

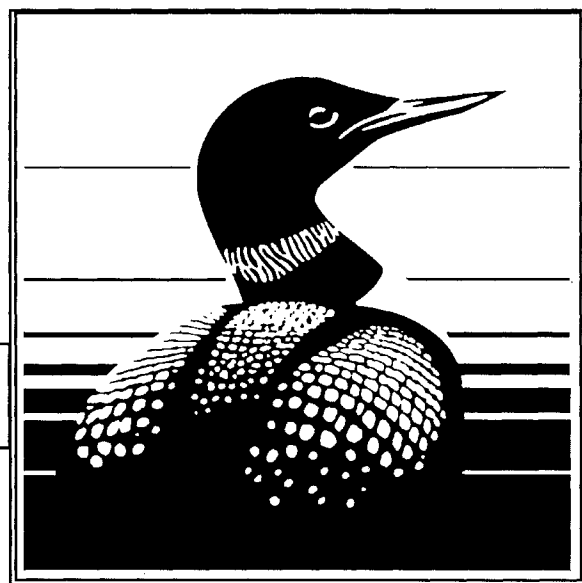


Fire-caribou relationships: (IV) Recovery of habitat after fire on winter range of the Beverly herd

Don C. Thomas and H.P.L. Kiliaan

Prairie and Northern Region 1998
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**FIRE - CARIBOU RELATIONSHIPS: (IV) RECOVERY OF HABITAT
AFTER FIRE ON WINTER RANGE OF THE BEVERLY HERD**

DON. C. THOMAS
H.P.L. KILIAAN

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7. Thomas, D.C. 1998b. Fire-caribou relationships: (VII) Fire management on winter range of the Beverly herd: final conclusions and recommendations. Tech. Rep. Series No. 315. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 100pp.
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SUMMARY

The cover and biomass of surface vegetation was measured at 197 sites located on winter range of the Beverly herd of barren-ground caribou (*Rangifer tarandus groenlandicus*). The primary objective was to explore the relationship between abundance of caribou forages and time since fire, between those two factors and indices of caribou use, and between plant cover and biomass (dry weight). Various species of lichens attained peak biomass at various periods after fire -- as early as 40-60 years for *Cladonia* spp. (except *Cl. uncialis*), to as late as 220-240 years for *Stereocaulon* spp. Total lichen biomass increased with age of forest until 180 years. Biomass was about constant after 60 years for lichens species given weighted values according to their perceived importance to caribou and seemingly preferred by caribou. *Cladina mitis* was considered to be the most important lichen for caribou throughout the winter range. It reached maximum biomass and height at 60-80 years after fire. *Stereocaulon* spp. was several times more abundant in eastern portions of the winter range than in the west. It was lightly grazed and then seemingly only incidentally because other species of lichens such as *Cetraria nivalis* were associated with it. The biomass of low evergreen shrubs that were eaten in small amounts by caribou did not change appreciably with age of forest. There were, with one exception, significant correlations at the site level between estimated cover and biomass of caribou forages. It is feasible, therefore, to assess caribou ranges relatively quickly by estimating cover of forages known to be important to caribou. Arboreal lichen abundance increased with time after fire until about 70 years and then stabilized. Caribou pellet groups were detectable for 2-3 years and

3-5 years in mesic and xeric sites, respectively. Forest stands became productive in terms of caribou forage as early as 40-50 years after fire but data for densities of pellet groups and field observations indicated that caribou made most use of forest stands 151-250 years old. Use of forests under 50 years old was negligible. In contrast, forests 21-40 years post-fire contained the highest density of moose (*Alces alces*) pellets. There was no clear relationship between age of forest and pellet densities of hare (*Lepus americanus*) or grouse/ptarmigan (*Canachites canadensis*/*Lagopus lagopus*). In western sites, there were trends towards greatest use by hare of forests in age classes 41-150 years; by grouse/ptarmigan, 41-100 years post fire.

RÉSUMÉ

La couverture et la biomasse de la végétation de surface a été mesurée dans 197 sites forestiers régénérés après un incendie dans l'aire d'hivernage du troupeau de Beverly de caribous de la toundra (*Rangifer tarandus groenlandicus*). Le principal objectif de l'étude était de déterminer le lien entre l'abondance des aliments des caribous et le temps écoulé depuis l'incendie, entre ces deux facteurs et les indices d'utilisation par les caribous, et entre la couverture végétale et la biomasse (poids sec). Les diverses espèces de lichens ont atteint une biomasse maximale à divers moments après l'incendie - 40 à 60 ans plus tard pour les espèces du genre *Cladonia* (sauf *Cladonia uncialis*), et 220 à 240 ans après l'incendie pour les espèces du genre *Stereocaulon*. La biomasse totale des lichens augmentait avec l'âge de la forêt jusqu'à 180 ans après l'incendie. La biomasse était pratiquement constante après 60 ans pour les lichens auxquels des valeurs pondérées ont été accordées en fonction de leur importance estimée pour les caribous et pour les lichens que les caribous semblaient préférer. *Cladonia mitis* semblait être le lichen préféré des caribous dans toute l'aire d'hivernage. Cette espèce a atteint une biomasse et une hauteur maximales 60 à 80 ans après l'incendie. Les espèces du genre *Stereocaulon* étaient plusieurs fois plus abondantes dans les parties est que dans les parties ouest de l'aire d'hivernage. Comme elles étaient associées à d'autres espèces, telles que *Cetraria nivalis*, elles n'étaient touchées que superficiellement et de manière apparemment occasionnelle. La biomasse des petits arbustes à feuilles persistantes qui sont consommés en petites quantités par les caribous ne s'est pas modifiée de façon appréciable avec l'âge de la forêt. Mis à

part une exception, des corrélations significatives ont été observées au niveau de chaque site entre la biomasse et la couverture estimée des aliments des caribous.

Nous en concluons qu'il est possible d'évaluer rapidement les aires d'hivernage des caribous d'après la couverture estimée des végétaux dont ils se nourrissent.

L'abondance des lichens arboricoles augmentait avec le temps après l'incendie, jusqu'à environ 70 ans, puis se stabilisait. Des tas de crottin de caribou étaient détectables pendant 2 à 3 ans dans les sites mésiques et pendant 3 à 5 ans dans les sites xériques. Les groupes d'arbres devenaient productifs en termes d'aliments des caribous 40 à 50 ans après l'incendie, mais les données relatives à la densité des tas de crottin et les observations sur le terrain ont indiqué que les caribous utilisaient de préférence les groupes d'arbres âgés de 151 à 250 ans. L'utilisation des forêts ayant moins de 50 ans était négligeable. Par contre, les forêts régénérées de 21 à 40 ans contenaient la plus forte densité de crottin d'orignal (*Alces alces*). Il n'y avait pas de relation évidente entre l'âge de la forêt et la densité du crottin de lièvre (*Lepus americanus*) et du crottin de tétras du Canada et de lagopède (*Canachites canadensis* et *Lagopus lagopus*). Dans les sites de l'ouest, il existait des tendances vers une utilisation plus intensive des forêts régénérées de 41 à 150 ans par le lièvre, et des forêts âgées de 41 à 100 ans par le tétras du Canada et le lagopède.

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INTRODUCTION

Studies on effects of natural fires on forested winter ranges of caribou in Canada (e.g., Scotter 1971, Johnson and Rowe 1975, Miller 1980) resulted in some divergent views on three key questions:

1. Do fires reduce the capacity of winter ranges to support caribou and, if so, does the lack of winter range limit or reduce caribou populations?
2. Does burned range restrict the movements and distribution of caribou and, if so, to what extent and what factors are involved?, and
3. What is the relationship between time since fire and productivity and standing crop of caribou forages?

In 1978, CWS proposed additional studies to help clarify some of the unresolved questions. Some large fires in the summer of 1979 burned 1.4 million hectares of potential caribou winter range east and northeast of Fort Smith, Northwest Territories (NWT). In response to concerns voiced by the Hunter's and Trapper's Association of Fort Smith, a review panel was struck to investigate fire management policy. Regarding caribou, the panel concluded that more information was needed on effects of fires on their winter range and their use of range (Murphy et al. 1980).

Preliminary studies on caribou diet and digestibilities were conducted in March 1980 and 1981. A major 5-year field study of fire-caribou relationships began in March 1982 and continued until March 1987. The adequacy of winter range to support the Beverly herd of caribou was assessed by monitoring changes in fat deposits and other variables from December to March each winter from 1983-84 through 1986-87. The winter range appeared to be adequate for the present herd (report 1 of this series, page i).

Reproduction and mortality are the two major factors influencing population numbers. Fecundity was normal and fluctuated among years and even within subherds in one year. There was a strong correlation between fecundity and fat reserves of caribou (report 2).

Movements and distribution of the herd in relation to burns, snow, and other physical features was monitored over five winters. Conclusions were that the general burn pattern affected caribou distribution in winter, though caribou freely traveled through individual burns of all sizes. There was a further conclusion that caribou movements in winter were affected by and adapted to snow characteristics (report 3).

This fourth report details findings of the third major phase of the study: relationships between time since fire and the quantity of caribou forage. A fifth report concerns caribou diet and the sixth records fire history of forested range in NWT and Saskatchewan. Those reports and results from other studies form a data base for the final conclusions and recommendations (report 7). Report 8 presents a literature review of aspects relating to fire-caribou relationships.

Major objectives of this habitat study were as follows:

1. To measure the quantity (cover and biomass) of forages (plants eaten by caribou) in forests at various periods after fire.
2. To assess relationships between the cover and biomass of caribou forages.
3. To obtain information on relative use of forests of various ages by caribou and other herbivores (plant eaters).
4. To obtain data on characteristics of the forest canopy (tall trees) with time since fire and investigate possible relationships to forage biomass.

METHODS

Study areas were selected in the core of the winter range where large lakes provided good access to a variety of forest ages (years since fire). Major study areas were at Nonacho, Porter, Thekulthili, Selwyn, and Beauvais lakes. We also traveled the Taltson River between Nonacho and Gray lakes and used helicopters and fixed-wing aircraft to sample sites over a wider area and to obtain sites at ages under-represented by ground-based sampling. The objective was to obtain an array of forest ages. At any one location only a few age classes were present.

When aircraft support was available, the crew was positioned at a site early in the morning and retrieved in the evening. The gear included a small tent, food, a first-aid kit, a shotgun, and a high frequency radio and long antenna. Contact was maintained during the day with a base camp.

Site selection was based on existing burn maps, on burn lines visible on LANDSAT or photographic images, and on burn lines mapped from reconnaissance flights in each study area or from a boat while cruising shorelines. Considerable experience was required to differentiate medium-aged sites (51-100 years) from older ones. The skyline, color, tone of the forest, and the shape and characteristics of individual trees were all diagnostic criteria. The ages of jack pine were estimated more accurately than those of spruce.

A basic sampling design was to sample two ages across a fire line and compare the biomass of caribou forages in the two sites. We selected, as much as possible, the same landform, surface materials, elevation, etc. for the paired sites. In this

way, other variables that could affect vegetative characteristics were “controlled” and time since fire and its effects on flora was the prime variable affecting floral differences. Sampling was sufficiently far (100-200 m) from a fire line that sites were considered to be essentially unaffected by each other. We also sought distinct, straight fire edges where burning was complete and controlled by winds. Ragged edges where burning was incomplete were avoided because the surface could be composed of vegetation of two ages.

Representative upland sites were chosen on ridge tops or on gentle slopes. These sites were favorable feeding areas for caribou. Initially a 10 m x 10 m plot was laid out and 25 cm x 50 cm quadrats were located within the grid using random numbers. This procedure proved to be too time consuming as 15-30 locations were required to position 10 quadrats. Many quadrats fell in locations under trees, on large rocks, on fallen trees, or on areas cratered by caribou. Those quadrats were relocated.

Our samples were restricted to canopy openings because vegetation under drip areas of trees differed from that in openings. Under-tree vegetation was dominated by low shrubs, mosses, and low cover of certain lichens such as *Cladonia* spp. and *Cladina rangiferina*. Thereafter, upon arrival at a site, several quadrats were tossed at least 5 m by one individual. While looking upward and slowly walking, the quadrats were tossed behind or to the sides. Those landing under trees with low branches were tossed again until the standard 10 plots were established. In recent burns and in young (11-50 years) sites, 15 to 25 quadrats were sampled because of greater variation in cover.

Upon arrival at a site, a stake was thrown over a shoulder to mark the southwest corner of a 10 m x 10 m plot. The area was established using compass settings

(N, E, S, and W) and roped off. Diameters at breast height (DBH) of all trees in a plot were measured by vernier caliper and their species recorded on standard forms.

Two or three of the tallest and thickest jack pine (*Pinus banksiana*), black spruce (*Picea mariana*), and, rarely, white spruce (*Picea glauca*) were felled near the site and measured for height, DBH, and, in 1986, diameter of widest branches.

Hereafter, "spruce" refers to black spruce and "pine" refers to jack pine. Several sections cut 25 cm above the ground were saved and numbered for ring counts. Fire scars, if present, were obtained from several pine and, if possible, from spruce. Fire scars were abundant in all but the oldest pine forests. Scars were more difficult to find in spruce and sometimes the burn edge was followed for some distance before suitable scars were obtained. Growth spurts caused by fire provided clues to fire date if scars were not distinct.

Pellet groups of caribou, moose, hare, and ptarmigan/grouse were counted in two belt transects each 100 m long and 4 m wide. Each transect was established by running a 100 m tape or chain through representative upland habitat from a representative starting point. A standard practice was to walk 1 m on each side of the tape and scan a 2 m-wide strip. Feces of bears and other species were also recorded. Summer-type moose feces comprised of 1 - 3 amorphous masses was counted as a pellet group. The following data and observations were recorded on a standard form: site number, date, location, aspect, slope (measured by clinometer), dominant and subdominant tree species, dominant surface vegetation, species present, humus depth, type of parent material in lower soil horizons, relative amount (scale 0-4) of arboreal lichens on branches 0-2 m above ground, and pellet-group counts.

Percent lichen cover was obtained from a 100 m line transect with point sampling at 10 cm intervals. These transects ran in straight lines to equally represent the two strata; openings and below trees.

Each quadrat was identified by numbering the basal edge of a paper bag with a site and plot number. The quadrat and plot was then photographed vertically at 0.8-1.0 m. Cover of species could be estimated from the photographs at a later date by use of a grid ocular in a dissecting microscope. Such data was not obtained in this study because of time constraints. Percent cover of each species within each quadrat was estimated visually and recorded on the bag. Also included were bare ground, rocks, twigs, dead leaves, and fecal pellets.

Biomass was obtained by first mist wetting vegetation with water transported to sites in plastic spray bottles. All live leaves were collected as was the current year's growth of woody tissue characterized by a paler green color and high flexibility (less lignification). Mosses were not picked because generally they are avoided or consumed incidentally by barren-ground caribou. Under wet conditions, paper bags were covered by a clear plastic bag or vegetation was placed directly into the plastic bag containing site and plot number. A rubber band was placed around the bags and they were transported to our camp. Cover values were recorded on master data sheets in the field if time permitted or later the same day in camp.

When mosquitoes or black flies were severe, we placed individual screen "tents" over ourselves while obtaining biomass samples. Each plot required an average of about 1 hour per person to obtain biomass. Bagged samples were sorted to species, genera, or species groups. Sorting entire samples proved to be too time consuming, entailing an average of about 3 hours per sample. We therefore sorted a subsample

with 33% as a minimum proportion. The percent subsampled depended on size of sample and ranged from 33% for large bags to 100% for small samples. The procedure was to mist dampen the sample (if dry) and thoroughly mix it. It was then laid out in a "loaf", further mixed, and then subdivided into sort and non-sort components. These were each weighed on an electric balance to the nearest gram and recorded. Sorting was done in the field camp on days when it was too wet or windy to conduct sampling or to travel on lakes. Remainder of the sorting was done in the laboratory. Experienced sorters helped inexperienced ones to identify species. Initial sorting was checked in the laboratory before drying samples at 55° C for 3 days and weighing them on a microbalance to nearest milligram. Weights were then adjusted to account for portion of the sample that was not sorted.

Forest ages were available for burns mapped by Indian and Northern Affairs Canada since 1968. Ages of other sites were obtained from fire scars where year of fire was: (1) *current year minus number of summer annulations* (for trees cut January through April) and; (2) *current year minus number of summer annulations minus 1* (for trees cut May-Dec). It was necessary to subtract an additional year if winter annulations were counted. We assumed that no summer wood was deposited after the fire in the summer in which the fire occurred. In some trees, no annual wood was deposited for up to 5 years anywhere on the circumference of cambium in the area of a scar. We obtained scars from several trees in an effort to obtain the correct number of years since fire.

At sites where no scars could be found, we estimated the age of the stand by adding 5 and 10 years to the maximum number of annulations in pine and spruce,

respectively. These adjustments were made after determining the relationship between numbers of annulations 25 cm above ground and known ages from mapped burns or reliable scar data. Minimum differences were 4 years for both tree species but only exceptional spruce trees attained 25 cm in 4 years after fire.

Species of lichens treated separately included *Cladina mitis*, *C. rangiferina*, *Cladonia uncialis*, *Cetraria nivalis*, and combined *Cet. islandica/arenaria*. Hereafter, *C. mitis* refers to that species plus *C. stellaris*, which was not common in uplands but was present in mossy lowlands. *C. stellaris (alpestris)* was included with *C. mitis* because small forms could be confused with *C. mitis* and fragments of it in biomass samples could not be differentiated. Genera of lichens treated separately included *Peltigera* spp. (largely *apthosa*), *Stereocaulon* spp. (largely *paschale*), and *Cladonia* spp. other than *Cl. uncialis*. (On the basis of form, *uncialis* should be grouped with *Cladina* rather than *Cladonia*). Lichen biomass was also totaled and a weighted total was calculated based on adjusted biomass. *Cladonia uncialis* and "other *Cladonia*" spp. were reduced by 50% and *Stereocaulon* spp. reduced by 75%. A group composed of *C. mitis*, *C. rangiferina*, and *Cet. nivalis* were totaled to form what are herein defined as "caribou lichens". Caribou lichens are variously defined but *Cladina* spp., a subgenera of *Cladonia*, is probably the most proper (Ahti 1977). There was evidence our caribou lichens were selected by caribou and they were readily available under snow cover. They were more readily grazed than the others because they grew above the mat formed by some of the other species. Branching fruticose lichens and large foliose forms would be easily grazed under snow in comparison with the cup, cactus, and sword types representative of *Cladonia* spp. Many *Cladonia* spp. adhere to the substrate as though they had roots and they

may fracture when pawed under snow by caribou.

Lichen nomenclature follows Thompson (1984). In this report *Cladina* is abbreviated to *C.*, *Cladonia* to *Cl.*, and *Cetraria* to *Cet.*

Forest ages were grouped into eight basic classes to describe changes in forage: 1-20, 21-40, 41-60, 61-80, 81-100, 101-150, 151-200, 201-250, and 251-300 years post fire. Those classes were a compromise between detection of changes and maintaining reasonable sample sizes. In this report, forest ages were also grouped and named, for convenience of discussion, in the following age classes: recent burn, 0-10 years; young, 11-50 years; medium, 51-100 years; mature, 101-150 years; old 151-200 years; and ancient >200 years.

Standard error (SE) was calculated as $SD/\text{sq. root } (n-1)$ to adjust standard deviation (SD) values generated by REFLEX as $SD = \text{sq. root } [n\sum x^2 - (\sum x)^2]/n^2$. Variables had near-normal distributions within selected sage classes.

RESULTS

Sites sampled

We sampled 197 sites in four summers including 140 sites west of 107°W and 57 east of 107°W (**App. 1**). Two additional sites were sampled in northern Alberta just south of Fort Smith but they are outside the normal winter range of the herd. The sites were clustered around Nonacho, Thekulthili, Porter, Beauvais, and Selwyn lakes (**Fig. 1**). Site locations, except for the six in Alberta and Saskatchewan, were mapped (**Figs. 2 and 3**) and larger-scale maps showing exact locations are available from the author.

Aircraft used in support of field studies totaled 219 hours (**Table 1, App. 2**). In

Figure 1

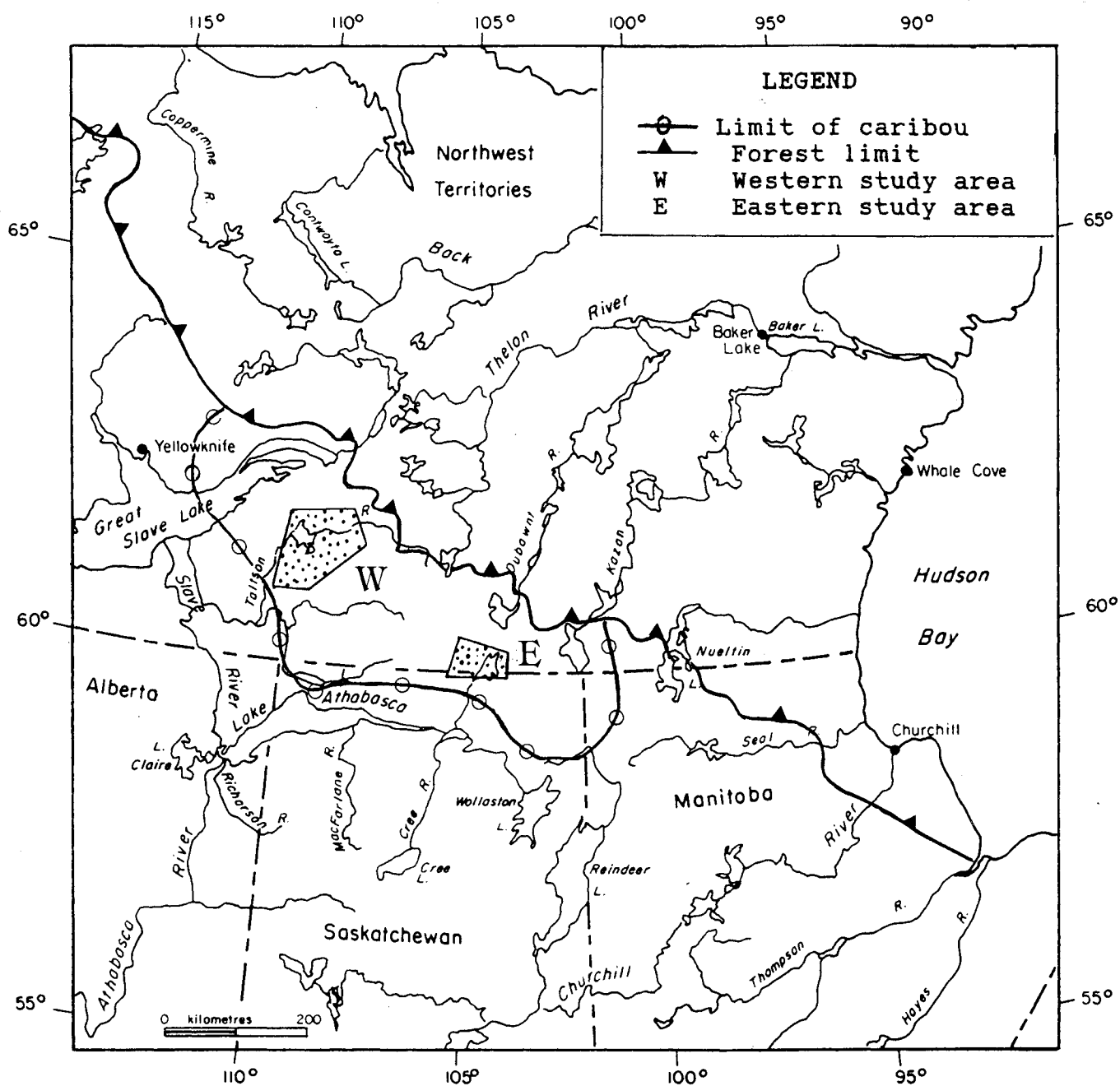


Figure 1. Locations of west and east sampling areas, where most sites were located, in relation to forested winter range generally used by the Beverly herd of caribou in the 1970s and 1980s.

