Data for decade age classes to 100 years (Table 1) in the west block indicated a rapid increase in biomass of caribou lichens from 20-30 years to 70-80 years and stability thereafter (Fig. 6). Stability was two decades earlier for weighted and caribou lichens.

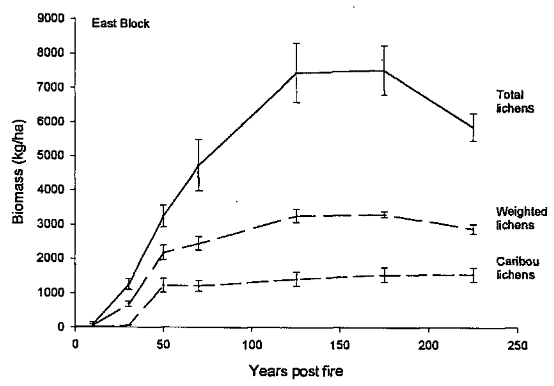

Fig. 5. Post-fire biomass of total, weighted, and "caribou lichens" at 20-year intervals to 100 years, and 50 years thereafter, in the east block of forested winter range of the Beverly herd of caribou. The bars are standard errors about mid-point means.

Table 1. Mean biomass (kg/ha) of lichen species in quadrats at 10- and 50-year intervals after fire in the west block of forested caribou winter range in northern Canada, 1983-85. Standard errors are in smaller print below each mean.

Age class (yr)	No. of sites	No. of quads	Other *Clad.*[1]	*C. mitis*	*Pelt.* spp.	*Cl. unc.*	*Cet. niv.*	*Cet. isl.*	*C. rang.*	*Stereo.* spp.
1-10	04	69	0	1	0	0	0	0	0	0
11-20	06	59	229	10	25	5	1	2	0	0
			47	5	9	3	1	1		
21-30	08	109	691	20	20	6	6	2	1	3
			65	5	7	2	3	0	0	2
41-50[2]	07	85	1128	336	202	162	14	21	12	160
			94	39	35	29	5	2	3	30
51-60	16	148	1108	811	127	225	38	34	27	335
			80	48	28	20	7	3	7	72
61-70	07	69	918	789	109	288	65	44	22	204
			68	54	35	33	13	5	6	54
71-80	11	107	668	1126	41	260	77	56	26	289
			49	75	9	21	12	6	8	60
81-90	07	67	557	1256	95	372	83	33	67	444
			71	98	20	34	18	5	12	135
91-100	02	20	585	1757	46	325	48	42	42	52
			89	328	13	36	12	7	12	18
101-150	23	227	610	853	38	236	242	43	56	503
			30	39	7	15	20	4	7	76
151-200	26	257	587	721	39	194	310	33	159	318
			25	28	10	11	19	3	20	55
201-250	19	198	497	541	41	163	352	30	220	893
			23	29	10	11	29	3	25	143

[1] Excluding *Cl. uncialis*. Abbreviations: quads=quadrats, *Clad.* = *Cladonia* spp., *C.* = *Cladina*, *Pelt.* = *Peltigera*, *Cl.* = *Cladonia*, *unc.* =*uncialis*, *Cet.* = *Cetraria*, *niv.* = *nivalis*, *isl.* = *islandica*, *rang.* = *rangiferina*, *Stereo.* = *Stereocaulon*.
[2] No sites 31–40 years.

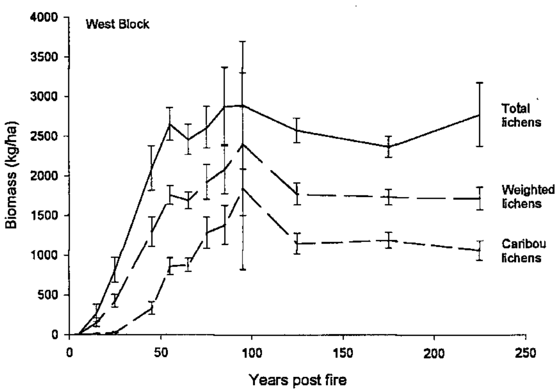

Fig. 6. Post-fire biomass of total, weighted, and "caribou lichens" at 10-yeat intervals to 100 years and 50 years thereafter based on quadrat data ftom the west block of the forested winter range of the Beverly herd of caribou. The bars are standatd etrots about mid-point means.

Terrestrial lichen cover in relation to time since fire

Cover values peaked as early as 21-40 years for other *Cladonia* spp. and as late as 201-250 years for *C. rangiferina* (Table 2). Cover of *C. mitis*, the key caribou lichen species, peaked at 81-100 years.

Frequency of occurrence of plants in quadrats at sites

The frequency of occurrence of species and groups in 1415 quadrats in the west block was tabulated at 10-year and 50-year classes (Table 3). Most quadrats in forests >50 years contained *C. mitis, Cl. uncialis, Cladonia* spp., and *Cet. islandica/arenaria. Cet. nivalis* was nearly ubiquitous in quadrats in sites >100 years and *C. rangiferina* and *Stereocaulon* spp. were common. The frequency of *Peltigera* spp. decreased after class 91-100 years.

Table 2. Mean percent cover of lichens in eight age classes of foresr sampled in the west block of the winter range of the Beverly herd of caribou, 1983-85. Standatd errors are in smaller print below each mean.

Age class, yr	No. sites	*C. mitis*	*C. rang.*	*Cetr. nivalis*	Other *Cladonia*[1]	*Stereo-caulon*	*Caribou* Lichens	Total Lichens[2]
1-20	10	0.9	0.0	0.2	4.5	0.0	1.1	7.2
		0.3		0.1	2.6		0.4	3.0
21-40	8	2.3	0.0	0.1	18.9	0.0	2.4	23.1
		0.5		0.1	3.3		0.6	3.8
41-60	23	18.4	1.0	1.5	17.7	4.2	21.0	52.7
		2.1	0.2	0.4	1.8	1.5	2.3	2.7
61-80	18	30.3	1.4	3.9	14.4	4.7	35.6	64.1
		2.3	0.4	0.8	1.6	1.2	2.0	1.9
81-100	9	35.9	2.9	3.6	9.4	4.0	42.3	65.1
		4.1	1.3	1.1	1.3	1.9	4.0	2.4
101-150	23	26.0	2.7	11.0	10.7	7.1	39.6	65.6
		2.0	0.5	1.9	0.8	2.0	2.9	2.0
151-200	26	24.6	5.8	14.2	11.9	4.7	44.5	66.7
		1.2	1.3	1.3	0.8	1.8	2.1	2.0
201-250	19	19.4	6.8	12.2	9.8	12.6	38.4	67.4
		1.7	1.3	1.8	1.0	4.0	3.2	2.8

[1] Excluding *Cl. uncialis.*
[2] *C. mitis, C. rangiferina* and *Cet. nivalis.*

Table 3. Percent frequency of occurrence of terrestrial lichen species in quadrats at 10-year and 50-year intervals aftet fire in the west block of forested caribou winter range in northern Canada, 1983-85.

Age class (years)	No. of quads[1]	*C. mitis*	*Cet. nivalis*	*Cet. island.*[2]	*Stereo-caulon*	*Peltigera* spp.	*C.rangi-ferina*
1-10	69	4	0	3	1	0	1
11-20	59	54	24	19	7	31	7
21-30	109	81	10	43	12	17	14
41-50	85	100	34	86	54	58	44
51-60	148	99	54	87	45	45	61
61-70	69	100	65	90	42	42	52
71-80	107	100	84	89	63	40	58
81-90	67	100	70	93	36	63	78
91-100	20	100	85	95	50	70	75
101-150	227	100	96	93	59	37	75
151-200	257	100	97	88	36	26	80
201-250	198	100	96	80	52	27	77

[1] Number of quadrats 25 cm x 50 cm. Number of sites is in Table 1.
[2] Included *Cetraria arenaria.*

Relationship between cover and biomass of lichens

Terrestrial lichens were more robust in the east block as indicated by comparative cover and biomass of species and groups (Table 4). Cover of most species was higher in the west and the reverse for biomass. Therefore, within block analysis was necessary.

Biomass and cover of all species at sites were significantly correlated in both blocks (Table 5). Correlation coefficients for data from all 197 sites were intermediate for five species and higher than west and east block coefficients for *C. mitis, C. rangiferina,* and *Cladonia* spp. Coefficients were lower for quadrat data yet still significant. In the west block,

Table 4. Mean cover and biomass of lichen species and groups at sites in forests older than 100 years in west and east blocks of caribou winter range in the Northwest Territories (standard errors in parentheses).