Figure 2

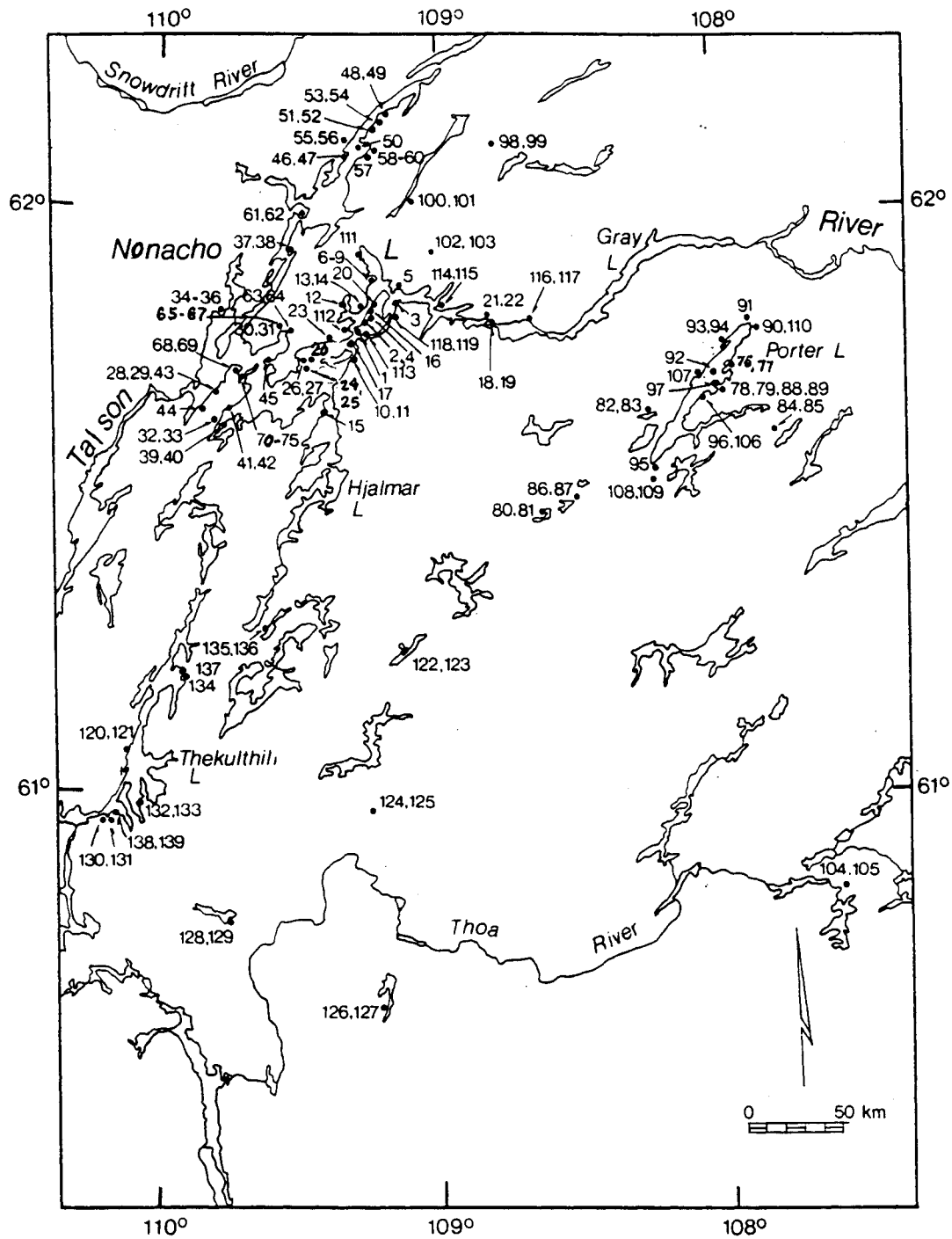


Figure 2. Locations of sites sampled in the vicinity of Nonacho, Porter, and Thekulthili lakes (numbers are site numbers).

Figure 3

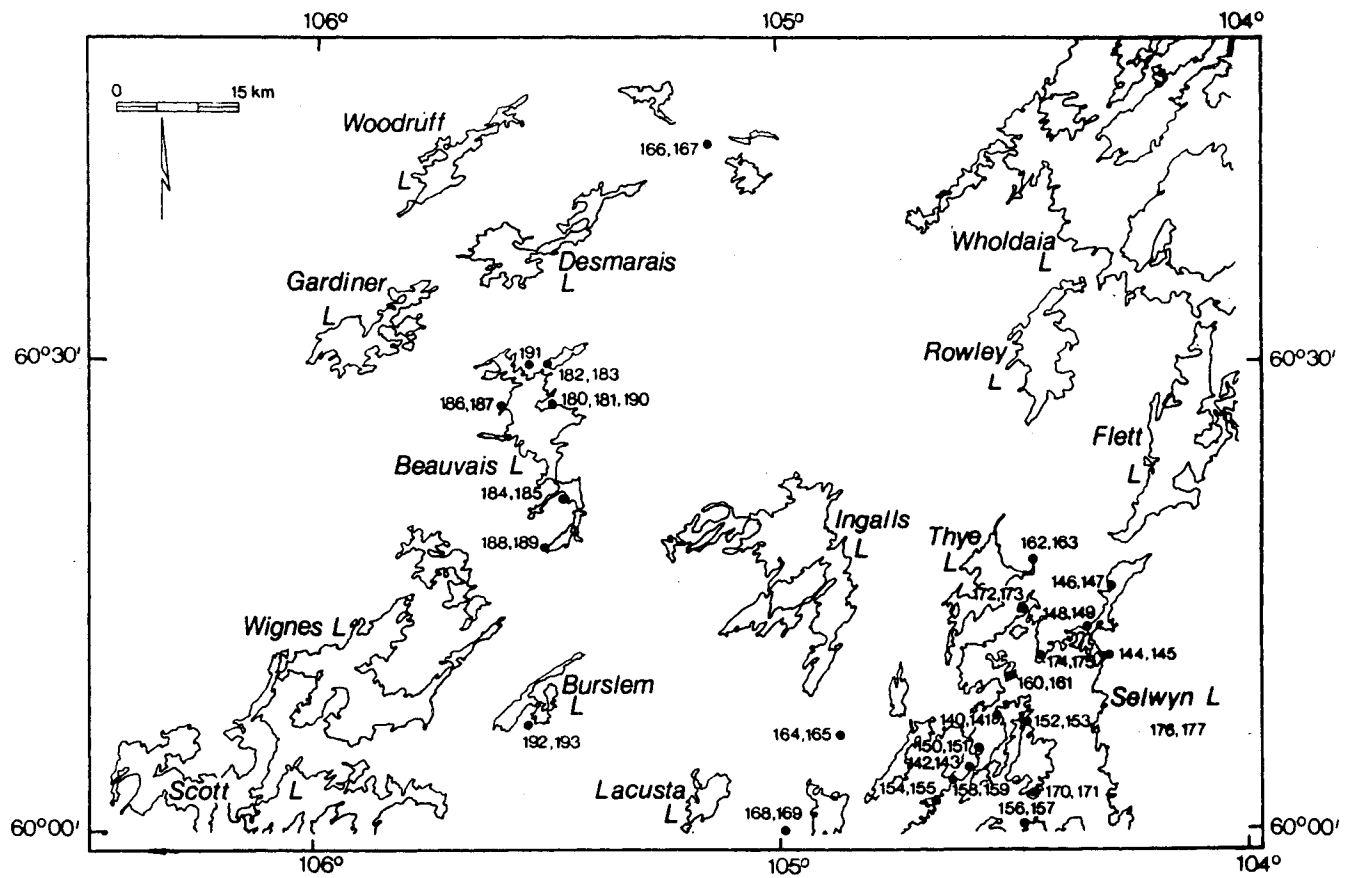


Figure 3. Locations of sites sampled in the vicinity of Beauvais and Selwyn lakes (numbers are site numbers).

Table 1. Summary of aircraft used in summers 1983 through 1986 to support sampling of vegetation at 197 sites on winter range of the Beverly herd of caribou.

Aircraft type	Hours flown				Totals
	1983	1984	1985	1986	
Twin Otter	0.0	2.0	10.1	0.0	12.1
Single Otter	9.3	15.9	4.0	26.8	56.0
Cessna 185, 206	16.0	13.0	43.6	66.1	138.7
Jet Ranger	0.0	12.0	0.0	0.0	12.0
Totals	25.3	42.9	57.7	92.9	218.8

1984, 1985, and 1986 we sampled 8, 18, and 14 sites, respectively, using aircraft based in field camps.

About 975 person days were required to sample 199 sites (2,106 quadrats) and sort about 129 of them. Time required to establish and break camps was additional. Another 300 person days were required to sort samples from the remaining 70 sites, resort some of them, and dry and weigh forage.

Lichen biomass *versus* time since fire

Upland sites

Biomass of lichens was low in the 1-20 and 21-40 year age classes except "other *Cladonia*" (all *Cladonia* spp. other than *Cl. uncialis*) in the 21-40 year class (**App. 3**). Those species were mostly "cup and sword (horn)" types that grew in dense patches in young sites and had a more-even distribution in older ones. Biomass of most other lichen species increased rapidly in the period 41-60 years post fire (post fire). Biomass of *Peltigera* spp. and "other *Cladonia*" spp. peaked in that period (**Fig. 4**).

Biomass of *Cet. islandica/arenaria* peaked in the 61-80 year class; *Cl. uncialis*, *C. mitis*, and grouped "caribou lichens" (*C. mitis/stellaris*, *C. rangiferina*, and *Cet. nivalis*) in the 81-100 year age class. Biomass of *Cet. nivalis*, *C. rangiferina*, *Stereocaulon* spp., total lichens, and weighted lichens peaked in the oldest age class (**Fig. 5**). Weighted lichen biomass was adjusted total biomass, where biomass of *Cl. uncialis* and "other *Cladonia*" spp. were reduced by 50% and biomass of *Stereocaulon* spp. by 75%. Weighted lichen biomass was similar in all age classes after the first two (1-20 and 21-40 years). Values in the 250-300 year class are not reliable because only three sites were sampled.

Cladina stellaris and *C. rangiferina* were most abundant in old forests. Largest forms of both species grew in areas with abundant feather mosses, such as on north slopes, under the drip lines of spruce, and on the sides of hummocks in wetlands.

East-west differences in lichen biomass were explored by comparing sites east and west of 107°30'W (**App. 4 and 5**). *C. mitis* attained near maximum biomass at 41-60 years in the east and 81-100 years in the west (**Fig. 6 and 7**). Biomass levels of *C. mitis* were maintained in older sites in the east but declined to the west of 107°W. Biomass of *Stereocaulon* spp. in the east gradually increased with time to high levels in forests 100-150 years post fire, after which it declined somewhat. In the west, highest biomass of *Stereocaulon* spp. was in forests older than 250 years and its biomass in forests 100-200 years post fire was over 10 fold lower than in the east. All other lichen species had similar changes in biomass with time in the two range divisions.

In western sites, there was little change in total, weighted, and caribou lichen

Figure 4

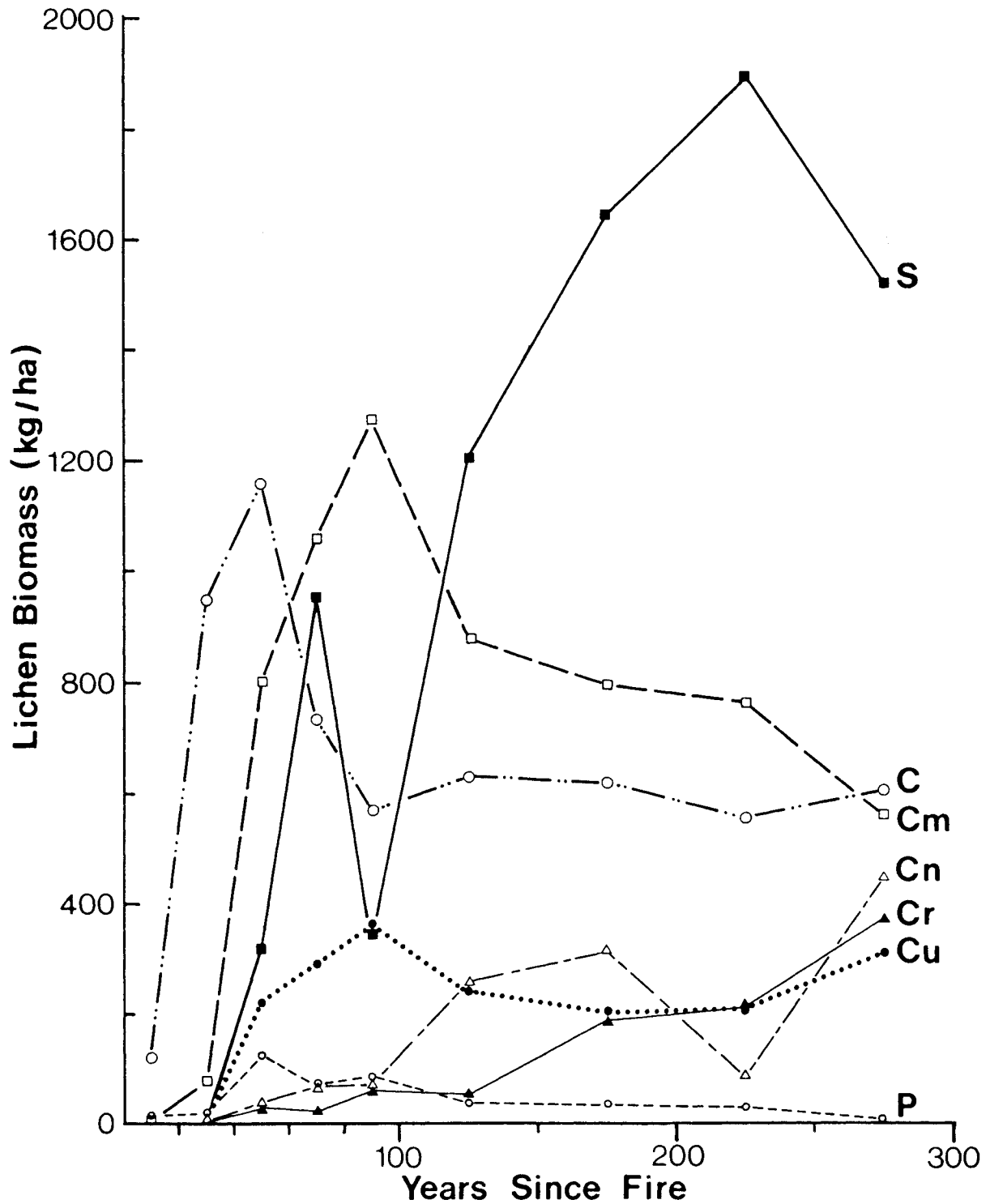


Figure 4. Biomass of *Stereocaulon* spp. (S), *Cladonia* spp. (C), *Cladonia mitis* (Cm), *Cetraria nivalis* (Cn), *Cladina rangiferina* (Cr), *Cladonia uncialis* (Cu), and *Peltigera* spp. (P) on upland sites at periods after fire on winter range of the Beverly herd of caribou.

Figure 5

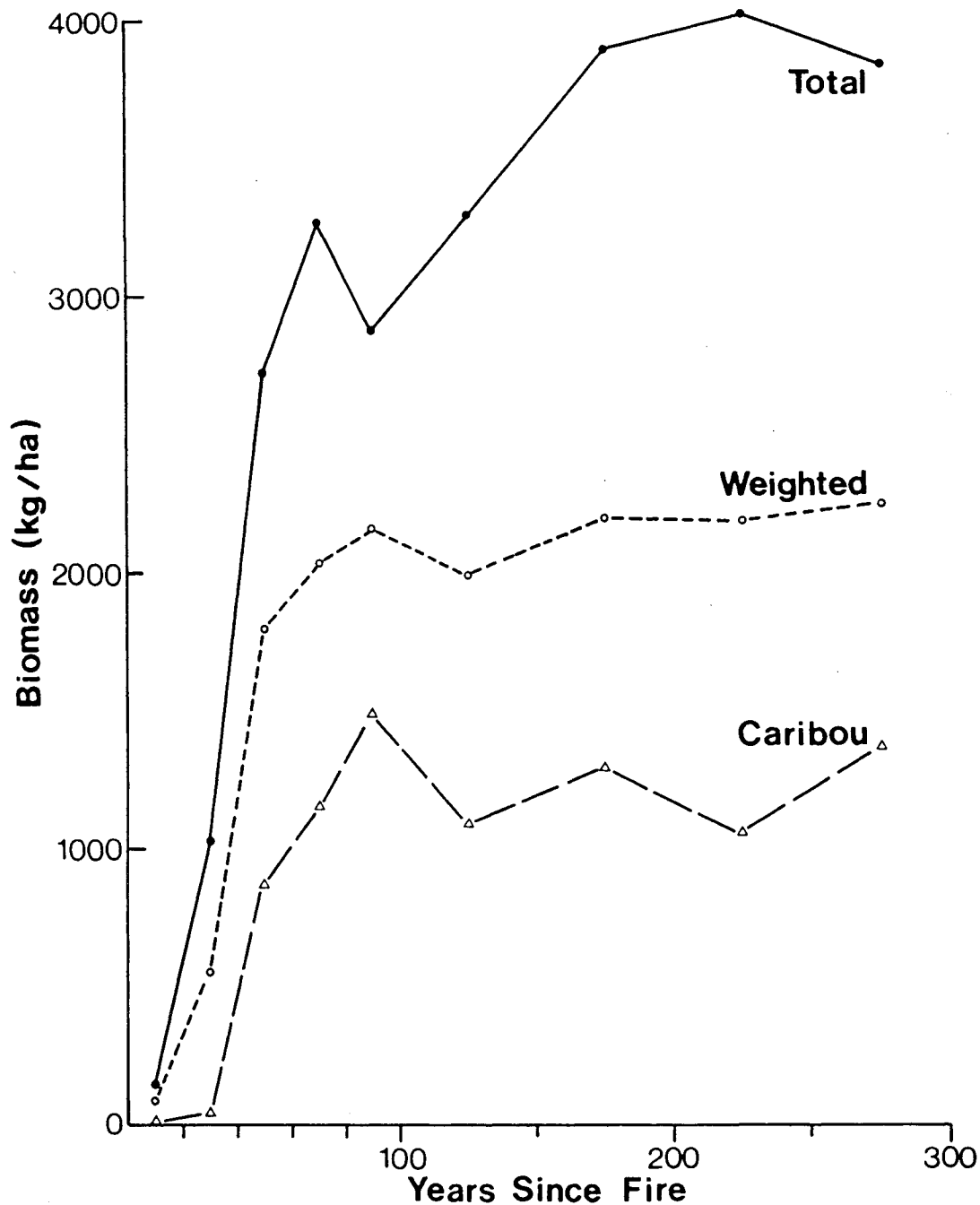


Figure 5. Biomass of all lichens (total), "weighted lichens" (all lichens with *Cladonia uncialis* and "other *Cladina*" spp. reduced by 50% and *Stereocaulon* spp. reduced by 75%) and "caribou lichens" (*Cladina mitis*, *C. stellaris*, *C. rangiferina*, and *Cetraria nivalis*) on upland sites at periods after fire on winter range of the Beverly herd of caribou.

Figure 6

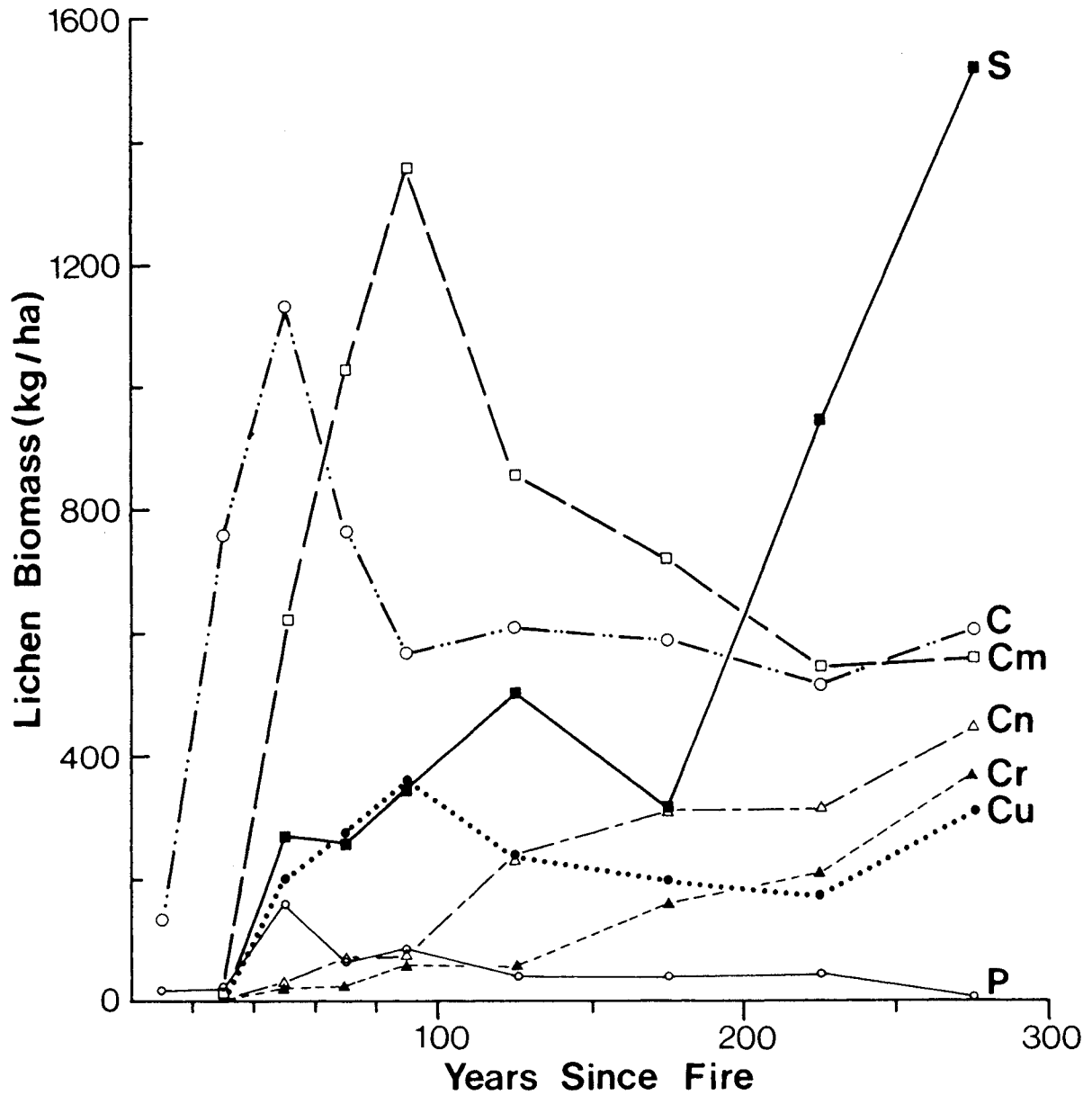


Figure 6. Biomass of *Stereocaulon* spp. (S), "other *Cladonia*" spp. (C), *Cladina mitis* (Cm), *Cetraria nivalis* (Cn), *Cladina rangiferina* (Cr), *Cladonia uncialis* (Cu), and *Peltigera* (P) spp. on upland sites at periods after fire on caribou winter range west of 107°30'W.