Lichen sp./group	Cover (%) West (n = 71)	Cover (%) East (n = 31)	Biomass (kg/ha) West (n = 71)	Biomass (kg/ha) East (n = 31)
C. mitis[1]	24.1 (1.0)	23.0 (1.7)	710 (43)	1026 (78)
Stereocaulon spp.	8.1 (1.5)	36.3 (3.3)	595 (134)	4149 (433)
Cetraria nivalis	12.7 (0.9)	8.1 (0.9)	294 (27)	294 (27)
Cladonia spp.[2]	10.9 (0.5)	4.8 (0.5)	577 (28)	670 (54)
C. rangiferina	5.1 (0.7)	3.6 (0.7)	148 (21)	203 (40)
Cladonia uncialis	3.6 (0.4)	2.2 (0.2)	207 (13)	241 (21)
Peltigera spp.	1.3 (0.2)	0.2 (0.1)	39 (7)	20 (6)
Cetraria islandica[3]	2.0 (0.2)	0.8 (0.1)	35 (3)	29 (4)
Caribou lichens[4]	41.9 (1.6)	34.7 (3.2)	1153 (65)	1524 (116)
Weighted lichens[5]	54.5 (1.4)	48.4 (2.6)	1767 (68)	3095 (76)
Total lichens	68.5 (1.4)	82.9 (2.1)	2606 (135)	6738 (354)

[1] Includes *C. stellaris.*
[2] Except *Cladonia uncialis.*
[3] Includes *Cetraria arenaria.*
[4] Caribou lichens=*C. mitis* + *C. rangiferina* + *Cetraria nivalis.*
[5] *Stereocaulon* reduced 75%, *Cladonia* spp. & *Cladonia uncialis* reduced 50 %.

Fig. 7. Mean arboreal abundance rating at 50 year intervals after fire in west (n=22, 35, 19, 24, & 18) and east (n=10, 16, 4, 8, & 13) blocks.

the highest correlations were for mat-forming *Stereocaulon* spp. and a foliose lichen (*Cet. nivalis*). The poorest fit was for sometimes misidentified *Cl. uncialis*. The second poorest correlation was for *Cet. islandica/arenaria,* species usually hidden by other species and sometimes overlooked in cover estimates.

Arboreal lichen abundance

The trend in the west and east was an increase in arboreal lichen mean abundance ratings with age of forest to the 201-250 year class (Fig. 7). Arboreal lichens were more abundant in the east in forests 101 to 250 years post fire (Mann-Whitney U test, $P < 0.001$).

Indices of past use of sites by caribou

Past use by caribou of west block sites was significantly higher than in the east (Fig. 8). For example, frequency of occurrence in forests >50 years was 64% in the west block and 29% in the east block. Mean number of pellet groups/ha was 87 in the west and 13 in the east. Excluding zeros, densities were 136±17(SE) and 44±8 in west and east blocks, respectively.

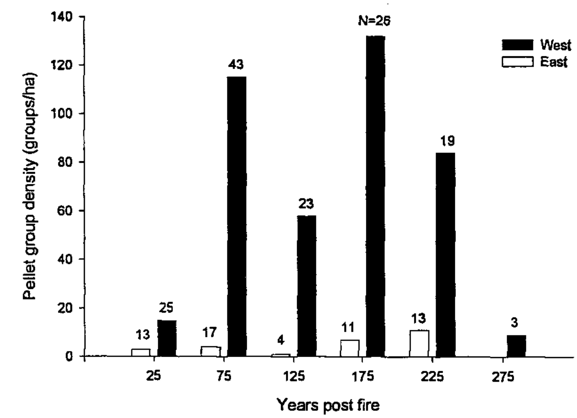

Fig. 8. Densities of caribou fecal groups in the west and east blocks in 50-year intervals after fire on the winter range of the Beverly herd in northern Canada.

Table 5. Regression variables used to predict biomass from cover of lichen species and groups in pine-spruce forest (west block) and spruce forest (east block). Shown are slope (*m*), intercept (*b*) and coefficent of determination(r^2). All equations are significant ($P<0.05$).

Plant species and group	West *m*	West *b*	West r^2	East *m*	East *b*	East r^2
C. mitis	36.24	-82.94	0.71	39.06	127.53	0.76
C. rangiferina	27.63	-0.40	0.78	52.14	10.85	0.90
Cl. uncialis	22.15	121.37	0.28	45.97	94.40	0.49
Cet. nivalis	24.35	-13.10	0.87	28.09	30.54	0.69
Cladonia spp.[1]	49.36	61.22	0.63	52.75	400.08	0.52
Stereocaulon spp.	82.22	-62.67	0.93	116.74	-91.55	0.89
Peltigera spp.	27.08	8.57	0.74	31.56	14.28	0.66
Cet. islandica[2]	10.85	13.38	0.49	13.53	19.84	0.35
Total lichens	45.15	-268.71	0.58	93.67	-872.58	0.57
Caribou lichens [3]	31.46	-59.48	0.73	41.91	67.46	0.79