Figure 7

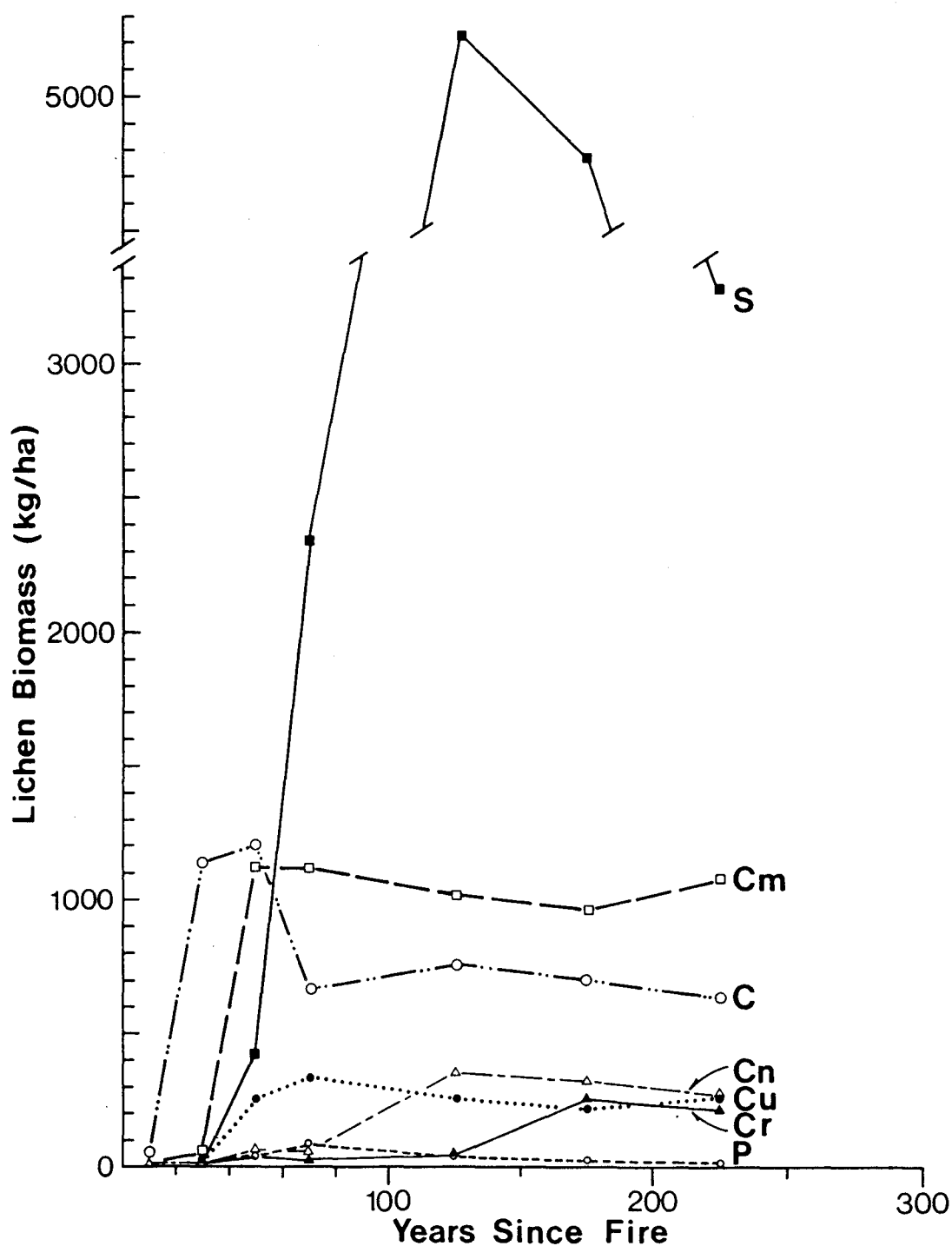


Figure 7. Biomass of *Stereocaulon* spp. (S), "other *Cladonia*" spp. (C), *Cladina mitis* (Cm), *Cetraria nivalis* (Cn), *Cladina rangiferina* (Cr), *Cladonia uncialis* (Cu), and *Peltigera* spp. (P) on upland sites at periods after fire on caribou winter range east of 107°30'W.

biomass after about 70 years (**Fig. 8**). Higher values for the 250-300 year class may not be reliable because they were based on only three sites (App. 3). High biomass of *Stereocaulon* spp. in eastern sites caused total lichens and weighted lichen biomass to peak after 100 years post fire. Biomass of caribou lichens remained about constant in sites older than about 50 years (**Fig. 9**).

Comparisons across burn lines

A major objective of this study was to compare lichen biomass across distinct burn lines (burn edges). In this way, age of stand and associated canopy changes were the primary difference and other factors were "controlled." In some cases there were no accessible burn lines because a fire stopped at a lake shore and comparisons were between sites on two islands or an island and the "mainland". The results (**App. 6**) were examined to compare lichen biomass of species, species groups, or genera between the two ages and within one age where replicates were obtained at slightly different locations.

The results reveal a large amount of variation within age classes. For example, site 16 was richer in lichens than adjacent site 20 of the same age. Many-fold differences in biomass of some species occurred between similar-aged sites 6 and 7, 8 and 9, 16 and 20, 28 and 43, 35 and 36, 47 and 55, and 58 and 60. This was also true of the same or similar-aged sites within the same general area. Examples were the 51 to 55, 71 to 74, 130 to 135, 160 to 165, and 210 to 220 year forests in the Nonacho Lake area, and the 31 to 36, 50 to 56, and 200 to 225 year stands in and around Selwyn Lake.

Some general trends did emerge however. The older-aged stand of paired

Figure 8

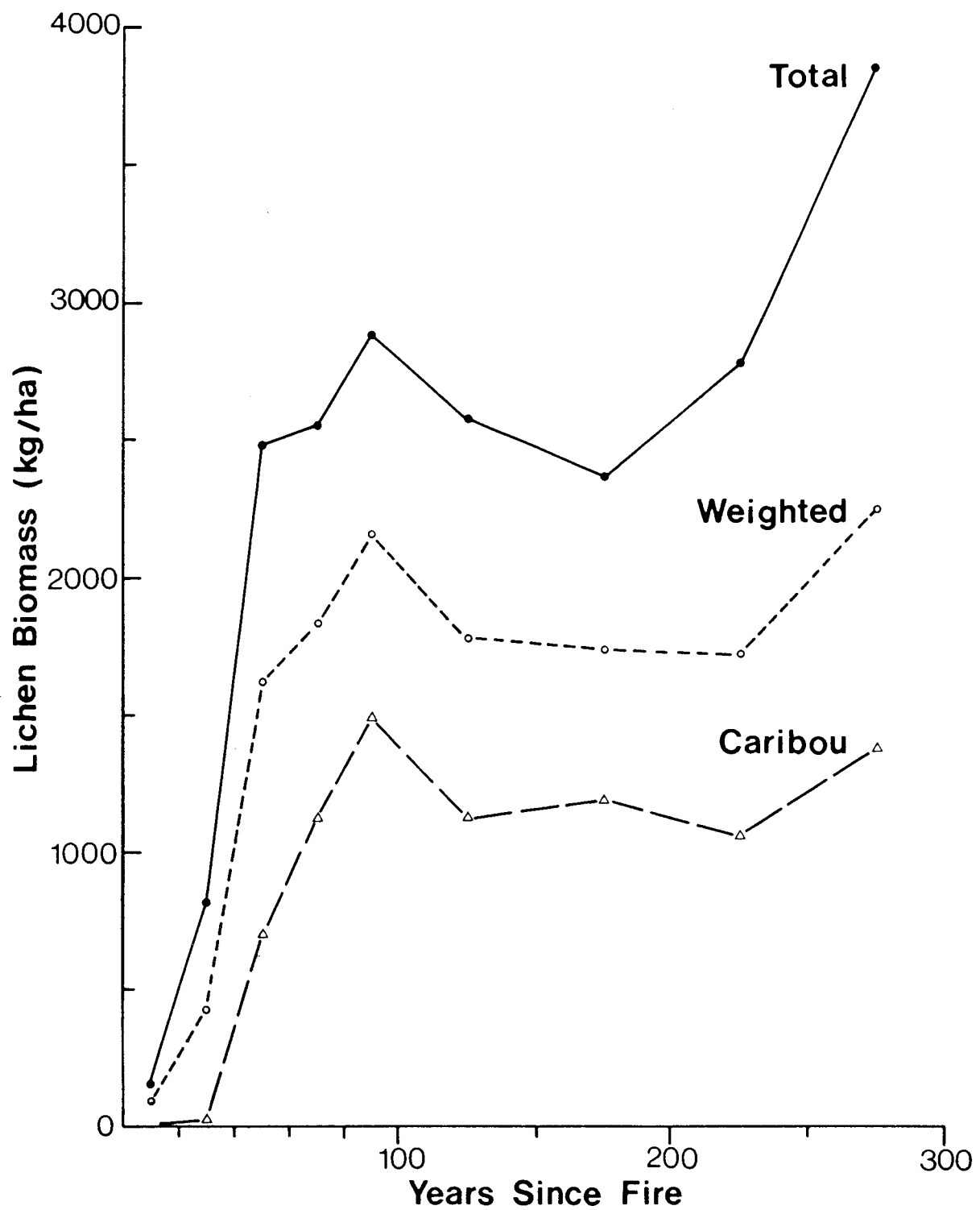


Figure 8. Biomass of all lichens (total), weighted lichens, and caribou lichens (Fig. 5) on upland sites at periods after fire on caribou winter range west of 107°30'W.

Figure 9

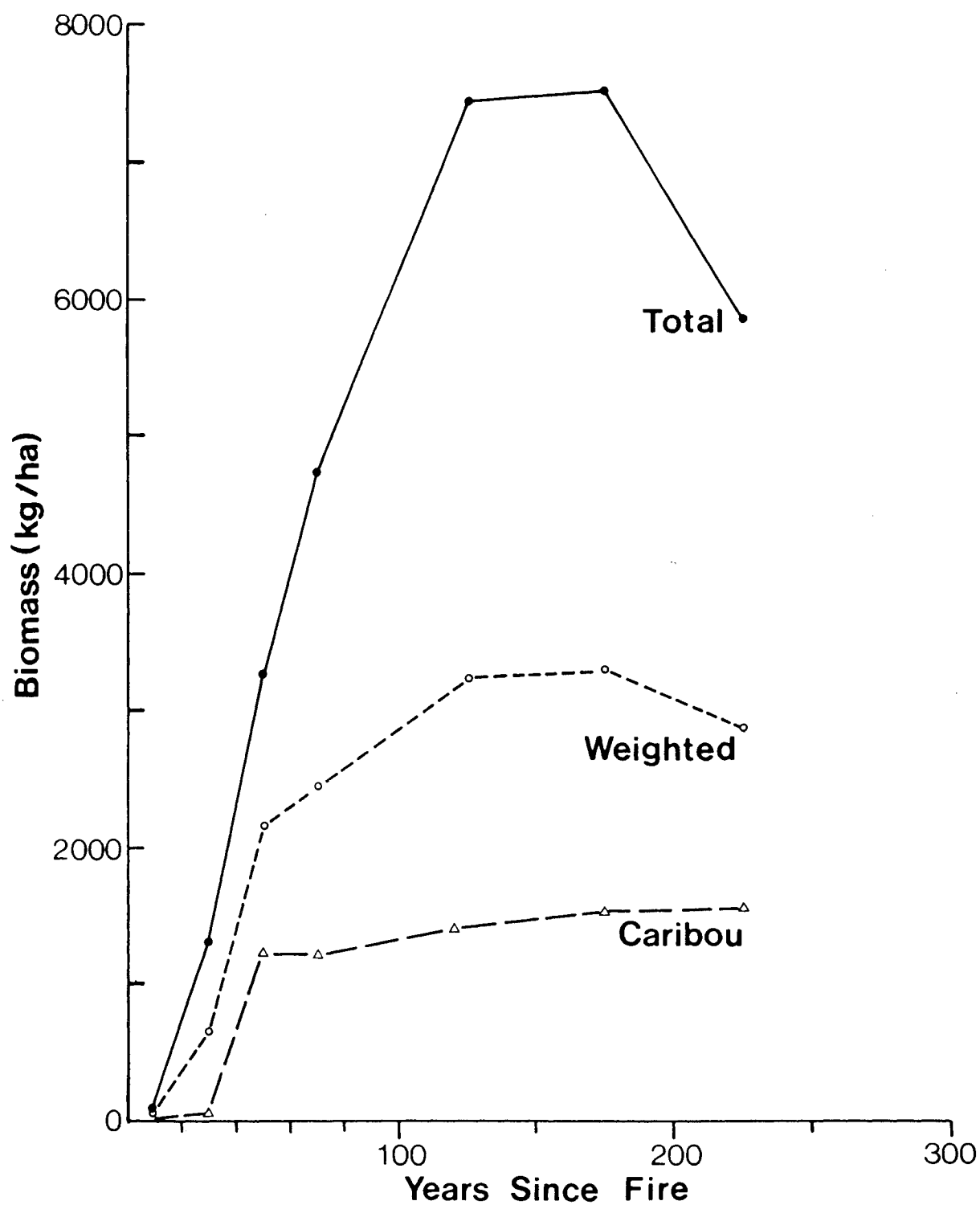


Figure 9. Biomass of all lichens (total), weighted lichens, and caribou lichens (Fig. 5) on upland sites at periods after fire on caribou winter range east of 107°30'W.

sites always had higher biomass of *C. mitis* up to age 50 years (sites 176 & 177); higher biomass of *C. rangiferina* up to age 51 years (sites 39 & 40); higher biomass of *Cet. nivalis* up to age 54 years (sites 188 & 189); and higher biomass of *Stereocaulon* spp. up to age 43 years (sites 126 & 127), exclusive of null or negligible values.

Biomass of total, weighted, and caribou lichens was higher in the older site than in the paired younger one up to age 41 years (sites 34 & 35), 55 years (sites 46 & 55) and 52 (sites 114 & 115) years, respectively. Site variability was such that either site could have higher lichen biomass values if the younger site was ≥ 60 years old.

Biomass of vascular plants

The ubiquitous (present everywhere) *Vaccinium vitis-idaea* was about equally abundant at all periods after fire except for a peak at 40-60 years post fire (**App. 7, Fig. 10**). Biomass of other *Vaccinium* spp. was also unrelated to time since fire. *Ledum* spp. were most abundant in class 1-20 years, moderately abundant in age classes 21-40, 41-60, and 61-80 years, and reduced in older classes except the last. The biomass of *Empetrum nigrum* and *Arctostaphylos* spp. were somewhat erratic with age, suggesting that other factors were more important. *Loiseularia* spp. was essentially absent from sites younger than 100 years (App. 7). Total low-shrub biomass was unrelated to age of stand except for one high value in age class 41-60 years. Grasses and sedges were rare in sites older than 20 years. They were much more abundant in lowland sites, along streams and lake shores and, by definition, in meadows.

Biomass of *Vaccinium* spp., *Ledum* spp., and *Empetrum nigrum* were higher in

Figure 10

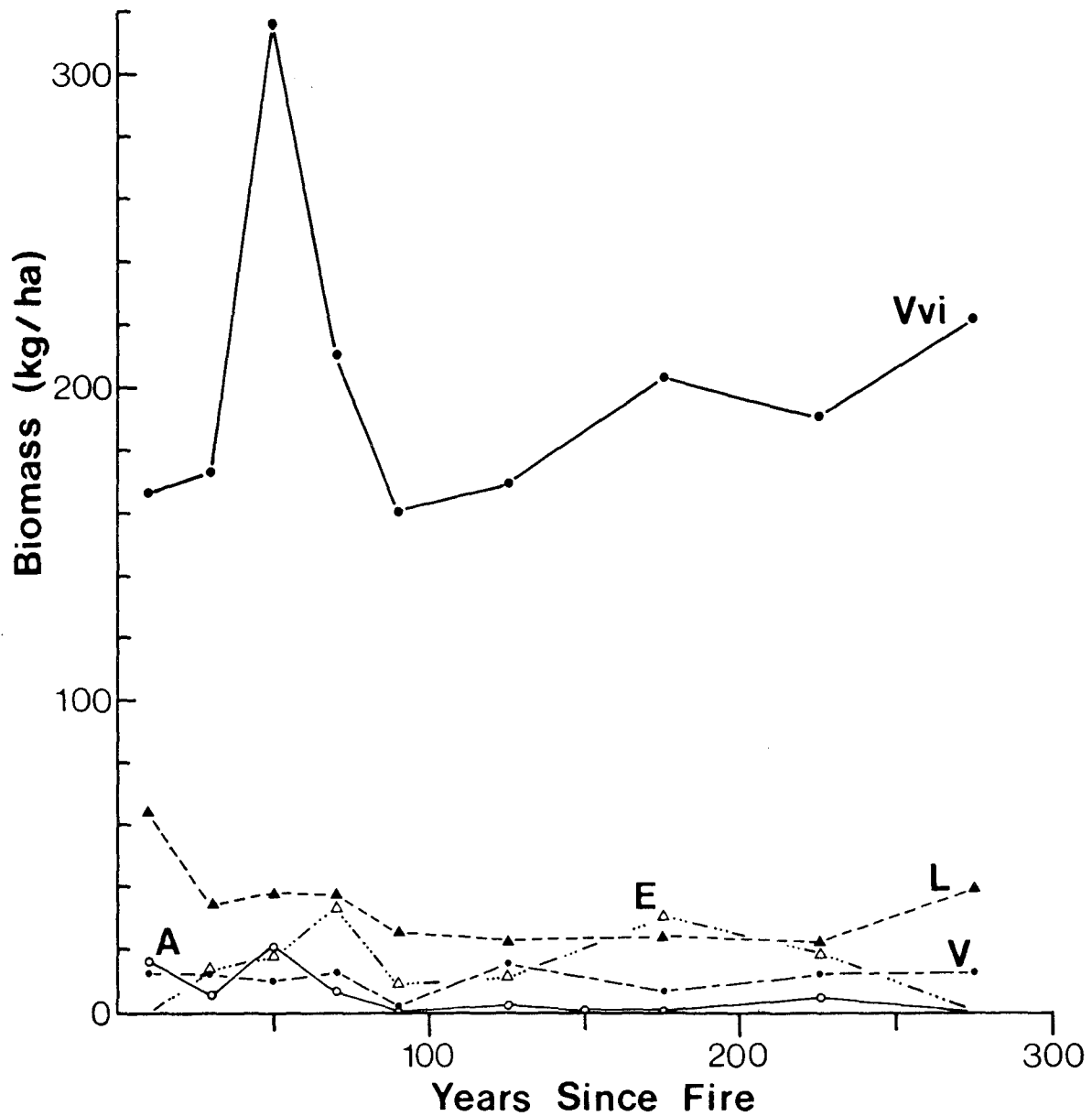


Figure 10. Biomass of leaves and current-year woody tissue of *Vaccinium vitis-idaea* (Vvi), "other *Vaccinium*" spp. (V), *Ledum* spp. (L), *Empetrum* sp. (E), and *Arctostaphylos* spp. (A) growing in forest openings at 197 sites at time periods after fire on winter range of the Beverly herd of caribou.

the east than in the west in six of seven age classes of forests (**App. 8 & 9**). There were no distinct trends in the biomass of *Vaccinium vitis-idaea* and *Arctostaphylos* spp. between the two general locations.

Cover

Visual estimates in quadrats

Total lichen cover based on visual estimates in each quadrat increased to 65% in class 61-80 years and then stabilized (**App. 10**). Cover of *Cladonia* spp. peaked at 18% in the 21-40 year class, whereas their biomass peaked in the 41-60 year class. Cover of *C. mitis* was highest at 36% in the 61-80 year class consistent with that of its biomass. Highest cover of *C. rangiferina* (7%) was in the oldest age class. Cover of *Cet. nivalis* was highest, at 10-13%, in forests >100 years post fire in keeping with a marked increase in biomass at that time. Cover of combined fruticose lichens (*C. mitis*, *C. rangiferina*, *Cet. islandica/arenaria*) was highest in classes 61-80 and 81-100 years. Addition of the accessible foliose lichen *Cet. nivalis* to those fruticose lichens produced biomass stability with age beginning with class 61-80 years.

Vaccinium vitis-idaea accounted for 7-12% cover in all age classes of forests (**App. 11**). It was evenly distributed and rarely absent from quadrats. Other low shrubs each accounted for a maximum of 3% (*Ledum* spp. in 251-300 year sites) cover. *Ledum* spp. comprised a uniform 1.0-1.8% of cover in age classes to 201-250 years. *Empetrum nigrum*, *Arctostaphylos* spp., and *Loiseularia* spp. never exceeded 1% cover in any age class (**App. 11**). *Ledum* spp. attained high cover values under branches of spruce and in lowlands where moisture always was available. In contrast, *Arctostaphylos* spp. prefers the driest of sites on southern exposures.

Cover of mosses in upland sites was highest in 1-20 and 21-40 year sites and then stabilized at about 3-6% in most age classes. Bare ground and rock declined in cover from 50% in the 1-20 year age class to a consistent 5-9% in age class 61-80 years and in older classes (App. 11).

Line transect data

Total lichen cover increased progressively through 20-year age classes to age class 101-120 years and then remained at about 74-80%, where sample size (number of sites) was ≥ 5 (App. 12). Lichen cover did not exceed 50% until the 61-80 year class (Fig. 11). We obtained no line transect data in 1983.

Relationship between cover and biomass

At the site level, biomass and cover of all species were closely related ($P < 0.05$) with correlation coefficients ranging from 0.64 to 0.95 (Table 2). The poorest fit was for *Cl. uncialis* because of misidentification problems. The second poorest correlation was for *Cet. islandica/arenaria*, species usually hidden by other species and sometimes overlooked in cover estimates. The relatively poor fit for *Geocaulon* sp. cannot be explained. The highest correlations were for mat-forming *Stereocaulon* spp. and species with large flat leaves (e.g., *Arctostaphylos* spp.) or flattened podetia (*Cet. nivalis*).

Scatter plots for *C. mitis* and *Stereocaulon* spp. (Fig. 12 & 13) indicate a straight-line fit. Cover for these mat-forming species is easier to estimate than that of a species that is scattered throughout a quadrat.

Figure 11

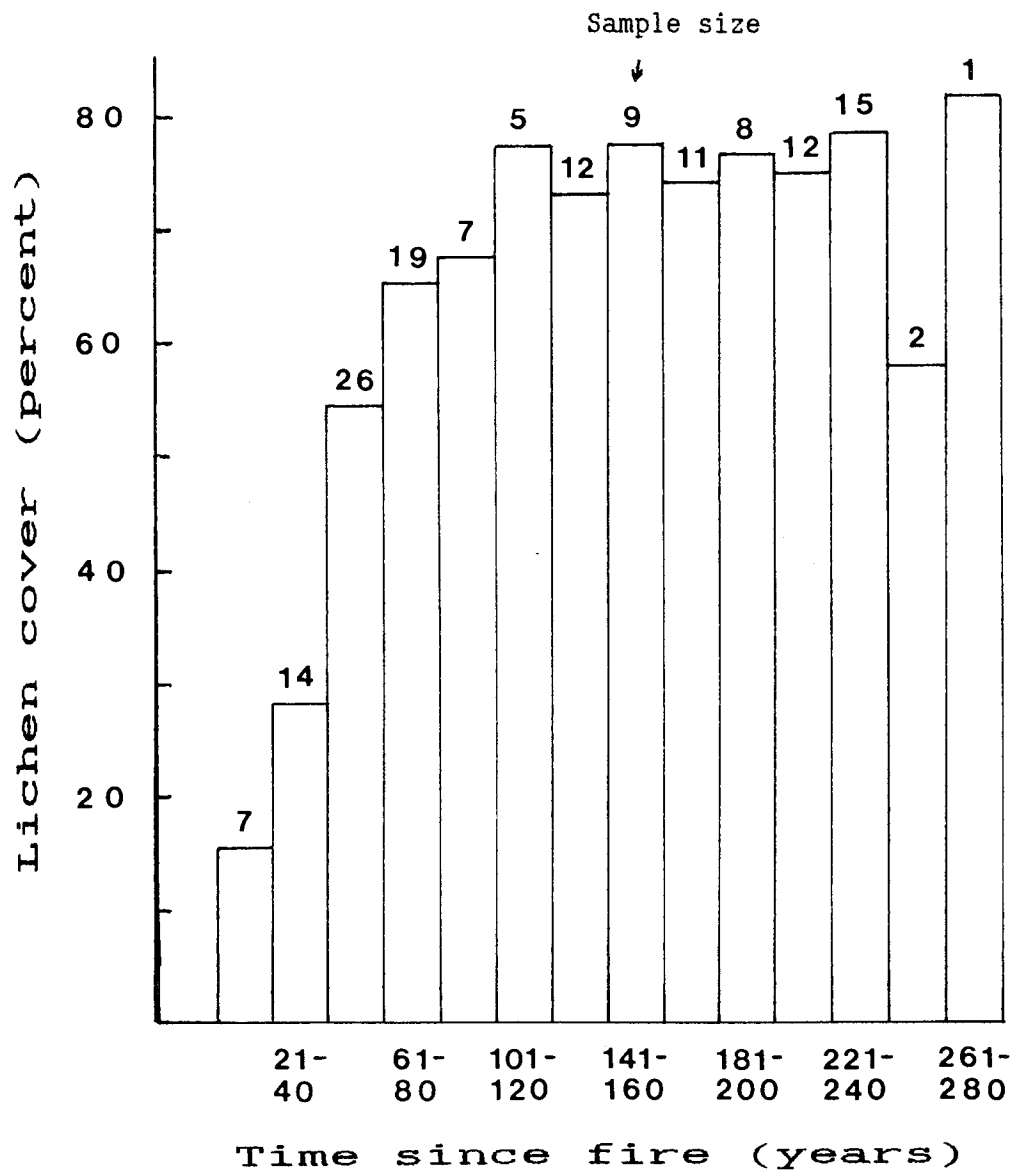


Figure 11. Percent cover of lichens in 20-year periods after fire at 148 sites on winter range of the Beverly herd of caribou.

Table 2. Correlation statistics for cover and biomass of lichens and vascular plants at 197 and 193 sites, respectively, on winter range of the Beverly herd of caribou.

Species or species group	Correlation statistics		
	Slope (<i>m</i>)	Y intercept (<i>b</i>)	<i>r</i>
<i>Cladina mitis</i>	36.5	-9.6	0.83
<i>Cladina rangiferina</i>	30.9	7.6	0.85
<i>Cetraria nivalis</i>	24.2	5.9	0.90
<i>Cetraria islandica/arenaria</i>	11.0	16.0	0.64
<i>Cladonia</i> spp.	43.0	239.1	0.69
<i>Peltigera</i> spp.	27.2	10.9	0.86
<i>Stereocaulon</i> spp.	109.0	-129.5	0.95
<i>Cl. uncialis</i>	25.6	121.3	0.55
<i>Vaccinium vitis-idaea</i>	25.9	-34.3	0.86
<i>Vaccinium</i> spp. (others)	10.1	1.5	0.89
<i>Ledum</i> spp.	22.1	-2.3	0.82
<i>Empetrum</i> spp.	27.4	1.7	0.85
<i>Arctostaphylos</i> spp.	42.4	0.9	0.90
<i>Loiseularia</i> spp.	44.1	0.5	0.88
Sedges/grasses	11.3	0.5	0.82
<i>Geocaulon</i> spp.	6.8	0.8	0.65

Note: Formula is $y = mx + b$, where y is biomass, m is slope, x is cover, and b is y intercept.

Frequency of occurrence of plants

Frequency of occurrence of plants in 2084 quadrats was tabulated at 50 year intervals post fire (App. 13 & 14). The data source was detectable biomass of species and therefore actual occurrence would be slightly higher. The lichens *C. mitis* and *Cladonia* spp. were virtually in every quadrat in forests older than 50 years.

Figure 12

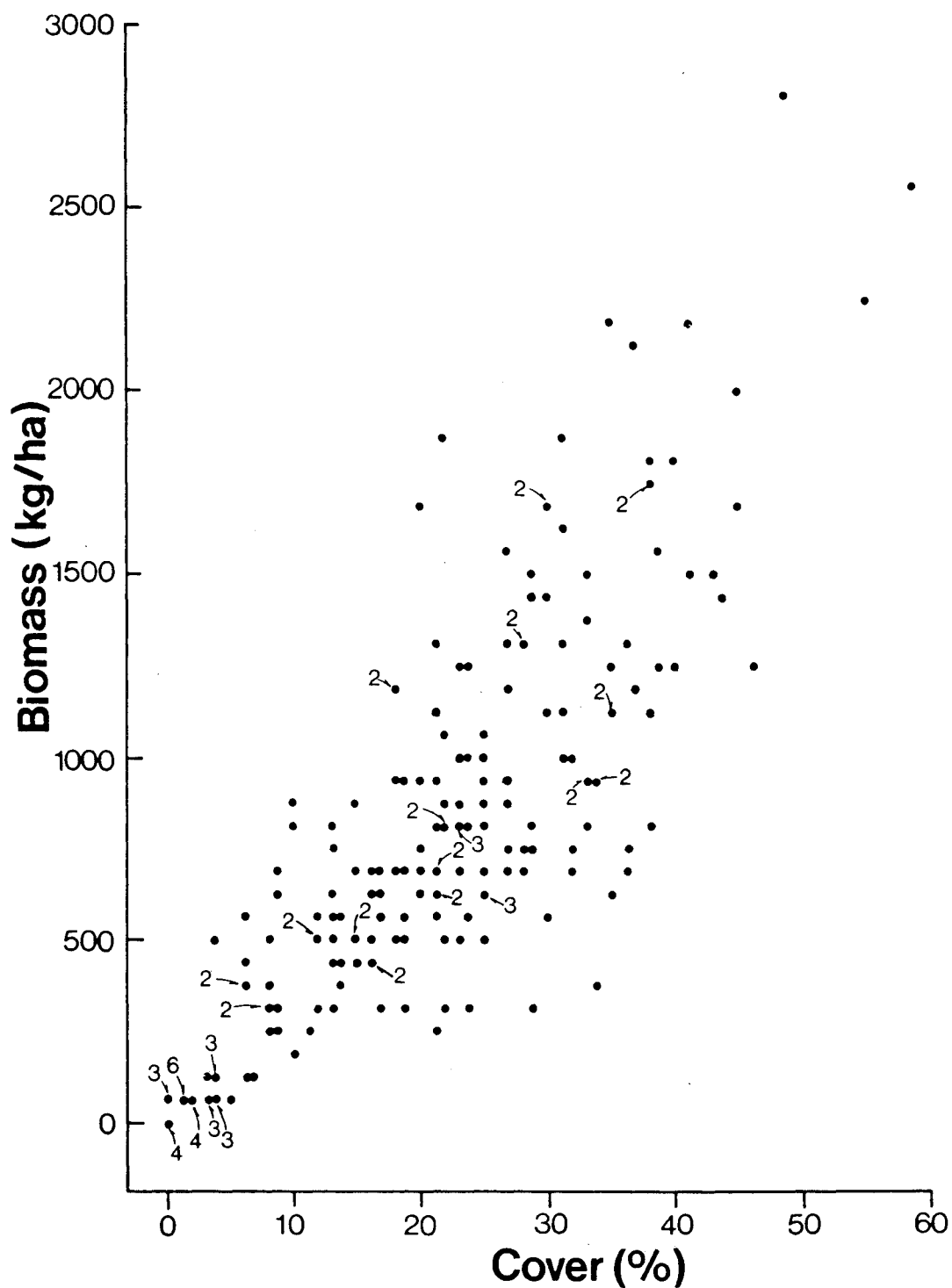


Figure 12. Relationship between cover and biomass of *Cladina mitis* at 197 sites on winter range of the Beverly herd of caribou. Numbers indicate more than one point at a location.

Figure 13

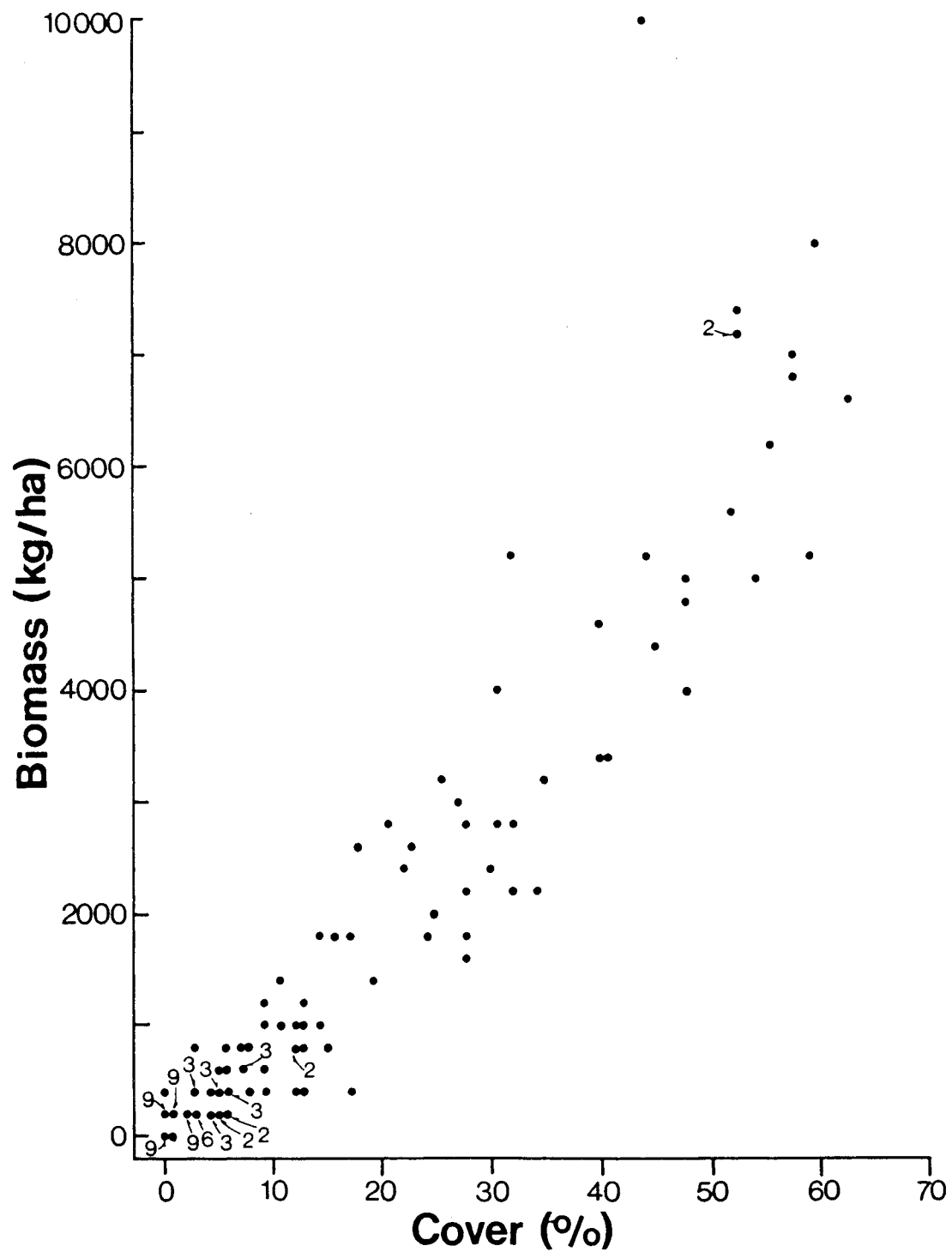


Figure 13. Relationship between cover and biomass of *Stereocaulon* spp. at 197 sites on winter range of the Beverly herd of caribou. Numbers indicate more than one point at a location.

Most quadrats in forests older than 50 years contained *C. mitis*, *Cl. uncialis*, *Cladonia* spp., and *Cetraria islandica/arenaria*. Those species plus *Cet. nivalis* occurred in almost all quadrats in sites over 100 years post fire. *C. rangiferina* was present in 77-87% of quadrats in forests older than 100 years. *Stereocaulon* spp. occurred in just over half the quadrats in forests older than 50 years. Frequency of *Peltigera* spp. decreased progressively as age interval increased.

Quadrats in eastern sites had higher frequencies of *Stereocaulon* spp. and, to a lesser extent, *C. rangiferina*. Comparisons within the 1-50 year class are not valid because of differences in age distributions. Most lichen species had recolonized sites at 30 years post fire (**Table 3**).

Cladonia mitis was present at 99% of sites (Table 3), exceptions being in forests 1, 3, 4, and 16 years post fire. Biomass of *C. rangiferina* was registered in 96% of sites, the nine exceptions were 1-24 years post fire except for one site 214 years post fire. *Cl. uncialis* was present at 97% of sites with all exceptions being <17 years post fire. *Cladonia* spp. were present in 99% of the sites, the exceptions being only 1, 3, and 4 years post fire. Biomass for *Cet. nivalis* was recorded at 94% of sites, the 10 exceptions all being under 30 years old. *Cet. islandica/arenaria* occurred in measurable quantities at 98% of sites, exceptions being 1, 3, 4, 14, and 44 years post fire. There was no appreciable east-west differences in these species but *Stereocaulon* spp. was present in 78% of western sites and 97% of eastern ones. The exceptions covered a range of all ages since fire, as was the case for *Peltigera* spp., which was present in 86% of all sites with no east-west differences.

Of low shrubs, only *Vaccinium vitis-idaea* frequently (82-94%) occurred in quadrats (**Table 4**, App. 14) with peak frequency in age-class 151-200 years. There were no differences among age classes -- only a reduced occurrence in the

Table 3. Frequencies of lichen species in quadrats and sites sampled west and east of 107°30'W on winter range of the Beverly herd of caribou.

Location --> Years post fire -->		Frequency of occurrence (%)								
		West			East			All		
		0-30	>30	All	0-30	>30	All	0-30	>30	All
Quadrats	<i>n</i> ¹ -->	237	1208	1445	45	594	639	282	1802	2084
<i>Cladina mitis</i>		51.9	100.0	91.8	53.3	99.7	96.4	52.1	99.8	93.4
<i>C. rangiferina</i>		8.4	70.3	59.0	6.7	79.6	74.5	8.2	73.4	64.5
<i>Cetraria nivalis</i>		10.5	82.2	69.6	4.4	71.7	67.0	9.6	78.7	69.4
<i>Cet. islandica</i>		25.3	87.3	76.5	31.1	84.2	80.4	26.2	86.3	78.2
<i>Cladonia uncialis</i>		23.2	95.4	83.1	20.0	91.6	86.5	22.7	94.1	84.5
<i>Cladonia</i> spp.		65.8	99.4	93.7	75.6	99.7	98.0	67.4	99.5	95.2
<i>Stereocaulon</i> spp.		7.6	48.2	39.9	11.1	73.1	68.8	8.2	56.4	49.9
<i>Peltigera</i> spp.		15.6	37.3	31.9	20.0	26.9	26.4	16.3	33.9	31.5
Sites	<i>n</i> ¹ -->	18	121	139	2	56	58	20	177	197
<i>C. mitis</i>		83.3	100.0	97.8	100.0	100.0	100.0	85.0	100.0	98.5
<i>C. rangiferina</i>		50.0	100.0	93.5	50.0	100.0	98.3	50.0	100.0	94.9
<i>Cet. nivalis</i>		61.1	100.0	95.0	0.0	96.4	93.1	55.0	98.9	94.4
<i>Cet. islandica</i>		77.8	100.0	97.1	50.0	100.0	98.3	75.0	100.0	97.5
<i>Cl. uncialis</i>		72.2	100.0	96.4	50.0	100.0	98.3	70.0	100.0	97.0
<i>Cladonia</i> spp.		83.4	100.0	97.8	100.0	100.0	100.0	85.0	100.0	98.5
<i>Stereocaulon</i> spp.		50.0	82.6	78.4	50.0	98.2	96.6	50.0	87.6	93.8
<i>Peltigera</i> spp.		44.4	81.8	77.0	50.0	76.8	75.9	45.0	80.2	76.6

¹ Sample size.

Table 4. Frequency of common vascular plant species in quadrats and sites sampled west and east of 107°30'W on winter range of the Beverly herd of caribou.

Location --> Years post fire -->		Frequency of occurrence (%)								
		West			East			All		
		0-30	>30	All	0-30	>30	All	0-30	>30	All
Quadrats	<i>n</i> ¹ -->	237	1208	1445	45	594	639	282	1802	2084
<i>Vac.vitis-idaea</i>		78.9	88.7	87.1	84.4	96.1	53.1	79.8	91.2	89.6
<i>Vaccinium</i> spp.		4.6	10.9	9.9	22.2	20.0	20.2	7.4	14.0	13.1
<i>Ledum</i> spp.		22.8	22.5	22.5	22.2	39.1	37.9	22.7	28.1	27.3
<i>Empetrum</i> spp.		0.4	5.0	4.3	0.0	6.5	15.3	0.4	8.9	7.7
<i>Arctostaphylos</i>		2.1	2.7	2.6	8.9	1.9	2.3	3.2	2.4	2.5
<i>Loiseularia</i> spp.		0.8	1.7	1.6	0.0	2.4	2.2	0.7	1.9	1.8
Grasses/sedges		15.6	2.1	4.3	22.2	3.2	4.5	16.7	2.4	4.4
<i>Geocaulon</i> sp.		3.4	10.2	9.0	0.0	6.7	6.3	2.8	9.0	8.2
Sites	<i>n</i> ¹ -->	18	117	135	2	56	58	20	173	193
<i>Vac.vitis-idaea</i>		100.0	99.1	99.3	100.0	100.0	100.0	100.0	99.4	99.5
<i>Vaccinium</i> spp.		33.3	36.8	36.3	100.0	69.6	70.7	40.0	47.4	46.6
<i>Ledum</i> spp.		87.8	80.3	80.0	50.0	82.1	81.0	75.0	80.9	80.3
<i>Empetrum</i> spp.		5.6	25.6	23.0	0.0	67.9	65.5	5.0	39.3	35.8
<i>Arctostaphylos</i>		22.2	12.0	13.3	50.0	10.7	12.1	25.0	11.6	13.0
<i>Loiseularia</i> spp.		5.6	5.1	5.2	0.0	10.7	10.3	5.0	6.9	6.7
Grasses/sedges		55.6	17.1	22.2	100.0	17.9	20.7	60.0	17.3	21.8
<i>Geocaulon</i> sp.		27.8	50.4	47.4	0.0	41.1	39.7	25.0	47.4	45.1

¹ Sample size.

1-50 year class because of its scarcity in sites 1-6 years post fire. "Other *Vaccinium*" spp. (*uliginosum* and *myrtilloides*) were most frequent in year class 101-150; slightly more abundant *Ledum* spp. in age class 51-100 years. Other species were not common in quadrats. The only other common plants in quadrats were *Empetrum nigrum* and *Geocaulon* sp. The two *Vaccinium* groups, *Ledum* spp., and *Empetrum* sp. occurred more frequently in the east than in the west.

Vaccinium vitis-idaea was universal in sites, followed by *Ledum* spp., other *Vaccinium* spp., *Geocaulon* spp., and *Empetrum* sp. "Other *Vaccinium*" spp. and *Empetrum nigrum* were more abundant in the east than in the west (Table 4).

Lichen thickness

Lichen thickness increased gradually and unevenly to highest values in age classes 201-220 years and 221-240 years (**Table 5**). Those high values reflected prevalence of thick mats of *Stereocaulon paschale* in some old sites. Differences were marginal after the first age class. An average measurement was difficult to obtain in each quadrat because of wide variation. Height varied with degree of hydration and therefore those data have considerable sampling error within and among individual observers. Those data should be viewed as only a crude index.

In old sites, height of *C. mitis* and other *caribou lichens* decreased and sampling for biomass became laborious. Lichen thickness should be specific to each major species. Pooled data for all species are of questionable value and may lead to faulty conclusions about the relationship between thickness and time after fire. Average or maximum lichen thickness is a subjective measurement of questionable value.

Table 5. Lichen thickness in 20-year age classes after fire at 152 sites on winter range of the Beverly herd of caribou.

Age class (years)	Lichen depth (mm)			
	Mean	Standard deviation	Standard error	Sample size
0 - 20	22.3	22.82	10.2	6
21 - 40	26.1	16.85	4.5	15
41 - 60	29.7	22.23	4.5	25
61 - 80	23.5	18.67	4.2	21
81 - 100	34.0	17.02	6.4	8
101 - 120	7.4	1.02	0.5	5
121 - 140	36.0	19.13	3.2	11
141 - 160	31.3	17.96	8.0	6
161 - 180	35.5	31.40	9.1	13
181 - 200	29.2	20.94	7.5	9
201 - 220	40.4	28.12	8.1	13
221 - 240	43.8	28.75	7.4	16
241 - 260	4.5	1.50	1.5	2
261 - 280	8.0	0.00	0.0	2

Arboreal lichens

Arboreal lichens were rated as absent in sites 1-20 years, rare in sites 21-40 year, sparse in sites 41-60 years, and light in sites 60-80 years (**Table 6**). The means of our subjective ratings were about constant in sites older than 80 years post fire.

Major species were *Alectoria americana* (formerly *A. jubata*, a black beard lichen), *Evernia mesomorpha*, and *Usnea hirta*.

Table 6. Average ordinal rating of arboreal lichen abundance in forests in 13 age classes at 176 sites on winter range of the Beverly herd of caribou.

Age class (years)	Arboreal lichen abundance ¹	
	Sample size	Mean
1 - 20	12	0.0
21 - 40	13	0.1
41 - 60	30	1.2
61 - 80	24	2.0
81 - 100	6	2.8
101 - 120	6	2.2
121 - 140	15	2.5
141 - 160	12	2.3
161 - 180	17	2.6
181 - 200	8	2.6
201 - 220	15	3.0
221 - 240	15	2.7
241 - 260	3	2.7

¹ Ordinal scale: 0 = nil; 1 = sparse; 2 = light; 3 = moderate; and 4 = abundant.

Indices of past use of sites by herbivores.