[1] Except *Cl. uncialis.*
[2] Included *Cet. arenaria.*
[3] *Cladina mitis, C. rangiferina* and *Cet. nivalis.*

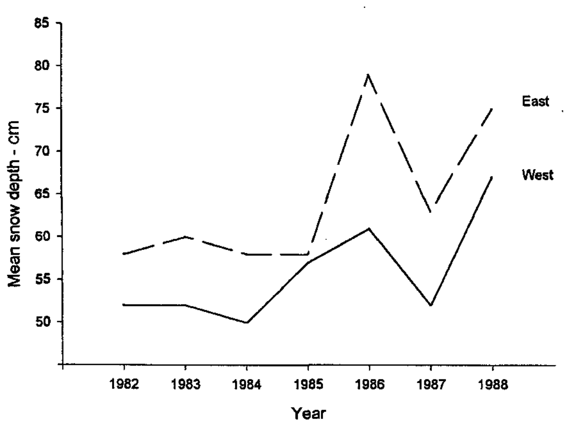

Fig. 9. Depth of snow in mid-March, 1983 through 1988, in west and east blocks of the winter range of the Beverly herd of caribou.

Use varied significantly (Kruskal-Wallis, $P<0.001$) with forest age. Peak use occurred in age class 151-200 years in the west block and at 201-250 years in the east block. We attribute higher use of west block forests in part to late-winter differences in snow depths (Fig. 9).

Caribou-pellet densities (groups/ha) in forests >50 years were 132±24 (SE) at Porter Lake, 90±11 at Nonacho Lake, 11±3 at Thekultheli Lake, 16±4 at Beauvais Lake and 12±2 at Selwyn Lake (Thomas & Kiliaan, 1994). At Nonacho Lake, where sample size was highest (n=84 sites), fecal densities at 50-year intervals were 5±3 (SE), 67±27, 53±11, 134±44, and 147±54. High densities occurred in age classes 51-200 years at Porter Lake. These significant differences in use indices means that correlations between them and vegetation components should be made within regions where use by caribou does not vary significantly.

Pellet-group densities correlated positively ($P<0.05$) with forest age, age class combinations, caribou lichens, *Stereocaulon* spp., *Cl. uncialis*, arboreal lichens, and pine density and negatively with number of trees >10 cm (DBH). Use by caribou was best predicted in the east block by age (r=0.96) and in the west block by combining the intercorrelated variables caribou lichen biomass, arboreal lichen mean rating, and number of trees >10 cm in DBH (r=0.95). Assumptions are violated and some correlations obviously are spurious. Associations between floral species and pellet densities will be explored in more detail in the future.

Discussion

Sampling design

At a landscape scale, site selection was based on where caribou tended to feed in late winter: xeric sites near water courses that were used as travel routes. For comparative purposes, selection of favorable feeding areas was deemed preferable to a completely random sampling design. Of course, biomass of lichens at representative feeding sites differ from sites chosen at random in the same habitat type (Edmonds & Bloomfield, 1984).

At a local scale, sampling was conducted in forest openings rather than under the branches of trees. Such stratification was necessary to reduce sample variation. In particular, lichen abundance was much higher in openings of young forests than under trees. Consequently, our results for lichen abundance and use by caribou are inflated for young (11-50 years) and early-mature (51-75 year) forests; less so for old (>150 year) forests. Bias from a completely random placement of quadrats may be as high as 50% in young age classes where trees are dense.

Adequate sampling for lichen biomass depends on the spatial variability of lichen species deemed important to caribou. Our sampling protocol was deemed adequate for abundant species and lichen groups. Previous standing crop estimates in this caribou winter range were semi-quantitative (Scotter, 1964; Miller, 1976).

Terrestrial lichen biomass

An increase from west to east in total lichen biomass and succession rate is indicated by our results combined with those of Foster (1985) and Couturier & St-Martin (1990). Total terrestrial lichen biomass at caribou feeding sites >60 years averaged 2594 and 6250 kg/ha, in west and east sites, respectively. In forests >55 years in Quebec, terrestrial lichen biomass averaged 1540, 4463, and 8354 kg/ha in pine, mixed, and spruce forests, respectively (Couturier & St-Martin, 1990). Russell *et al.* (1993) tabulated lichen biomass for various studies and listed sampling differences that confound comparisons. Comparative total lichen biomass is of botanical and ecological significance but caribou ecologists must focus on lichen species most utilized by caribou.