Sites in the east and west were treated separately because of obvious differences in past use by caribou (**Fig. 14**). Peak use by caribou was in sites 151-200 and 201-250 years post fire in the Nonacho-Porter area and at Selwyn Lake. A grouping of all western sites indicated the third highest use was of sites 61-80 years (**Table 7**). There was relatively high use of age class 41-60 years in the east. Lower pellet group densities in the oldest sites in the west may be an artifact of sampling only

Figure 14

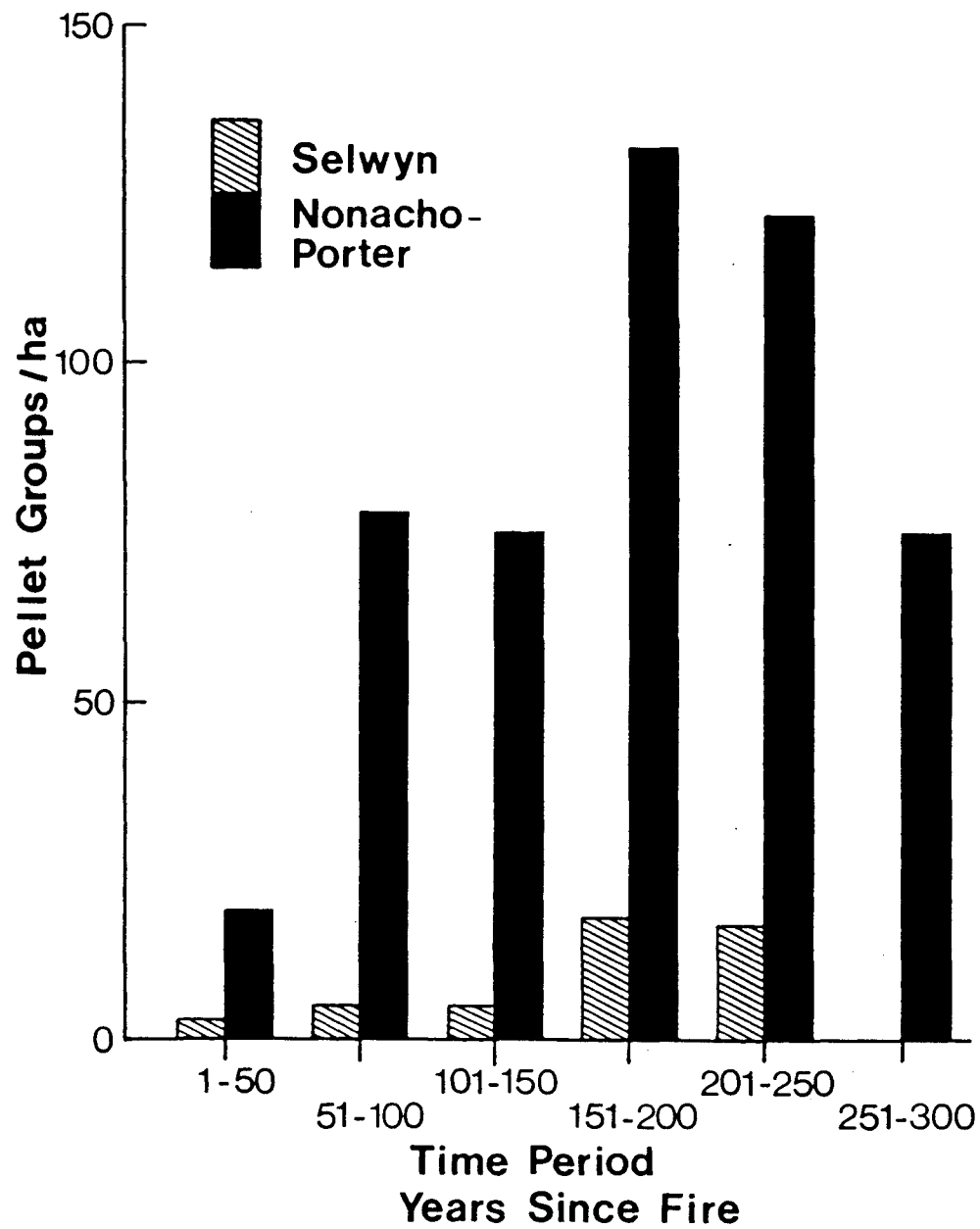


Figure 14. Densities of caribou pellet groups at 50-year periods after fire in upland sites at two locations on winter range of the Beverly herd.

Table 7. Mean pellet-group densities of herbivores in age classes of forests sampled west and east of 107°30'W on winter range of the Beverly herd of caribou.

Age class (yr) (nW, nE) ¹	Herbivore pellet-group densities (groups/ha)							
	Caribou		Moose		Hare		Ptarmigan ²	
	West	East	West	East	West	East	West	East
1 - 20 (10, 2)	25 (20) ³		40 (14)	50 (25)	5 (3)	13 (13)	33 (22)	75 (50)
21 - 40 (8, 8)	3 (3)	6 (6)	213 (72)	150 (46)	9 (9)	16 (9)	53 (23)	22 (9)
41 - 60 (23, 11)	21 (8)	9 (4)	50 (10)	23 (8)	64 (35)	34 (22)	162 (41)	48 (27)
61 - 80 (18, 9)	107 (48)	3 (3)	42 (11)	6 (4)	14 (8)	6 (4)	140 (36)	33 (13)
81 - 100 (9, 0)	64 (38)		36 (10)		28 (13)		253 (99)	
101 - 150 (23, 4)	63 (16)	6 (6)	9 (3)	25 (18)	12 (5)	75 (75)	61 (18)	50 (23)
151 - 200 (26, 11)	127 (30)	16 (8)	18 (5)	11 (7)	5 (2)	14 (14)	73 (19)	39 (14)
201 - 250 (19, 13)	111 (32)	21 (11)	25 (7)	12 (5)	11 (5)	6 (3)	32 (15)	17 (7)
251 - 300 (3, 0)	75 (38)		17 (17)		8 (8)			
1 - 50 (25, 13)	15 (9)	6 (4)	102 (28)	102 (33)	50 (33)	33 (16)	69 (18)	40 (13)
51 - 100 (43, 17)	67 (22)	6 (3)	41 (7)	16 (6)	20 (4)	9 (6)	176 (33)	37 (15)

¹ Sample sizes in the west and east.

² Ptarmigan and grouse.

³ Standard error.

three such sites. In the east, highest density was in the oldest age class.

Caribou pellet-group densities were high in sites around Porter and Nonacho lakes compared with three other areas (**App. 15**). At the Nonacho Lake sites, high densities occurred from 151 to 300 years post fire. High densities occurred in stands aged 51-100, 101-150, and 151-200 years post fire at Porter Lake.

Highest densities of moose pellets were in the 21-40 year class in both regions (Table 7). In the west, use of 1-20 year sites was about equal to that in age classes 41-60, 61-80, and 81-100 years (**Fig. 15**).

Densities of moose pellet groups did not vary appreciably among the five locations that were intensively sampled (**App. 16**). High variability among age classes within a location tended to obscure any regional differences in moose pellet densities. Moose pellet-group densities were higher than those of caribou in forests up to age 60 years post fire (west) and 80 years post fire (east). Moose pellets were also much easier to detect than those of caribou and they may persist for slightly longer periods.

Microhistological analysis of winter-type moose pellet groups obtained at 23 sites across winter range of the Beverly herd of caribou indicated that *Betula* spp. dominated the diet, along with small amounts of *Salix* spp., and *Pinus* spp. Diet of moose and their use of forests of various ages after fire is the topic of a separate paper (Thomas 1990). In terms of caribou management, a consideration is extent, if any, of competition between moose and caribou for forages. Other considerations are predator-prey relationships and potential interchange of parasites.

Densities of hare pellets were highest in age class 41-60 years in the west and in class 101-150 years in the east. Sites 1-50 years old contained higher densities than those 51-100 years post fire (Table 7). Pellets were more difficult to detect in 1-50

Figure 15

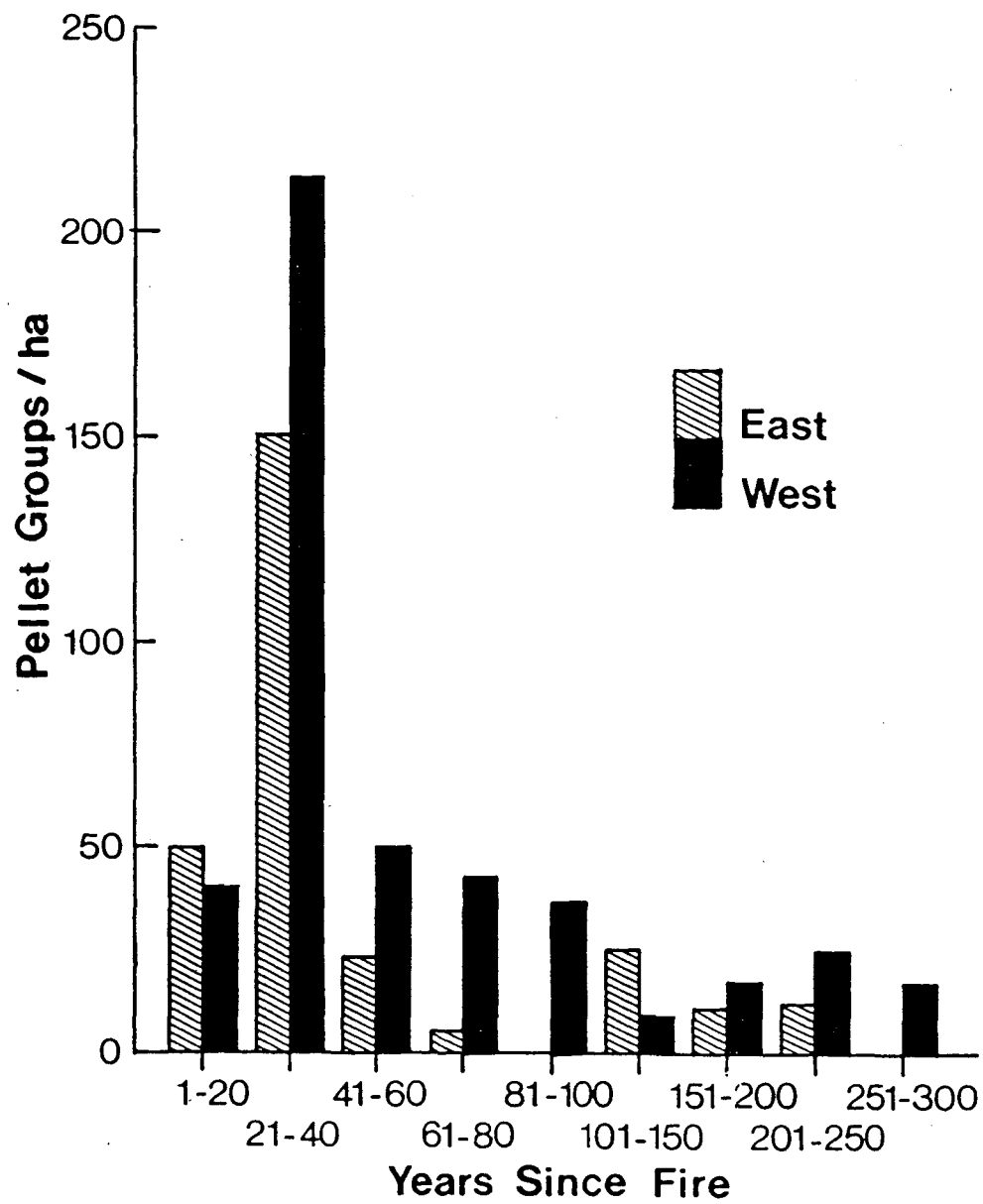


Figure 15. Densities of moose pellet groups in upland sites west and east of 107°30'W at periods after fire.

year sites because of abundant leaves on the ground from shrubs and birch. The ca. 10-year hare cycle was at a low ebb from 1983 through 1986, with the previous peak in numbers in 1980 or 1981.

Hare pellet groups were scarce around Porter Lake (**App. 17**) possibly because of little trapping in that area and, consequently, marten and foxes were numerous.

Ptarmigan/grouse fecal pellets were most dense in forests aged 81-100 years (west) and 1-20 years (east) (Table 7). In the west, densities were high in age classes 41-60, 61-80, and 81-100 years. There was no age effect in the east but numbers of sites were small in most age classes. Ptarmigan/grouse pellets were most abundant around Thekulthili Lake and scarce around Beauvais Lake (**App. 18**).

Survival of caribou pellets

At Nonacho Lake, pellets deposited in late November and early December, 1982, and marked and photographed vertically in July 1983, were examined in July 1985 and August 1987. Pellets in a mesic (vs. hydric or xeric) site were only about 50% detectable in 1985, *i.e.*, half the groups would have been missed in our pellet transects. By 1987 they had disappeared. All pellet groups in a xeric site were clearly visible in 1985 but detectability was estimated at only about 50% in August 1987. Three of seven pellet groups were not visible except with close inspection and the other four were barely visible.

Pellet groups deposited at Porter Lake in March 1984, marked and photographed in August 1984, and examined in July 1985 and August 1987, deteriorated slightly faster on xeric sites than at Nonacho Lake. Only 3 of 10 groups were barely detectable at 2 years and 5 months after deposition. They were located mostly on

Stereocaulon spp., which dries faster during a warm day than some other terrestrial lichen species (Alexander et al. 1989).

In summary, the 50% detectability level was reached after nearly two summers in a mesic site and in 3.5-4.5 years in a xeric site. Minimum and maximum survivability of pellets ranged from 2-3 years in mesic sites (feather moss dominated) and 3-5 years on xeric sites (lichen dominated).

The canopy

Tree species

West of about 107°30'W in the NWT, jack pine dominated upland sites after fire and black spruce dominated lowland wet sites. Pine continued to dominate upland sites to 151-200 years post fire at dry, rocky, and sandy sites. Even where pine dominated the canopy, a count of trees usually revealed a greater number of spruce. Most spruce were relatively small compared with pine and so pine comprises most of the canopy and appears to dominate a site.

East of about 107°30'W in the NWT, spruce is the only conifer that regenerates after fire except on the most-favorable southern exposures where pine may occur. Black spruce is by far the most common spruce. White spruce occurs throughout the forested region in favorable locations characterized by sandy or gravelly alluvial soil. It is the dominant tree species on stream and river benches. For example, white spruce is abundant in the Snowdrift River Valley and at river deltas, *i.e.*, where flat, thick alluvial deposits occur. Some of the tallest and largest-diameter trees occur near or at tree line in association with eskers. For example, trees 16-18 m tall were measured east of Tent Lake and at Brooks Lake, both at the limit of trees. Eskers provided protection from north winds at both locations. Such areas have not

burned in the last 200-300 years or longer.

Paper birch (*Betula papyrifera*) was a common tree throughout the study area. It returns quickly after fire by suckering from live roots. It is the chief food of moose throughout the area with the exception of the Slave River Lowlands where willows (*Salix* spp.) are abundant. Aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*) were abundant in a strip along the outer edge of the Slave River Lowlands and on southern and western slopes along the edge of the Taiga Shield. A few small balsam poplar were found on a gravel beach at Porter Lake and they occur elsewhere near the lake (T. Trottier pers. commun.).

Larch or tamarack (*Larix laricina*) is present throughout the range and is common in eastern parts of caribou winter range near the limit of trees. Normally a small tree in bogs to the west, trees reach 12 m and DBHs of 20 cm near tree line in the Wholdaia Lake region. Alder (*Alnus crispa*) occurs in wet areas throughout forested winter range.

Growth forms

Maximum heights and diameters at breast height (DBH) of black spruce and jack pine at sites did not increase uniformly with age because of region and site differences (**Table 8**). For example, spruce 41-60 years old were taller, on average, than spruce 61-80 years old. Initial growth of jack pine was more rapid than spruce but maximum spruce heights equaled those of pine by age class 41-60 years. At face value, tree heights are deceptive. In mixed conifer forests up to 100 years post fire, pine on average were considerably taller than spruce. Pine are of more uniform height whereas spruce vary greatly in height. Most pine begin to grow within 3 years of a fire whereas spruce are of all ages. Therefore a few spruce at a location are almost

Table 8. Average maximum tree heights and diameters at breast height (DBH) in 20-year periods after fire at 168 upland sites on winter range of the Beverly herd of caribou.

Age class (yr)	No. of sites	Height (m) and DBH (cm) maximums at site											
		Spruce height (m)			Spruce DBH (cm)			Pine height (m)			Pine DBH (cm)		
		Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
1- 20	2	1.5	0.5	2	2.0	2.0	2	3.3	0.5	4	5.8	0.8	4
21- 40	16	4.4	0.4	15	6.1	0.7	15	6.4	0.9	5	9.0	1.6	5
41- 60	29	8.4	2.0	27	8.7	0.6	27	7.3	0.4	16	9.8	0.7	17
61- 80	25	7.1	0.3	24	10.7	0.8	24	8.0	0.5	15	15.4	2.0	14
81-100	7	9.3	0.3	7	12.9	1.6	7	10.2	1.0	5	13.8	1.2	5
101-120	7	9.7	1.3	7	12.9	1.0	7	9.4	0.8	5	13.5	0.6	4
121-140	16	9.5	0.4	15	14.8	0.8	15	8.4	1.7	9	14.3	2.6	8
141-160	9	11.3	0.3	10	17.1	1.2	10	9.3	0.9	8	15.1	2.0	7
161-180	17	9.7	0.4	17	15.3	1.0	17	10.6	0.7	5	18.0	1.1	5
181-200	8	10.8	1.5	8	14.8	1.1	8	13.3	1.8	3	20.3	2.3	3
201-220	15	10.7	0.7	13	15.5	0.7	13	8.0		1	24.0		1
221-240	15	10.1	0.9	13	14.8	0.7	13	8.0	0.6	3	20.0	2.9	3
241-260	1	8.0	0.0	2	14.5	0.5	2						
261-280	1	9.0		1	12.0		1						

as tall as pine in forests younger than 100 years. The general impression of such forests, in particular to age 80 years, is that pine are much taller than spruce. Pine maximum DBHs were greater than spruce maximum DBHs in most age classes. Most large trees that we measured were located outside but near the 10 m x 10 m plots used for canopy descriptions.

Plots of height of pine and black spruce with age using plot and range-wide data (Fig. 16 & 17) indicated near-linear growth with age to 100 years and then cessation of growth. The average growth of pine was of polynomial form

$H = 9.032 - 8.910e^{-0.02705x}$ where H is height in meters and x is age in years. The corresponding relationship for black spruce was $H = 8.695 - 10.405e^{-0.02347x}$.

DBH, measured in plots only, also increased in a near-linear form with age to about 100 years in pine and 101-120 years in black spruce (Fig. 18 & 19). The respective average growth forms were $DBH = 19.0 - 15.123e^{-0.008902x}$ (pine) and $DBH = 13.0 - 17.951e^{-0.02332x}$ (spruce) with DBH in centimeters. Growth of pine, as indicated by width of summer wood, decreased sharply at 40 - 60 years post fire. Summer annuli widths in spruce increased to 101-200 years then decreased.

The growth form of white spruce was not obtained because only tall trees were measured. Four trees 120-185 years old were 16.4-18.0 m in height.

Tree densities

The average number of trees in 5-cm DBH size classes of pine and spruce in 20-year age classes of forests (Table 9) per unit area provides an index to temporal changes in forest structure and the canopy. Densities of spruce per 100 m² (0.01 ha) were similar in age classes 21-40 through 201-240 years at 17-38 trees, with the exception of one high value (52). Numbers declined to 11 and 12 trees in the two oldest age

Figure 16

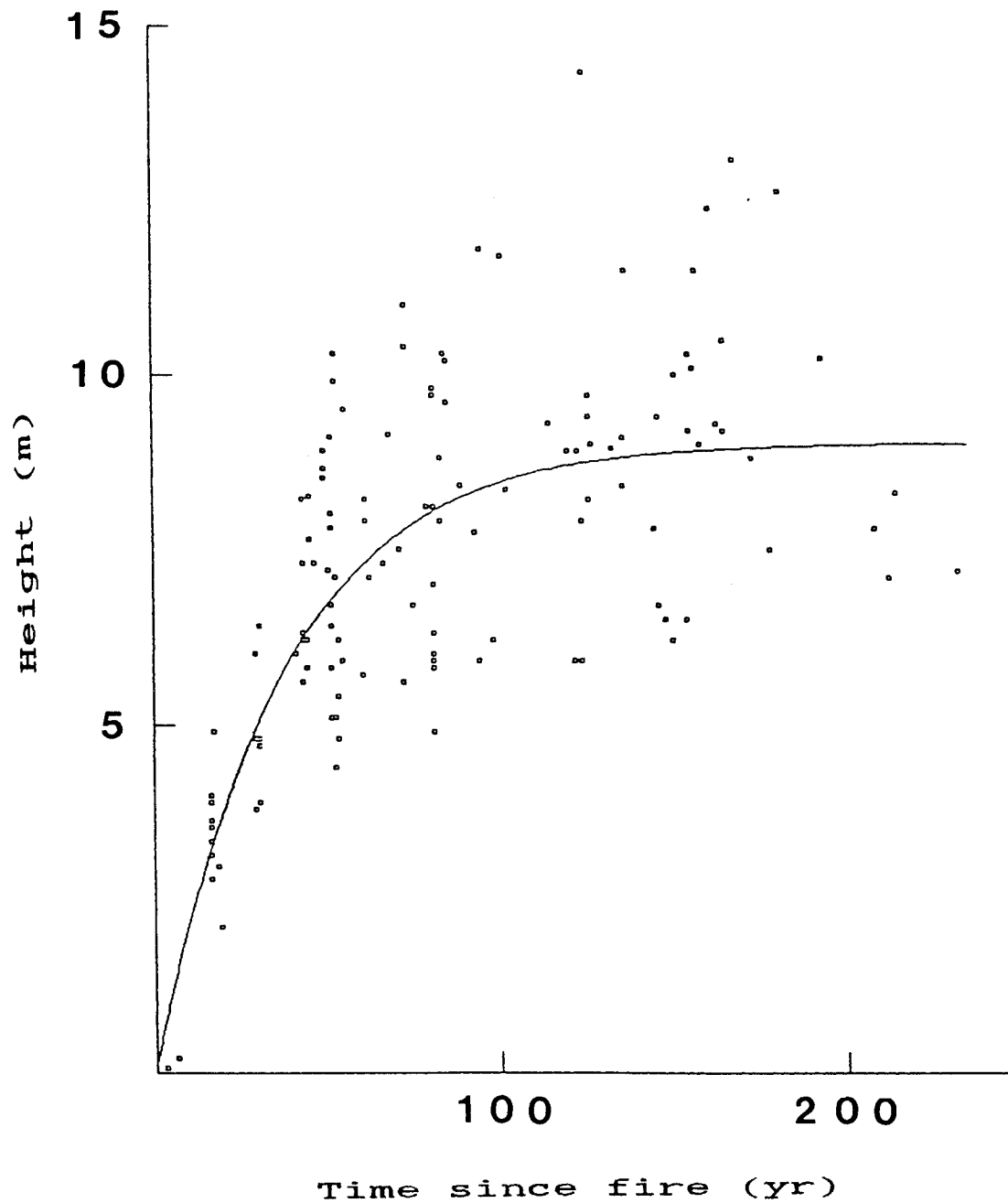


Figure 16. Relationship between maximum height of pine and time since fire at 196 upland sites on winter range of the Beverly herd of caribou.

Figure 17

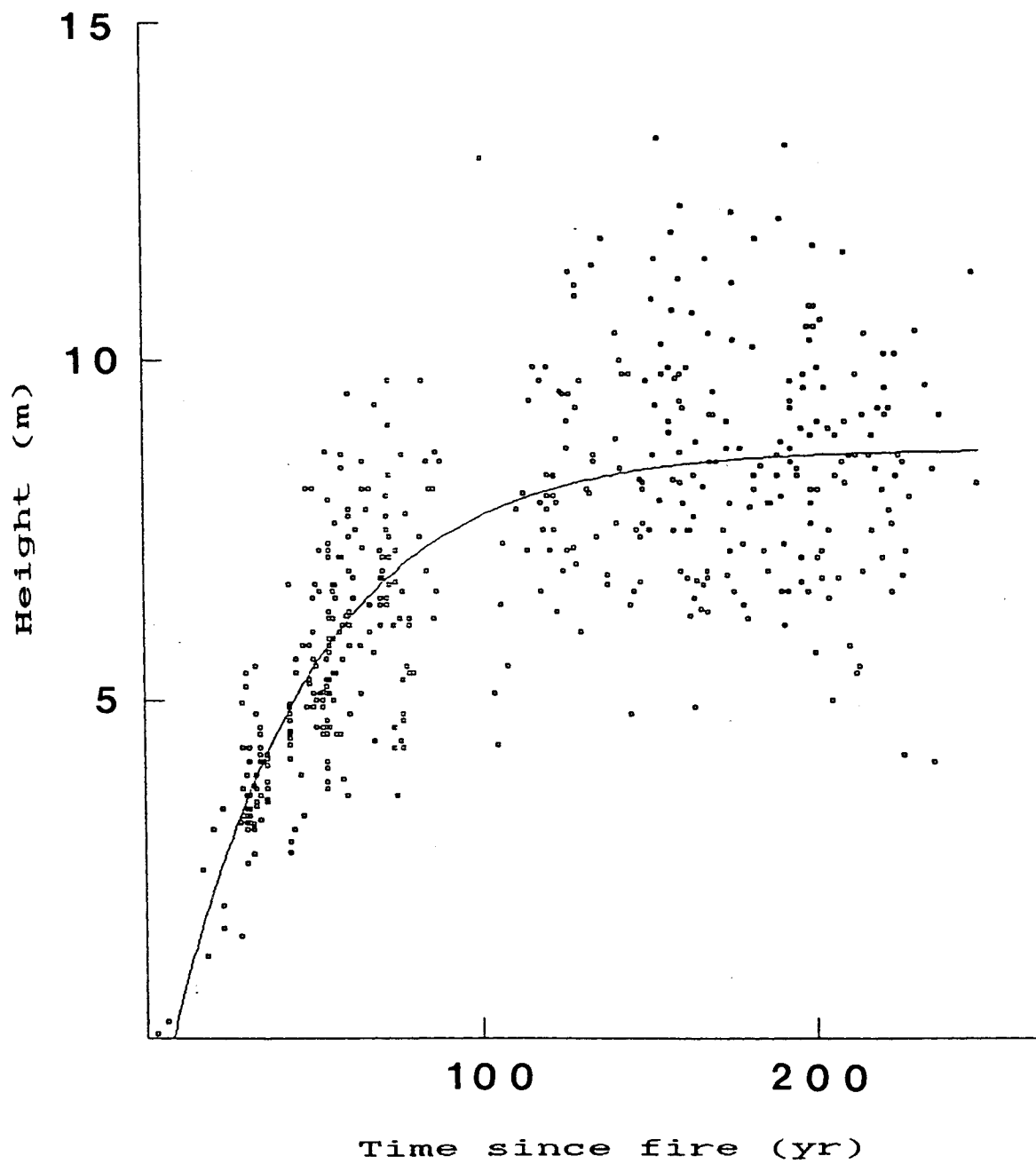


Figure 17. Relationship between maximum height of black spruce and time since fire at 196 upland sites on winter range of the Beverly herd of caribou.

Figure 18

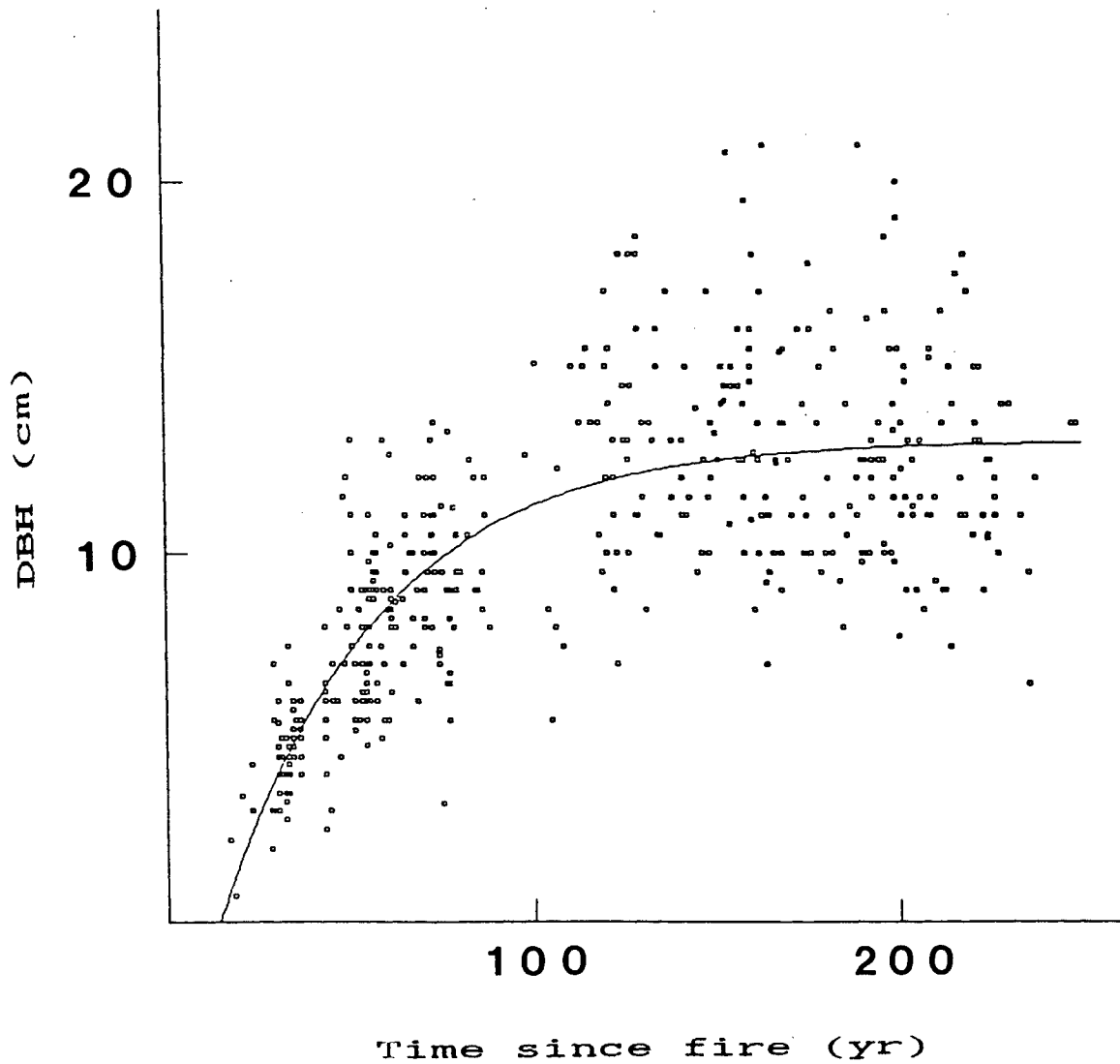


Figure 18. Relationship between maximum diameters-at-breast-height (DBH) of pine and age of forest at 196 upland sites on winter range of the Beverly herd of caribou.

Figure 19

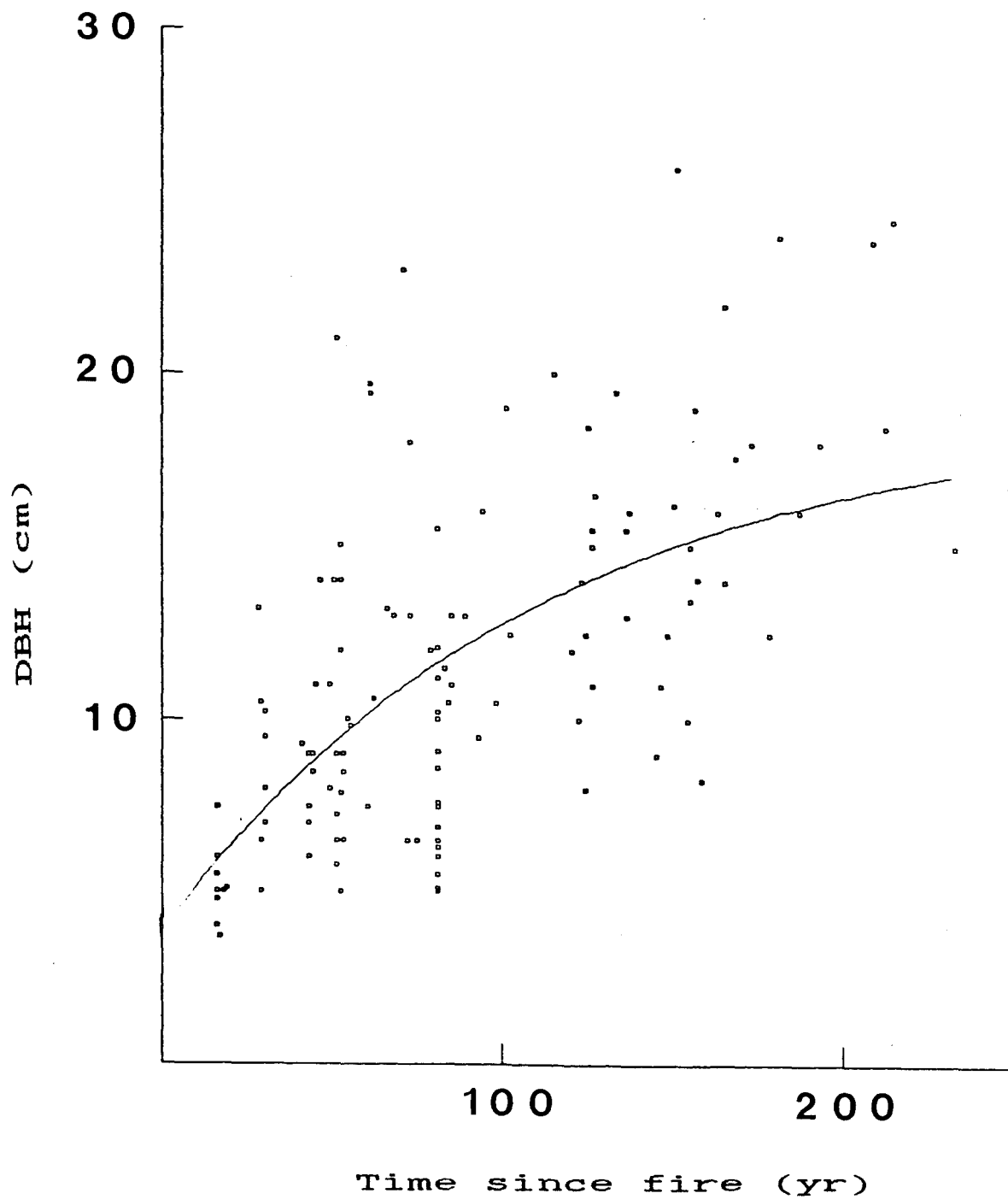


Figure 19. Relationship between maximum diameters-at-breast-height (DBH) of black spruce and age of forest at 196 upland sites on winter range of the Beverly herd of caribou.

Table 9. Average numbers of spruce and pine trees of 5 cm diameter-at-breast-height (DBH) classes in 10 m x 10 m plots at 20-year intervals after fire at 196 upland sites on winter range of the Beverly herd of caribou.

Age class (yr)	No. of sites	Average number of trees in each DBH (cm) class:											
		Black spruce						Jack pine					
		1-5	6-10	11-15	16-20	>20	Total	1-5	6-10	11-15	16-20	>20	Total
1-20	12	3.9	0	0	0	0	3.9	3.9	0	0	0	0	3.9
21-40	16	25.8	0.4	0	0	0	26.2	0.9	0.8	0.1	0	0	1.9
41-60	34	34.9	3.6	0.1	0	0	38.6	10.5	5.9	0.2	0	0	16.6
61-80	27	19.9	4.7	0.7	0.1	0	25.4	1.0	1.8	0.7	0.2	0	3.7
81-100	9	11.0	5.3	0.7	0.1	0	17.1	0.8	6.4	2.1	0.2	0.1	9.6
101-120	8	40.3	8.8	2.4	0.1	0	51.6	0	0.3	0.6	0.3	0	1.2
121-140	16	9.6	6.3	1.4	0.6	0.7	18.6	0.3	0.3	0.3	0.1	0.1	1.1
141-160	13	12.3	11.2	2.3	0.1	0.1	26.0	0.2	0	0.2	0.1	0	0.5
161-180	18	14.7	12.9	2.6	0.1	0.1	30.4	0	0.1	0.4	0.2	0	0.7
181-200	9	18.9	12.6	3.3	0.1	0	34.9	0	0	0	0.1	0	0.1
201-220	15	13.3	11.5	2.3	0.2	0.1	27.4	0	0.1	0	0	0	0.1
221-240	15	11.3	6.1	1.2	0.1	0	18.7	0	0.1	0	0	0	0.1
241-260	3	3.7	3.3	3.7	0	0	10.7	0	0	0	0	0	0
261-280	1	11.0	1.0	0	0	0	12.0	0	0	0	0	0	0

classes. The largest number of trees per 100 m² were in the 1-5 cm size class in all age classes.

Maximum numbers of 1-5 cm trees was in age class 101-120 years, with relatively large numbers in age classes 21-40 and 41-60 years. Numbers of 1-5 cm spruce were similar in age classes 81-100 years, 121-140 years, and older classes. Largest number of black spruce in DBH classes 6-10, 11-15, 16-20, and >20 cm were in age classes 161-180, 181-200, 121-140, and 121-140 years, respectively. Pine was relatively scarce compared with spruce except in the first age class. The highest density of 1-5 cm pine was in age class 41-60 years; the largest number of 6-10 cm and 11-15 cm pine in class 81-100 years. Largest number of all size classes of pine was in age class 41-60 years.

The data was split into west (**App. 19**) and east (**App. 20**) components because pine was common in the west but rare in eastern sites.

Total DBHs, calculated as a product of average number of trees in each DBH class and mid value of each DBH class (e.g. 7.5 for the 6-10 class), is an index of amount of canopy. At all sites, high total DBHs of spruce were present in age classes 101-120 to 201-220 years old (**Table 10**). High variation among older age classes reflects great variation among sites. Pine attained relatively high total DBH values at 41-100 years and then declined rapidly to nil at >240 years. The oldest pine, 271 years, was found at D'Aoust Lake and outside site locations. Most pines older than 150 years had center rot and their ages were difficult to estimate. Alexander et al. (1989) estimated the age of one pine at Porter Lake as 284 years. We saw pine snags that probably were >300 years at death but did not cut them because of certain centre rot. Data for total DBHs of spruce and pine were split for sites west and east of 107°W (**App. 21 & 22**).

Table 10. Calculated total diameter-at-breast-height values in five DBH size classes at 20-year intervals after fire at 196 upland sites on winter range of the Beverly herd of caribou.

Age class (yr)	No. of sites	Total diameter-at-breast-height values ¹											
		Black spruce						Jack pine					
		1-5	6-10	11-15	16-20	>20	Total	1-5	6-10	11-15	16-20	>20	Total
1-20	12	11.7	0	0	0	0	11.7	11.7	0	0	0	0	11.7
21-40	16	77.4	3.2	0	0	0	80.6	2.7	6.4	1.3	0	0	10.4
41-60	34	104.7	28.8	1.3	0	0	134.8	31.5	47.2	2.6	0	0	81.3
61-80	27	59.7	37.6	9.1	1.8	0	108.2	3.0	14.4	9.1	3.6	0	30.1
81-100	9	33.0	42.4	9.1	1.8	0	86.3	2.4	51.2	27.3	3.6	2.2	86.7
101-120	8	120.9	70.4	31.2	1.8	0	224.3	0	2.4	7.8	5.4	0	15.6
121-140	16	28.8	50.4	18.2	10.8	15.4	123.6	0.9	2.4	3.9	1.8	2.2	11.2
141-160	13	36.9	89.6	29.9	1.8	2.2	160.4	0.6	0	2.6	1.8	0	5.0
161-180	18	44.1	103.2	33.8	1.8	2.2	185.1	0	0.8	5.2	3.6	0	9.6
181-200	9	56.7	100.8	42.9	1.8	0	202.2	0	0	0	1.8	0	1.8
201-220	15	39.9	92.0	29.9	3.6	2.2	167.6	0	0.8	0	0	0	0.8
221-240	15	33.9	48.8	15.6	1.8	0	100.1	0	0.8	0	0	0	0.8
241-260	3	11.1	26.4	48.1	0	0	85.6	0	0	0	0	0	0
261-280	1	33.0	8.0	0	0	0	41.0	0	0	0	0	0	0

¹ Product of average number of trees in the DBH size class and the mid-point of the size class.

DISCUSSION

Sampling design

Use of 10 quadrats 25 cm x 50 cm to sample sites where the distribution of vegetation was dense and rather uniform and up to 30 quadrats to sample sites where forage species were sparse and clumped in distribution was based on results of experimental work on the best sampling designs for surface vegetation (Wein pers. commun.). Judging degree of non randomness, and therefore number of quadrats to use, requires experience. Even so, the sample size is adequate only for relatively abundant species that are rather uniformly scattered throughout the sampled area. There must be a trade-off between obtaining reliable data and time considerations. Over sampling must be avoided as much as the alternative. Numbers of required quadrats can be calculated for the species or species group of most concern from cover estimates and the formula: $no. \text{ quadrats} = s^2 t^2 / d^2$ where s^2 is the variance, t is tabulated t for the selected 95% confidence level ($\alpha = 0.05$), and d is half the required confidence interval (Steel and Torrie 1960, p. 87).

Our main purpose was to compare the amount (cover and biomass) of caribou forages in forests of various ages after fire. Site selection was based on where caribou were most likely to feed in late winter: upland sites in preference to lowland ones; in forest openings rather than under the branches of trees; and near water courses that are used as travel routes. If our objective was to measure range forage production, and perhaps carrying capacity for caribou, we would need a more-random design. We would also need adequate sampling of all habitat types and various strata including uplands and lowlands, in openings and under trees, along and away from travel routes, and various aspects and slopes. Habitat types must then be mapped, which was far beyond resources of this study.

Our cover and biomass values are much higher than would be obtained by some completely random sampling design. We thought it was better to consistently sample sites used or preferred by caribou than sample areas that may not be used as feeding sites. Site selection by caribou may be more random in high-use areas such as habitats intensively used in late winter when snow is deep. In general, however, there was much higher use of habitats beside travel routes and much higher use of upland ridges adjacent to the travel routes than other habitat types and locations. For comparative purposes, selection of favorable feeding areas at all locations was deemed to be preferred to some more random but less ecologically-based sampling design. Our biomass and cover values are those for good or preferred feeding sites sampled areas.

The bias towards potential caribou feeding sites was most pronounced for forests 21-70 years post fire. Lichen abundance was much higher in openings of such forests than in the general area. In young forests, there was little growth of lichens where the trees and shrubs were dense. Forests openings, conducive to lichen growth, may constitute only 5 to 10% of an upland area. Our results, therefore, are inflated for young (11-50 years) and early (51-75 years) examples of medium-aged (51-100 years) forests. They also are inflated for old (>100 years) and ancient stands (>150 years) compared with results expected from a random sampling design, but less so.

Our results must be compared to those of other studies with caution. These results are more comparable to those of Miller (1976a, 1976b, 1980) than those of Scotter (1964, 1965, 1970, 1971) because the former selected caribou feeding sites (cratered areas), whereas the latter set out a systematic grid to sample sites.

We stratified sites into open areas between drip lines and areas under drip lines

and sampled only the former to reduce variability. Failure to stratify would produce different and more-variable results. Cratering usually was greater in openings between trees than under them even though snow was deeper in openings. *Cladina mitis*, *Stereocaulon* spp., and *Cetraria* spp. were more abundant in the openings, whereas *Peltigera* spp. and *C. rangiferina* preferred moister conditions and greater shade under trees and low shrubs. In old and ancient forests, *Cet. nivalis* usually was most abundant in centers of openings and *Stereocaulon* spp. peripheral to drip lines. Where spruce branches reach the ground or are close to it, there is little vegetation, except moss, because of shading. Therefore, there are two major and related elements involved; moisture (including humidity) and light. Those factors, along with time since fire, are critical to growth of lichens.

Differences between biomass of lichens at feeding sites and in a general habitat type are evident in results of Edmonds and Bloomfield (1984) for a foothills region of Alberta. Biomass (kg/ha) values for locations of feeding craters and for control plots in the same general habitat type (parentheses) for seven forest habitat types were approximately 4800 (1850), 3400 (990), 2500 (570), 4000 (1000), 3000 (540), 6100 (3100) and 3400 (240). Edmonds (pers. commun.) did not feel that the 10 divots, of 100 cm² (dm²) each, adequately sampled feeding sites. General habitat types were sampled with 10 quadrats each of 1000 cm² (20 x 50 cm) for a total area of 1 m². Miller (1976b) also used 100 cm² divots ($n = 10$) to sample sites for biomass. His standing crop estimates were a product of visual estimates of percent cover and biomass in 100 cm² divots where lichen cover was near 100%.

In contrast, Scotter (1964) employed up to 16 samples each of 9.6 ft² (8920 cm²) for a total of 153.6 ft² (14.27 m²) and obtained five replicates for a total area of 768 ft²

(71.35 m²). However, he used a weight-estimate technique, as such large samples for standing crop of forage would be prohibitive in time. Therefore, his standing crop data were semi-quantitative.

Snyder (1987), in west-central Alberta, used random transects and m² quadrats (plots) ($n = 30$). Lack of stratification resulted in low biomass values compared with those of Edmonds and Bloomfield (1984) for similar habitat types. Intensive sampling of trees for arboreal lichen biomass resulted in only four sites and ages being sampled in two field seasons. The method of estimating forest ages and their rounding means that ages of the four stands undoubtedly are older than indicated in the report, in particular the "50-year-old" site.

In Alaska, Fleischman (1990) reduced biomass sampling from eight 20 cm x 50 cm quadrats to four quadrats, i.e., from 0.2 m² to 0.1 m². He only sampled every 10th or 12th quadrat for biomass but obtained visual estimates of cover on the others. Products of lichen cover and height were "volume", which was converted to biomass by a ratio method.

Relative use of various-aged forests by caribou

The most important statistics in assessing the role of fire on winter range of the Beverly herd is relative use by caribou of various forest ages. Caribou demonstrated a distinct preference for forests between 151 and 250 years post fire (Fig. 14).

Relative to class 1-50 years, pellet group densities at Nonacho Lake were 12 times higher in 51-150 year forests, and 28 times higher in 151-250 year forests. Densities in forests aged 151-250 years were 2.3 times higher than in forests 51-150 years old. At Porter Lake, indicated use was highest in a 101-150 year forest, with progressively lower pellet-group densities in younger and older forests, however sample sizes were

small (App. 14). Relative to age class 1-50 years, pellet-group densities at Selwyn Lake were two times higher in forests 51-150 years old and 5.8 times higher in forests aged 151-250 years. At Beauvais Lake, apparent use of forests 201-250 years old was 3.1 times higher than use of sites aged 51-100 years.

A fruitful use of resources would be extensive sampling of forests of various ages for pellet-group densities of caribou. The purpose would be to more-accurately estimate relative use of forests of various ages and structure. Sampling design would be specifically for pellet groups, whereas our design was primarily for caribou forages. A knowledge of caribou distributions in the previous two winters would be useful in establishing study areas. The fire history map arising from this study would help in selecting sites. Such a study would cost little if crews and aircraft were already deployed in field camps such as Porter and Nonacho lakes for fire observation and management duties. Additional forest ages could be obtained, which would contribute to a much needed range-wide, fire history map that could be updated annually and accessed by Geographic Information System technology.

How do these data on relative use of forest ages fit with previous information? Scotter (1964, 1965) recorded highest caribou fecal densities in the oldest (120+ years) stands in two study areas (**Table 11**). Scotter's data indicated low use of age classes under 50 years but considerable apparent use in older forests.

Miller (1976b) stated that caribou in northern Manitoba and Saskatchewan showed no preference for older-aged stands as main feeding sites. His conclusion apparently was based on mean ages of 88 and 94 years for sites cratered by caribou in Manitoba and Saskatchewan, respectively. Data are meaningless unless they are linked to ages of available forests. There was evidence that a low proportion of forests in northern Manitoba and Saskatchewan were older than 100 years (Kelsall

Table 11. Pellet-group densities of caribou and moose and biomass of total and high value lichens recorded by Scotter (1964, 1965) in six age classes at study areas in Saskatchewan and Manitoba.

Forest age class (years)	Caribou pellet gps/ha		Moose pellet gps/ha		Lichen biomass (kg/ha)			
	Sask. ¹	Man.	Sask. ¹	Man.	Total		High value	
					Sask.	Man.	Sask.	Man.
1-10	17	0	20	0	6	T ²	1	T ²
11-30	11	188	34	141	84	351	13	168
31-50	81	175	23	0	216	594	68	405
51-75	206	1226	8	35	317	731	74	573
76-120	134	1905	4	27	398	898	230	731
>120	237	2355	4	0	540	981	296	861

¹ Spruce forest.