Our weighting of terrestrial lichen biomass was an attempt to reflect proportionate consumption by caribou in the study area. The weightings were arbitrary but based on preference order in cafeteria-style feeding experiments (DesMuelles & Heyland, 1969; Holleman & Luick, 1977; Norberg *et al.*, 1995), rumen and fecal microhistological analyses (Thomas & Barry, 1991), and examination of feeding craters (Thomas, 1994). Some adjustment of total terrestrial lichens was necessary because *Stereocaulon* spp., of low palatability and digestibility (Thomas *et al.*, 1984), dominated terrestrial lichens in old forests, particularly in the east block. Perhaps *Peltigera* spp. should be weighted low based on lowest preference (Holleman & Luick, 1977). The higher correlation of pellet-group densities with caribou lichens than weighted lichens indicates that *Stereocaulon* spp., *Cladonia* spp., and *Peltigera* spp. may be consumed incidentally, as suggested for conifer needles and moss (Thomas & Barry, 1991).

Factors affecting use of forests by caribou

Little use was made of forests younger than 60 years, though adequate forage was present 40-60 years after fire in some locations. Deadfall was not an impediment to movement in young stands. The high biomass of *C. mitis* 50-150 years after fire corresponded to increased use by caribou in that age group. *C. rangiferina* and *Cet. nivalis* had peak biomass corresponding to highest use by caribou in forests >150 years but their biomass was low. Weighted lichens did not correlate with caribou use indicating invalid weighting. There was no indication at feeding sites that *Stereocaulon* spp., *Peltigera* spp., and "other *Cladonia*" spp. were used to any extent by caribou. Caribou clearly were not responding to total lichen biomass. Use by caribou was 5-11 times higher at Nonacho and Porter lakes than at Beauvais and Selwyn lakes yet total lichen biomass was 2.4 times higher in the east than in the west.

Perhaps there are threshold values for cover and biomass of certain lichen species or groups that caribou respond to. From age class 41-60 to 61-80 years, indices of caribou use in the west block increased from 21 to 107. Concurrently, mean biomass of *Cet. nivalis* increased from 30 to 72 kg/ha; that of *C. mitis* increased from 547 to 1029 kg/ha, while changes were less or reversed in other lichen species. Thus, in terms of food, the caribou seemed to be responding most to these lichen species. If caribou key to threshold amounts of species or species groups, linear analyses may produce poor correlations.

How we partitioned age and floral components is critical yet artificial. For example, some high correlations between caribou use indices and plant species/groups resulted for sites 50-150 years. Caribou may have a more holistic view of habitat!

Predator avoidance behavior may be a factor in habitat use by caribou. Caribou seemed to prefer open forests 150 to 250 years post-fire. Open forests facilitate visual contact with other members of the group and wolves.

Caribou in the Beverly herd seem to have adapted their movement pattern to differences in late-winter snow depths at a landscape scale (Thomas, 1991). Movement to parts of the range with shallower snow in late winter generally occurred early in winter when snow cover was shallow and uniform across the range. Average snow depths were slightly lower in openings of mature and old forests compared with young ones but snow depth was not a problem in most winters (Thomas, 1991).

Most feeding by caribou was in forests along and adjacent to travel routes. These are lakes and lowland connections between lakes where travel is easy and visibility is high. Some routes are traditional. Because of numerous environmental and behavioral factors, that vary annually, prediction of habitat suitability or caribou use by any one factor will have low probabilities. Food is important but confounding factors include distance from travel routes, escape habitat, and snow conditions.

Management implications

Our results for lichen cover and biomass defined the sequence of lichen succession after fire in the study area. Previous results were semi-quantitative and not in the core of current winter range (Scotter, 1964, 1965; Miller, 1976). Our data on relative use by caribou of forests of different ages is the first available for a wide range of age classes. These results were used, in part, to develop a fire suppression strategy for the winter ranges of two herds of caribou (Beverly & Qamanirjuaq Caribou Management Board, 1994). The strategy is based on current proportions of productive caribou range (>50 years) relative to goals for such habitat in zones mapped by local hunters.

The significant correlations between lichen cover and biomass (Bergerud, 1971; this study) means that ocular cover estimates can be used to assess the abundance of terrestrial lichens. This is important for future studies where staff, funds, and time are constrained. Cover estimates could be restricted to *Cladina* and *Cetraria* spp. if sites were sampled quickly using aircraft for access.

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