² Trace.

1968). For example, E. Kuyt (in Kelsall 1968) estimated that only about 2% of a study area in Saskatchewan between 58°N and 60°N and 104°W and 108°W was "unburned". Those old forest blocks located west of Black Lake and north of the Fond-du-Lac River have burned since his survey! Only a low proportion of sites investigated by Scotter (1964, 1965) in those areas were older than 125 years. Caribou observed by Miller (1976b) may have been utilizing the oldest forests in the area. What is needed are data on relative use of various ages of forests in relation to their relative occurrence.

Forage preferences

An assessment of data on plant compositions in rumens and fecal pellets by macro- and micro-histological techniques indicates that lichens comprise 80-95% of the diet of caribou on winter range of the Beverly herd (Thomas and Hervieux 1984; Thomas

1991a; Thomas and Barry 1990). *Cladina mitis* and *Cetraria nivalis* appeared to be preferred by caribou and were the most important lichens. The most abundant lichen genus, *Stereocaulon*, was eaten in small amounts and seemingly incidental to grazing of other species. Food preferences of *Rangifer* spp. are discussed in the fifth paper in this series (Thomas 1998).

Digestibility studies (Thomas and Kroeger 1981, Thomas et al. 1984) indicated high digestibilities for most lichen species, especially when urea was added to species with low protein contents. Digestibility of *Stereocaulon paschale* was lowest of all lichen species tested in March 1980 when fat reserves of caribou were below average.

Terrestrial lichen biomass

Miller (1976b) reported that lichen biomass at feeding sites in Saskatchewan averaged 5847 kg/ha (range 951-13 756). The mean was 4277 kg/ha at similar sites in Manitoba (range = 2 611-10 653). The mean was 6162 kg/ha for three exclosures in place for 9 years (Miller 1976b). Sites younger than 36 years were excluded but no age difference in biomass was found thereafter. Miller (1976b) acknowledged that greater use of old sites by caribou could have accounted for a lower biomass of lichens in them.

Miller's (1976a, 1976b) lichen biomass values for cratered sites and exclosures in Manitoba and Saskatchewan (**Table 12**) were higher than in this study, particularly in younger age classes. His ages may be underestimated because he indicated no adjustments for years between fire and number of annulations at 30 cm above ground. Fire scar data are required for forests up to 100 years post fire.

Scotter's (1964, 1965) lichen biomass values (**Table 13**) are considerably lower

Table 12. Lichen biomass in areas of high lichen cover at 59 sites in Manitoba and Saskatchewan arranged in 20-year age classes post fire (data modified from Miller 1976a, 1976b).

Age class (years)	Lichen biomass (kg/ha) ¹			Sample size
	Mean	Standard deviation	Standard error	
20-40	4258	1186	839	3
41-60	4917	2682	948	9
61-80	4449	2752	711	16
81-100	5572	2345	957	7
101-120	6221	3996	1570	9
121-140	5585	1324	441	10
141-160	3831	797	564	3
161-180	2828			1
181-200	560			1

¹ Includes lowland sites and exclosure data.

than in this study because his samples were more randomly placed.

At caribou feeding sites in Alberta, terrestrial lichen biomass in six pine forests types averaged 4017 kg/ha (Edmonds and Bloomfield 1984). In another study in Alberta, where forests were not stratified, mean biomass of four sites was 310 kg/ha (range 77-671) (Snyder 1987).

Terrestrial lichen biomass values in pine, spruce-pine, and spruce forests of Canada and Alaska are presented in Table 13.

Lichen cover

Total lichen cover from quadrat data should be higher than that from line transect data. Lichen cover is higher in the open areas where quadrats data was obtained

Table 13. Biomass of terrestrial lichens on forested winter ranges of caribou in North America.

Location	Habitat type	Lichen biomass (kg/ha)		Reference
		Mean	Range	
Sask.	Pine	146 ¹		Scotter 1964
	Spruce	418 ²	317-540	
Manitoba	Spruce/pine	870 ²	731-981	Scotter 1965
Sask/Man.	Pine/spruce	604	474-813 ³	Scotter 1967, 1971
Manitoba ³	Pine/spruce	4748	2477-10 653	Miller 1976a, 1976b
	Spruce lowland	3170	560-5240	
Sask.	Pine/spruce	5895	951-13 756	
Alberta ⁴	Pine, pine/spr.	990	540-1850	Edmonds & Bloomf. 1984
Alberta	Spruce/fir/ pine forest	310	77-671	Snyder 1987
Labrador	Spruce	2200		Hustich 1951
Newfound- land	Forest	420	400-600	Bergerud 1971
	Woodland	4820	1-12 000	
Alaska	Open spruce	3060		Pegau 1972
Alaska	Spruce		179-567	Fleischman 1990
Alaska	Average	6276		Courtright 1959

¹ Stand 65 years old since fire.² Forests older than 50 years.³ Inclosures sampled after 9 years.⁴ Average for five habitat types.

than under trees with low branches. Transect data were not stratified and included low-cover lichen areas under low tree canopies. Line transect point data are believed to yield high values because any lichen fragment under a line point was counted. This bias is more likely to occur where only one class of vegetation is

surveyed by the technique. The results, though inflated, are valid for comparisons among age classes, though absolute values probably are 20-30% high.

Miller (1976a, 1976b) found lichen cover values for forests 41-60 years post fire were similar to those of older age classes at 53 sites in northern Manitoba and Saskatchewan (**Table 14**). However, 6 of 9 sites in the 41-60 year class were estimated as 55-60 years post fire and forest ages may have been underestimated by 5-12 years or more. Similarly, 7 of 16 sites in class 61-80 years were estimated to be >75 years post fire. Cover ranged between 75 and 80% in forests older than 40 years (Table 14). Apparently Miller's (1976a, 1976b) microplots generally were in forest openings. His data were converted from cover classes (Braun-Blanquette) to integers in an unexplained manner.

Kershaw et al. (1975) reported lichen cover values to 91.5% at only 52-70 years post fire on drumlins in the Abitau/Dunvegan lakes region (**Table 15**). In contrast, Edmonds and Bloomfield (1984) reported lichen percent cover values in the 20s for most of their sites in west-central Alberta.

A significant relationship between cover and biomass in the study area means that cover can be used to predict biomass and to compare different habitat types (Thomas et al. 1996). Bergerud (1971) also found a significant relationship between the two variables for 19 ranges in Newfoundland. Bergerud's (1971) significant relationship between lichen height and both cover and weight was not supported by these results and may only be applicable to small sampling areas, e.g., 100 cm² rather than 1000-1250 cm², i.e., only applicable to lichen patches. We found that measurements of lichen height were difficult because of variability in height within a small area and variability caused by degree of wetness. Maximum height could be measured after wetting the lichens but average height was semi-quantitative at best.

Table 14. Visual lichen cover estimates at 53 sites examined in northern Manitoba and Saskatchewan in 1972 and 1973 (data modified from Miller 1976a, 1976b).

Age class ¹ (years)	Lichen cover (%)			
	Mean	Standard deviation	Standard error	Sample size
20-40	32.0	45.25	45.3	2
41-60	75.0	8.66	6.1	3
61-80	75.1	10.48	2.7	16
81-100	79.7	10.18	4.2	7
101-120	77.0	13.97	4.9	9
121-140	75.3	12.08	5.4	6
141-160	80.1	8.43	3.2	8
161-180	79.0	2.82	2.8	2

¹ Ages increased 5 and 10 years for presumed pine and spruce-dominated sites, respectively; and lowland sites and a site with 38% cover were omitted.

Lichen growth and productivity

Obviously it is important to know the relationship between biomass or standing crop and productivity, the amount of lichen added annually. At equilibrium the amount of new growth added annually equals the amount that dies at the base. During the growth phase, more is added than dies at the base. During senescence or degeneration, the annual growth is exceeded by the amount dying. Grazing and fluctuations in weather can alter this theoretical account of lichen growth and death.

Scotter (1964, 1965) found that annual growth to *C. mitis*, *C. rangiferina*, and *C. stellaris* was 3.6-3.8, 4.1-4.9, and 3.4-4.1 mm in taiga of northern Canada. Average time to grow live podetia present in lichen mats for the three species was 11, 8, and 13 years, respectively (Scotter, 1965). In Finland, annual growth rates of *C. mitis* and

Table 15. Cover of major lichen genera on drumlinoid ridges in the Dunvegan/Abitau lakes region (after Kershaw et al. 1975).

Lichen genus	Percent cover at periods (years) after fire			
	3	12 - 23	32 - 49	52 - 70
<i>Cladina</i> spp.	1.0	1.3	44.8	43.3
<i>Cladonia</i> spp.	0	9.1	22.0	20.9
<i>Cetraria</i> spp.	0	0.7	17.3	10.6
<i>Stereocaulon</i> spp.	0	0	1.7	16.7
Totals	1.0	11.1	85.8	91.5

C. rangiferina were 3.0-3.5 and 3.9-4.3 mm, respectively (Helle et al. 1984). In Sweden, growth per year was 5.1 mm for *C. silvatica* (= *mitis*); 4.5 mm for *C. rangiferina*; and 4.2 (wet conditions) and 2.8 (dry) for *C. alpestris* (Skunke 1969). Larin et al. (1937) reported fastest growth in *Stereocaulon paschale*: 60 mm in 15 years. Zhigunov (1968) provided lichen height and new-growth values for several species: *C. rangiferina* 4.0-7.5%; *C. alpestris* 1.6-3.3%; *Cl. amourocraea* 4.0-4.4%; *Cet. cucculata* 14.0-22.5%; *Stereocaulon paschale* 8.0-12.5%.

In Scandanavia and Finland, annual growth of lichens on the most productive reindeer ranges was 60-160 kg/ha, where biomass was 500-1500 kg/ha (Ahti 1977). Thus, annual production was about 11 to 12% of biomass. Regeneration from a grazed condition took 3 to 5 years (Ahti 1977). Biomass in an older *C. stellaris* stage could exceed 3000 kg/ha but annual growth was low. In Norway, annual primary production of dense lichen mats was 1000 kg/ha and productivity was 20% of biomass (Wielgolaski 1975 in Ahti 1977). Karenlampi (1971) estimated relative

annual growth for young *C. stellaris* at 19%. Scotter's (1965) data indicate that annual growth of *Cladina* spp. should average about 9% of their biomass. Divots of *C. mitis* increased in weight by 4-7% over a 6 year period (Gaare 1986). Our impression was that re-colonizing or small patches of lichen in favorable micro habitats grew perhaps 2-3 times faster than, for example, *C. mitis* in openings in old forests where lichen density was high and the mat was subject to rapid drying and xeric conditions. Hustich (1951) noted relative growth rates of 12-20%, 8-13%, 6-9%, and 8% in lichen height classes of 15-25, 26-40, 41-60, and >60 mm, respectively. Karenlampi (1970) found that relative growth rates of lichens declined with age. There may be a density-dependent effect but multiple factors are involved, including plant associations and canopy effects.

Frequency of occurrence of forages

Frequency of occurrence by quadrat and by site (quadrat data pooled) provides data on distribution of plant taxa in quadrat-sized (25 x 50 cm) areas and in 10 to 30 such areas within an area of 100-200 m². We did not always confine our quadrats to the 10 x 10 m plot but they always were within 10 m of it.

Plant succession

Successional stages after fire in the general area were documented by Scotter (1964), Rowe et al. (1975), Kershaw et al. (1975), Miller (1976a, 1976b), Black and Bliss (1978), Johnson (1979, 1981), and Carroll and Bliss (1982). Ahti (1977), described generalized successional stages for boreal forest and transitional forest (taiga) types. There was agreement on early stages of lichen succession: crustose lichens, then cup and sword (horn) *Cladonia* forms along with *Peltigera* species, and

then fruiticose reindeer lichens and *Stereocaulon* species. Cover values for crustose lichens were low in class 1-10 years in this study. Use of climax and subclimax terminology seems to have added nothing and has led to confusion. For example, Miller, (1976b) described *Stereocaulon* spp. as subclimax, whereas we found the genus to be most abundant in old forests. In old forests, either *C. mitis*, *Stereocaulon* spp., or *Cet. nivalis* dominated the ground cover.

Succession appears to be accelerated in Labrador where paradoxically the fire cycle generally is long (Foster 1985). Any extrapolations from one area to another are questionable.

Arboreal lichens

Based on apparent limited use of arboreal lichens by the Beverly herd and large amounts available to them, we decided not to sample biomass of these epiphytic lichens. Sampling procedures are time consuming and not justified in this study because of low use of arboreal lichens by caribou relative to their use of ground lichens. Scotter (1964) already had documented biomass of arboreal lichens on spruce and pine trees in the general area. The low dietary contribution of arboreal lichens in most winters was evident from field observations at feeding sites throughout winters of 1979-80 through 1986-87, on evidence of arboreal lichen grazing at 197 sites examined in summer, and on diet compositions (Scotter 1961, Miller 1976a, Thomas and Hervieux 1984, Thomas and Barry 1991).

Ratings of abundance of arboreal lichens at 1-2 m above ground was marginally higher in forests older than 160 years (average unweighted rating of 2.72) than in sites aged 61 to 160 years (average rating = 2.36). Scotter (1964) found 145-231 and 88-472 kg/ha of arboreal lichens on spruce and pine trees, respectively, at sites in northern Saskatchewan. Average values for all studies in Manitoba, Saskatchewan, and NWT were 380 and 678 kg/ha for pine and black spruce, respectively (Scotter

Table 16 Values for arboreal lichen biomass in pine-spruce forests at several locations.

Location	Habitat	Height range (m) ¹	Lichen biomass (kg/ha)	Reference
N. Sask.	Spruce forest	0 - 3	679	Scotter 1974
N. Sask.	Pine forest	0 - 3	381	Scotter 1974
Alberta	Various	0 - 4	119,298,331 104 - 1199	Edmonds & Bloomfield 1984
Alberta	Pine/spr./fir forest	0 - 3 0 - 5 1 - 2	25 - 51 31 - 125 11 - 22	Snyder 1987

¹ Above ground level.

1971) (**Table 16**). In west-central Alberta, biomass to 3 m in six habitat types averaged 406 kg/ha (range 104-968). The highest biomass occurred in forests older than 130 years, however the canopy type was different (Edmonds and Bloomfield 1984). At a nearby location, arboreal lichen biomass at 0-2 m a.g.l. was 11, 22, 18, and 17 kg/ha in forests estimated to be 50, 100, 150, and 200 years old (Snyder 1987), but probably older.

We observed that most grazing of arboreal lichens occurred at heights of 0.5-1.7 m above ground. Caribou did not raise their front feet from snow in order to reach arboreal lichens. The maximum vertical range in which caribou fed in 40 to 60 cm of snow, characteristic of late winter, was 0.5-2 m. There was no need to sample arboreal lichens to 3, 4, or 5 m except in mountain areas where crusted, deep snow supports caribou. Some of the biomass values in Table 16 should be reduced somewhat to reflect the practical height at which caribou feed on tree lichens.

Relationship between caribou use of forests and forage type and quantity

Results of this study emphasize that vegetation studies in isolation of the grazer or browser are inadequate. *C. mitis* appeared to be the most widespread lichen that was extensively eaten by caribou in the study area. The peak biomass of *C. mitis* at 81-100 years after fire, the higher growth forms at 61-100 years after fire, and the estimated greater productivity (annual growth) suggests that caribou should seek out forests about 61-100 years old. There was no indication that they do. Obviously the characteristics of *C. mitis* are only one part of a complex of factors that determine the distribution and feeding patterns of barren-ground caribou.

Our data indicate greatest use of forests 151-250 years after fire. How does this correlate with forage abundance and form? We can focus on lichens as they comprise most of the diet in winter (Thomas and Barry 1991). The best fit for genera was with the biomass of *Stereocaulon* spp. (largely *S. paschale*). That genus prefers an open canopy and dominates large openings characteristic of old forests. Its biomass peaks in sites over 150 years since fire. Robust but small patches occurred in forests as early as 50 years after fire. It gradually replaces other lichen species on some upland sites as canopy shading declines in very old stands.

The fit between high caribou use of areas and lichen biomass was also good for *Cet. nivalis* and *C. rangiferina*, both of which attain highest biomass in ancient forests. *Cet. nivalis* also prefers extremely open canopies and is most abundant where shade is almost completely lacking. Hence it is abundant in the center of clearings in association with *Stereocaulon* species, which prefers some shading. *Cet. nivalis* was also abundant in flat depressions between hummocks in open bogs

and lowland sites. Such areas have a low density of stunted spruce that provides little shading. They are moist (mesic) areas whereas open upland sites are dry (xeric), thus indicating a wide moisture tolerance for the species.

Moisture conditions of lichens obviously was influenced greatly by their association with mosses. *C. rangiferina* often was associated with feather mosses and thus was most abundant on north slopes, under drip lines of trees or shrubs, and in hummocky spruce lowlands, sometimes in association with *Ledum* spp. Of those plant associations, only the area under trees was cratered to any extent by caribou in winter. Thus, presence of *C. rangiferina* would not appear to influence use of forests of various ages to any extent. Additionally, biomass of *C. rangiferina* and *Cet. nivalis* is relatively low and there was no detected tendency for caribou to seek out either of those species.

High use of sites 151-250 years post fire correlates well with total biomass of lichens. Total biomass was highest in sites 151-250 years post fire, just as use was. The fit would be even better if "other *Cladonia*" spp. (highest biomass 21-80 years after fire) were subtracted from total lichen biomass. There was no indication that *Cladonia* spp. were used to any extent by caribou except perhaps incidental to grazing on preferred species. Tall forms, mostly sword types, generally are restricted to uplands in forests 21-60 years after fire. The dominant species in mature forests (101-150 years) and old and ancient forests (>150 years) are low cup types, which are scattered about a quadrat or abundant in disturbed situations (e.g. a rotting log). Further, the *Cladonia* spp. are anchored to the substrate and thus would be fractured

by pawing actions of cratering caribou. *Cl. uncialis* is most abundant in old and ancient forests but its established growth form (anchored, short, and spiky) reduces its value as a caribou forage in winter.

We felt justified in reducing the biomass of *Stereocaulon* spp. in calculating weighted lichen biomass because there was little evidence of it being grazed in almost pure stands encountered at many locations. Evidence of grazing was common where other species, and in particular *Cet. nivalis* and *C. mitis* was associated with *Stereocaulon* spp. At such cratered sites it appeared that *Cet. nivalis* was grazed with little inclusion of *Stereocaulon*.

Calculated weighted lichens and caribou lichens fit less well with caribou use of forests of various ages. Those results would predict about equal use by caribou of forests older than 60 years. One possible influence is the location of forests of various ages in relation to caribou densities on a regional and local scale. For example, if all 61-80 year sampled forests occurred in areas lightly used by caribou in the previous two-four winters, biased results would be obtained. Similarly, on a local scale, if most sites 101-150 years old were located on caribou travel routes and sites 41-60 years were in locations off main travel routes, then these biases would be difficult to overcome except with large sample sizes. Some sought-after forest ages are difficult to find because of the uneven distribution of fire with time and the non-random distribution of caribou. The best comparisons are in local areas where the pattern of recent use by caribou is known. Comparisons of pellet densities across burn lines is a useful indicator. The problem is largely overcome with large sample sizes and within-region comparisons. Results from just a few sites would be questionable unless comparisons were made with adjacent sites and not over several kilometers.

Obviously factors besides lichen biomass are involved in use of forests by caribou. Although most lichen species favored by caribou are near maximum height in 61-80 year stands, distribution of lichens remains patchy. Cover of lichens generally increases with age of forests to about 81-100 years. It takes time for colonizing patches of lichens to spread and the percentage of open areas among the trees increases with time. The change in percentage of favorable locations for caribou lichens to grow is most pronounced in spruce forests. Initially trees are dense and branches are at or near the ground. As spruce trees mature, lower branches die and old trees have live branches largely restricted to their upper half. There is continual regeneration of young spruce trees but their distribution is clumped, which leaves openings where conditions are favorable for growth of lichens.

Visibility in forests may be a factor affecting use. In general, visibility increases with age in the sequence medium, old, and ancient forests. Lower branches of pine die and break off to create excellent visibility in pure stands >100 years. Lower branches of spruce die but the branch stems persist and, combined with regeneration, create variable visibility with age in spruce forests.

There is disagreement whether old spruce forests become more open or closed with time (Strang and Johnson 1981). We agree with Bradley et al. (1982) that the forests open with time. Kershaw and Rouse (1971, 1976) stated that spruce forests closed with time, moss cover increased, and lichen cover decreased. Miller (1976b) also stated that spruce forests closed with age, which favored growth of mosses to the detriment of lichens. Young spruce forests are open but the discussion referred to old and ancient forests. Some ancient spruce forests perhaps have reduced

openings where vegetative reproduction or layering occurs. A large ring of young trees can result from branches of "mother" trees taking root. But these are exceptions to a general rule. Whether spruce forests become more open or closed with time is dependent on moisture conditions. Xeric sites certainly become more open in ancient forests because large trees are dying, nutrients are tied up in large trees, and a thick carpet of lichens discourages sexual reproduction of spruce and pine. In more-mesic sites, spruce trees grow more slowly and are more dense and therefore could result in greater closure with time up to 200 to 300 years at least.

Average snow depths are lower in mature and older forests compared with younger ones. Snow retained by large trees result in shallower snow under the trees. Differences amount to as much as 10 cm.

Fire-caribou range relationships: differences of opinion

Miller's (1976a, 1976b, 1980) evaluation of the relationship between stand age and cover/standing crop of lichens appeared to be influenced by some sampling and reporting problems. A statement that lichen standing crop was higher in a 30 year site than in the oldest 181 year site must be clarified. A wet lowland site with low cover of lichens should not be compared with an upland site where most lichen species grow better. Sampling problems relate to non-random selection of divots that totaled an inadequate area of 0.1 m² per site; questionable cover values based on cover-class data that was used to calculate standing crops along with the divot data; and apparent underestimation of time since fire by 6-12 years because tree annulation data was not adjusted to account for the time it takes trees to attain 30 cm in height where cores presumably were obtained. His divot data is a guide to maximum production of lichens at sites whose ages should be adjusted 6 years older

for pine and 10 years older for spruce (Table 12).

Use by moose in relation to time since fire.

In terms of forage, sites less than about 50-60 years old are preferred by moose.

Scotter (1964) reached the same conclusion. Moose require older forest for cover, including thermal cover (cool locations on hot days). Even in old forests, paper birch provides some food for moose. They also utilize shrubs growing along edges between habitat types. Included are lake, river, and stream edges and edges of large openings such as muskegs, fens, and raised peatlands. Moose were noted to use willows (preferred), paper birch, and even green alder.

Regeneration of willows, birch, and alder occurs within a year of fire from roots not killed by fire. It seems to take a few years for moose to become established in a new area that includes a recent burn. Moose are unlikely to find a burn unless it occurred in existing range or on a migratory route. Within 15-20 years of fire there is adequate cover to conceal moose but inadequate escape and thermal cover.

Density of moose pellets was by far the highest in the 21-40 year class in both western and eastern regions of this study. Moose pellet group densities exceeded those of caribou in age classes 1-20, 21-40 and 41-60 years.

Moose pellet groups in Scotter's (1964) study were most dense (34 groups per ha) in 11-30 year spruce stands followed by 23, 20, 8, 4, and 4 groups per ha in 31-50, 1-10, 51-75, 76-120, and 120+ year spruce stands. Although Scotter (1964) didn't find moose pellets in six pine stands, we found some of the highest densities in mixed spruce and pine stands (we had no stands we could classify as pure pine stands).

Highest use of large recent burns by moose was around their periphery. Tiny burns are of limited value because shrubs are not sufficiently abundant to support

moose on an annual basis. Burns favorable to moose in the study area were medium or large and irregular in shape or medium and large with many large unburned inclusions. The potentially favorable condition of many small burns of various ages within an area of 100-1000 km² does not occur.

Use of fire-succession forests by other herbivores

Results for hare, although somewhat inconsistent between western and eastern sites and among age classes, generally indicated most use of forests in age classes 41-150 years post fire (Table 7). There may be more forage in younger forests but cover from avian predators and weather is inadequate in them.

Sign of grouse/ptarmigan was most abundant in age classes 41-100 years post fire in western sites but seemingly age independent in eastern sites. Ptarmigan feed on buds of shrubs including those exposed through cratering activities of caribou.

Fire, forest, and wildlife

Fire-forest-wildlife relationships were described in general in various publications, e.g., Kelsall et al. (1977) and Viereck and Schandelmier (1980). Fire is a natural process and yet that realization was slowly accepted for unfathomable reasons. Forests came to be described as "fire dependent", which can cause confusion because a forest would be there regardless. Fire dependency means that forest composition and structure is related to fire characteristics and time since fire. For example, species with serotonous cones depend on fire to release large quantities of seeds. In the absence of fire, species such as jack pine gradually would disappear and re-colonization presumably would be slow.

The term "succession" was and is used to suggest that types of vegetation were replaced in sequence by others. In fact, changes in vegetative composition are gradual and continuous. There are considerable overlaps in occurrence and abundance of species over time and space. Succession means that the proportions of each species changes over time. Successional stages are merely arbitrary "snapshots" of differences in composition over time, usually keyed to major canopy species that are dominant at certain periods after fire or other disturbance.

The term "climax" was introduced to indicate the final composition of a forest after a undefined long period of time. One problem is that age of ancient forests cannot be estimated. Therefore, climax forests are merely old or ancient forests - usually in the order of 200-500 years. The changes that occur from old to ancient forests are not understood although predictions are possible.

All forests are in a state of flux depending on time since fire and changes in weather (short term) or climate (long-term changes in weather). Thus, there are no average or normal conditions for an area. What happened in the past cannot be used to predict future changes, except in a general way.

The importance of fire to wildlife is that it causes vegetational diversity. This diversity in turn permits diversity in wildlife species, as each species has an ecological niche where it is most successful. Most species can span a range of forest successional stages. Some small species can thrive in habitats of a certain successional stage. Individuals of other species prefer and almost require a range of successional types within their ranges and the population does best under diverse habitat conditions. For example, moose thrive on a mosaic of successional stages - from recent burns for food production to old forests for thermal and escape habitat.

Other requirements for high moose densities include lakes and streams that produce aquatic vegetation and riparian shrub species, and draws with willow and alder cover.

Caribou have adapted to use lichens as a major food resource. In summer, other forages with high protein content are required for growth and milk production. In winter, surface lichens are preferred but tree lichens are used where they are sufficiently abundant. Fruticose lichens preferred by caribou take 40-60 years to re-colonize areas after fire and 80-100 years or longer to attain maximum cover and biomass. The species is ecologically associated with old-growth forests and could persist in the absence of fire. Fire does produce pine and pine/spruce forests where lichen biomass can be high. Productivity of lichens (addition of new growth annually) in forests aged 51-100 years can be higher than in old forests for some species. The other forages needed to supplement lichens grow in forests of all ages and in bogs, on stream banks, and lake edges.

There are conflicting views as to the importance of lichens to caribou in winter and how rapidly lichens re-colonize habitats after fire or other disturbances.

Generalizations are difficult and dangerous. Data are needed for each population of caribou. In the case of the Beverly herd, lichens are critical in winter and habitats are used little by caribou until 51-70 years after fire and older forests are preferred for winter foraging. Contrary data usually are flawed by inaccurate forest ages or failure to acknowledge that caribou have lichen preferences and perhaps dislikes.

A summary of the results in this report was published (Thomas et al. 1996).

CONCLUSIONS

1. Biomass of terrestrial lichen species and genera peaked at various times after fire: most *Cladonia* spp. and *Peltigera* spp. at 41-60 years post fire; *Cetraria islandica/arenaria* at 61-80 years; *Cladonia mitis* and *Cladonia uncialis* at 81-100 years; *C. rangiferina*, *Cetraria nivalis*, and *Stereocaulon* spp. in sites older than 200 years.
2. Biomass of all terrestrial lichens peaked about 201-250 years post fire, whereas the primary caribou lichens (*C. mitis*, *C. stellaris*, *C. rangiferina*, and *Cet. nivalis*) and "weighted" lichens (weighted as to their estimated relative value for caribou) remained about constant in biomass after about 70 years post fire.
3. In the eastern half of winter range, *Stereocaulon* spp. dominated surfaces of spruce forests as early as 61-80 years post fire, whereas the genus was abundant only on some of the oldest sites in the western portion of winter range.
4. The productivity of shrubs was remarkably consistent with time after fire except that *Vaccinium vitis-idaea* was most abundant 41-60 years after fire and *Ledum* spp. were most prolific in the first 20 years.
5. Ocular cover of lichens in quadrats and on line transects increased until age classes 61-80 years and 101-120 years, respectively, and then stabilized.
6. There was a strong correlation between cover and biomass of all major plant groups indicating that caribou forages can be assessed from cover data, with great economy of time and personnel.
7. In sites 30+ years after fire, *C. mitis* occurred in 99.8% of quadrats; followed by "other *Cladonia*" 99.5%; *Cl. uncialis* 94.1%; *Cet. islandica/arenaria* 86.3%; *Cet. nivalis* 78.8%; *C. rangiferina* 73.4%; *Stereocaulon* spp. 56.4%; and *Peltigera* spp. 33.9%.

8. Arboreal lichens 0-2 m above ground increased to light quantities by 61-80 years post fire and to moderate levels by 160 years.
9. Lichen thickness did not vary greatly after age class 1-20 years but height of *C. mitis* and *Cl. uncialis* declined in many upland sites >150 years after fire, which became more open and dry because large trees were dying.
10. Based on pellet group densities, caribou used 151-250 year forests the most, followed by about equal use of 51-100, 101-150, and 251-300 year sites, and low use of 1-50 year sites. In contrast, highest densities of moose pellets were in the 21-40 year class.
11. Caribou pellet groups survived 2-3 years in mesic (moist) sites and 3-5 years in xeric (dry) conditions.
12. Canopy characteristics, including tree heights, trunk diameters, and tree densities could not be linked directly to lichen cover or biomass because of other confounding variables such as time. Such average statistics are only an index of canopy characteristics, which in turn influence light, moisture, and thermal conditions on the forest floor. Such statistics do not reflect microhabitat variations.
13. A summation of tree diameters revealed highest values of spruce between 101 and 200 years after fire and a marked decline thereafter. In contrast, pine diameters peaked from 41 to 100 years and declined sharply thereafter.
14. High use of forests 151-250 years post fire was associated with high total terrestrial lichen biomass.
15. Terrestrial lichens dominate the diet of the Beverly herd of caribou in winter and other species, with the exception of green sedges and arboreal lichens in some winters, apparently play minor roles in winter nutrition of that caribou herd.

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Appendix 1. Dates, ages, and locations of 199 sites sampled in summers 1983 through 1986 for habitat characteristics, plant cover and biomass, and fecal densities.

Site no.	Date sampled ¹	Age (yr)	General location	Coordinates (N lat., W long.)
1	070783	133	N.E. Nonacho L.	61 49, 109 15
2	080783	74	N.E. Nonacho L.	61 48, 109 15
3	100783	214	N.E. Nonacho L.	61 50, 109 09
4	110783	130	N.E. Nonacho L.	61 48, 109 15
5	120783	219	N.E. Nonacho L.	61 52, 109 10
6	120783	81	N.E. Nonacho L.	61 52, 109 14
7	130783	81	N.E. Nonacho L.	61 52, 109 14
8	140783	154	N.E. Nonacho L.	61 52, 109 14
9	140783	154	N.E. Nonacho L.	61 52, 109 14
10	160783	168	N.E. Nonacho L.	61 44, 109 19
11	170783	74	N.E. Nonacho L.	61 44, 109 19
12	190783	167	N.E. Nonacho L.	61 50, 109 20
13	200783	73	N.E. Nonacho L.	61 49, 109 16
14	210783	154	N.E. Nonacho L.	61 49, 109 16
15	220783	4	Hjalmar L.	61 39, 109 25
16	230783	71	N.E. Nonacho L.	61 48, 109 15
17	240783	120	N.E. Nonacho L.	61 46, 109 19
18	250783	61	Taltson R.	61 48, 108 48
19	250783	134	Taltson R.	61 48, 108 48
20	260783	71	N.E. Nonacho L.	61 48, 109 15
21	280783	16	Taltson R.	61 48, 108 48
22	280783	136	Taltson R.	61 48, 108 48
23	290783	55	N.E. Nonacho L.	61 46, 109 23
24	100883	150	Nonacho L.	61 44, 109 26
25	120883	55	Nonacho L.	61 44, 109 26
26	120883	260	Nonacho L.	61 44, 109 28
27	140883	166	Nonacho L.	61 44, 109 28
28	160883	51	W. Nonacho L.	61 41, 109 49
29	170883	164	W. Nonacho L.	61 41, 109 49
30	180883	17	W. Nonacho L.	61 46, 109 32
31	180883	210	W. Nonacho L.	61 46, 109 32
32	190883	111	W. Nonacho L.	61 48, 109 38
33	200883	27	W. Nonacho L.	61 48, 109 38
34	210883	187	W. Nonacho L.	61 49, 109 47
35	210883	41	W. Nonacho L.	61 49, 109 47
36	220883	41	W. Nonacho L.	61 49, 109 47
37	230883	28	N. Nonacho L.	61 55, 109 32
38	240883	162	N. Nonacho L.	61 55, 109 32

(continued)

Appendix 1 (continued)

Site no.	Date sampled ¹	Age (yr)	General location	Coordinates (N lat., W long.)
39	250883	108	W. Nonacho L.	61 37, 109 47
40	260883	51	W. Nonacho L.	61 37, 109 47
41	270883	67	W. Nonacho L.	61 39, 109 45
42	280883	165	W. Nonacho L.	61 39, 109 45
43	290883	51	W. Nonacho	61 41, 109 48
44	290883	12	W. Nonacho L.	61 39, 109 51
45	300883	19	Nonacho L.	61 44, 109 37
46	270684	146	N. Nonacho L.	62 05, 109 19
47	280684	55	N. Nonacho L.	62 05, 109 19
48	290684	220	N. Nonacho L.	62 10, 109 12
49	020784	60	N. Nonacho L.	62 10, 109 12
50	010784	234	N. Nonacho L.	62 06, 109 16
51	030784	60	N. Nonacho L.	62 08, 109 14
52	050784	210	N. Nonacho L.	62 08, 109 14
53	040784	62	N. Nonacho L.	62 08, 109 12
54	050784	210	N. Nonacho L.	62 08, 109 12
55	060784	55	N. Nonacho L.	62 05, 109 19
56	070784	55	N. Nonacho L.	62 07, 109 19
57	080784	103	W. Nonacho L.	62 05, 109 15
58	090784	189	N. Nonacho L.	62 05, 109 14
59	090784	105	N. Nonacho L.	62 05, 109 14
60	100784	189	N. Nonacho L.	62 05, 109 14
61	110784	66	N. Nonacho L.	61 59, 109 29
62	110784	160	N. Nonacho L.	61 59, 109 29
63	150784	75	Nonacho L.	61 47, 109 32
64	150784	116	Nonacho L.	61 47, 109 32
65	150784	75	Nonacho L.	61 47, 109 34
66	160784	129	Nonacho L.	61 47, 109 34
67	160784	122	Nonacho L.	61 47, 109 34
68	080884	160	W. Nonacho L.	61 43, 109 44
69	090884	55	W. Nonacho L.	61 43, 109 44
70	110884	164	W. Nonacho L.	61 42, 109 43
71	120884	101	W. Nonacho L.	61 42, 109 43
72	130884	155	W. Nonacho L.	61 42, 109 43
73	140884	103	W. Nonacho L.	61 42, 109 43
74	150884	243	W. Nonacho L.	61 42, 109 43
75	160884	20	W. Nonacho L.	61 44, 109 37
76	180884	229	Porter L.	61 43, 107 57
77	190884	76	Porter L.	61 43, 107 57
78	200884	74	Porter L.	61 41, 107 59
79	210884	260	Porter L.	61 41, 107 59

(continued)

Appendix 1 (continued)

Site no.	Date sampled ¹	Age (yr)	General location	Coordinates (N lat., W long.)
80	220884	166	S. Tejean L.	61 28, 108 38
81	220884	23	S. Tejean L.	61 28, 108 38
82	230884	62	W. of Porter L.	61 39, 108 15
83	230884	160	W. of Porter L.	61 39, 108 15
85	240884	29	McRea L.	61 37, 107 48
86	250884	162	S. Tejean L.	61 30, 108 31
87	250884	59	S. Tejean I.	61 30, 108 31
88	290884	267	Porter L.	61 42, 108 00
89	290884	154	Porter L.	61 41, 107 58
90	300884	225	N. Porter L.	61 48, 107 52
91	300884	18	N. Porter L.	61 48, 107 53
92	010785	127	Porter L.	61 46, 107 58
93	280685	225	Porter L.	61 46, 107 58
94	290685	236	Porter L.	61 47, 107 58
95	300685	163	S. Porter L.	61 33, 108 12
96	020785	226	Porter L.	61 33, 108 12
97	030785	240	Porter L.	61 42, 108 01
98	040785	171	D'Aoust L.	62 06, 108 46
99	040785	24	D'Aoust L.	62 06, 108 46
100	050785	212	E. Stewart L.	62 01, 109 04
101	050785	61	E. Stewart L.	62 01, 109 04
102	060785	195	S.E. Stewart L.	61 56, 109 00
103	060785	30	S.E. Stewart L.	61 56, 109 00
104	070785	45	Spearfish L.	60 49, 107 37
105	070785	137	Spearfish L.	60 49, 107 37
106	100785	29	Porter L.	61 33, 108 12
107	100785	1	Porter L.	61 42, 108 02
108	110785	160	S. Porter L.	61 32, 108 13
109	110785	65	S. Porter L.	61 32, 108 13
110	120785	3	N. Porter L.	61 48, 107 52
111	170785	6	N.E. Nonacho L.	61 55, 109 17
112	180785	76	N.E. Nonacho L.	61 47, 109 20
113	190785	97	N.E. Nonacho L.	61 47, 109 17
114	200785	52	Taltson R.	61 50, 108 58
115	200785	155	Taltson R.	61 50, 108 58
116	210785	55	Taltson R.	61 48, 108 42
117	220785	89	Taltson R.	61 48, 108 42
118	230785	84	N.E. Nonacho L.	61 49, 109 09
119	230785	225	N.E. Nonacho L.	61 49, 109 09
120	080885	53	Thekulthili L.	61 03, 110 08
121	090885	139	Thekulthili L.	61 03, 110 08

(continued)

Appendix 1 (continued)

Site no.	Date sampled ¹	Age (yr)	General location	Coordinates (N lat., W long.)
122	100885	146	S. Heron L.	61 05, 109 08
123	100885	43	S. Heron L.	61 05, 109 08
124	120885	85	Kidder L.	60 58, 109 15
125	120885	43	Kidder L.	60 58, 109 15
126	130885	43	Grampus L.	60 38, 109 12
127	130885	232	Grampus L.	60 38, 109 12
128	140885	58	Salmon L.	60 47, 109 45
129	140885	127	Salmon L.	60 47, 109 45
130	160885	44	Thekulthili L.	60 57, 110 12
131	180885	94	Thekulthili L.	60 57, 110 12
132	190885	77	Thekulthili L.	60 59, 110 05
133	200885	140	Thekulthili L.	60 59, 110 05
134	210885	133	Thekulthili L.	61 12, 109 50
135	220885	84	N. Sparks L.	61 16, 109 39
136	220885	29	N. Sparks L.	61 16, 109 39
137	240885	220	Thekulthili N.	61 12, 109 50
138	270885	84	Thekulthili L.	60 58, 110 09
139	270885	169	Thekulthili L.	60 58, 110 09
140	060786	76	Selwyn L.	60 07, 104 32
141	060786	194	Selwyn L.	60 07, 104 32
142	070786	180	Selwyn L.	60 07, 104 35
143	070786	76	Selwyn L.	60 05, 104 35
144	080786	14	Selwyn L.	60 11, 104 18
145	080786	126	Selwyn L.	60 11, 104 18
146	080686	56	Selwyn L.	60 15, 104 17
147	090786	193	Selwyn L.	60 15, 104 17
148	110786	57	Selwyn L.	60 12, 104 17
149	110786	200	Selwyn L.	60 12, 104 17
150	120786	180	Selwyn L.	60 05, 104 34
151	120786	57	Selwyn L.	60 05, 104 34
152	130786	206	Selwyn L.	60 07, 104 28
153	130786	50	Selwyn L.	60 07, 104 28
154	160786	218	Selwyn L.	60 02, 104 40
155	160786	16	Selwyn L.	60 02, 104 40
156	170786	163	Selwyn L.	60 01, 104 29
157	170786	127	Selwyn L.	60 01, 104 29
158	180786	73	Selwyn L.	60 03, 104 38
159	180786	200	Selwyn L.	60 03, 104 38
160	190786	170	Selwyn L.	60 09, 104 31
161	190786	77	Selwyn L.	60 09, 104 31

(continued)

Appendix 1 (continued)

Site no.	Date sampled ¹	Age (yr)	General location	Coordinates (N lat., W long.)
162	200786	31	Thye L.	60 17, 104 28
163	200786	127	Thye L.	60 17, 104 28
164	210786	36	W. of Turner L.	60 07, 104 52
165	210786	226	W. of Turner L.	60 07, 104 52
166	220786	43	N.E. of Turner L.	60 44, 105 10
167	220786	235	N.E. of Southby L.	60 44, 105 10
168	230786	180	W. of Selwyn L.	60 00, 105 59
169	230786	36	W. of Selwyn L.	60 00, 105 59
170	250786	197	Selwyn L.	60 03, 104 28
171	250786	56	Selwyn L.	60 03, 104 28
172	260786	34	Selwyn L. N.	60 15, 104 28
173	260786	123	Selwyn L. N.	60 15, 104 28
174	270786	201	Selwyn L.	60 12, 104 27
175	270786	71	Selwyn L.	60 12, 104 27
176	270786	210	Selwyn L.	60 12, 104 27
177	280786	50	Selwyn L.	60 07, 104 29
178	140886	107	Slave R.	59 55, 111 41
179	150886	54	Slave R.	59 55, 111 41
180	180886	54	Beauvais L.	60 27, 105 30
181	180886	227	Beauvais L.	60 27, 105 30
182	200886	79	Beauvais L.	60 30, 105 31
183	200886	212	Beauvais L.	60 30, 105 31
184	220886	30	Beauvais L. S.	60 22, 105 29
185	220886	204	Beauvais L. S.	60 22, 105 28
186	230886	77	Beauvais L.	60 27, 105 37
187	230886	225	Beauvais L.	60 27, 105 37
188	250886	54	Beauvais L.	60 19, 105 29
189	250886	235	Beauvais L.	60 19, 105 29
190	260886	55	Beauvais L.	60 27, 105 30
191	260886	80	Beauvais L.	60 27, 105 30
192	270886	33	E. Wignes L.	60 07, 105 33
193	270886	217	E. Wignes L.	60 07, 105 33
194	280886	222	W. Marchant L.	59 45, 106 06
195	280886	31	W. Marchant L.	59 45, 106 06
196	290886	176	Breynat L.	59 48, 105 21
197	290886	61	Breynat L.	59 48, 105 21
198	010986	51	Tazin L.	59 53, 108 46
199	010986	36	Carleton L.	60 20, 106 54

¹ Day Month Year.

Appendix 2. Aircraft used to transport people (TP), haul freight (HF) and sample sites (SS) in support of habitat studies conducted in summers of 1983 through 1986.

Year	Month	Day	Aircraft type	Hours	Purpose ¹
83	Jul	6	Single Otter	6.2	TP, HF
83	Jul	15	Cessna 206	2.6	HF
83	Jul	30	Cessna 185	5.6	TP
83	Aug	9	Single Otter	3.1	TP, HF
83	Aug	15	Cessna 185	2.6	TP, HF
83	Aug	30, 31	Cessna 185	5.2	TP
84	Jun	24, 25	Single Otter	8.1	TP, HF
84	Jun	27	Cessna 206	4.3	TP
84	Jul	19	Single Otter	2.9	TP
84	Aug	8	Twin Otter	2.0	TP, HF
84	Aug	12	Single Otter	1.1	TP
84	Aug	16, 18	Cessna 185	8.7	TP
84	Aug	31	Single Otter	3.8	TP
85	Jun	27	Twin Otter	4.0	TP, HF
85	Jul	3-8	Cessna 185	19.3	SS
85	Jul	14	Twin Otter	2.2	TP, HF
85	Jul	24	Twin Otter	3.9	TP, HF
85	Aug	7	Single Otter	2.0	TP
85	Aug	10-14	Cessna 185	18.5	SS
85	Aug	28, 29	Cessna 185	5.8	SS, TP
85	Aug	29	Single Otter	2.0	TP, HF
86	Jul	4, 5	Single Otter	11.0	TP, HF
86	Jul	5	Cessna 185	5.2	TP
86	Jul	14	Cessna 185	5.4	HF
86	Jul	19-25	Cessna 185	30.0	SS
86	Jul	29	Single Otter	3.7	TP, HF
86	Aug	17	Single Otter	4.5	TP
86	Aug	27-29	Cessna 185	18.7	SS
86	Aug	30, 31	Single Otter	7.6	TP, HF
86	Sep	1	Cessna 185	6.8	SS

¹ Purposes: TP = transport people, HF = haul freight, SS = systematic survey.

Appendix 3. Biomass of lichens in openings of upland sites at time periods after fire in forests on the winter range of the Beverly herd of caribou.

Age class (yr)	No. sites	Mean biomass (kg/ha) (SE)										
		<i>Cladina mitis</i> ¹	<i>Cladina rangif.</i>	<i>Cetraria nivalis</i>	<i>Cetraria island</i> ²	<i>Cladonia uncial.</i>	other	<i>Stereocaulon</i>	<i>Pelt. igera</i>	Total lichens	W'ted lichens	Caribou lichens ³
1-20	12	7 (4)	0	1 (1)	1 (0)	2 (2)	122 (64)	2 (2)	14 (7)	149 (65)	85 (34)	8 (4)
21-40	16	40 (8)	1 (0)	3 (2)	9 (4)	11 (3)	948 (113)	7 (2)	21 (11)	1036 (120)	553 (64)	44 (8)
41-60	34	801 (91)	29 (5)	40 (9)	38 (5)	218 (23)	1156 (97)	319 (106)	125 (33)	2726 (164)	1797 (109)	870 (96)
61-80	27	1059 (103)	25 (5)	69 (11)	53 (7)	293 (28)	734 (60)	957 (333)	74 (18)	3275 (334)	2035 (126)	1153 (111)
81-100	9	1353 (271)	60 (15)	75 (23)	35 (6)	359 (46)	569 (100)	346 (193)	85 (23)	2882 (403)	2158 (284)	1488 (247)
101-150	27	879 (85)	54 (11)	256 (42)	42 (4)	240 (27)	632 (58)	1203 (375)	39 (10)	3296 (380)	1994 (158)	1189 (113)
151-200	37	795 (58)	186 (33)	314 (28)	30 (4)	202 (17)	621 (44)	1643 (437)	36 (10)	3898 (452)	2201 (139)	1295 (94)
201-250	32	761 (81)	211 (38)	90 (41)	31 (3)	207 (19)	557 (40)	1895 (369)	30 (10)	4029 (395)	2190 (142)	1062 (114)
251-300	3	561 (161)	370 (186)	447 (192)	23 (18)	308 (73)	606 (153)	1520 (1400)	5 (5)	3851 (944)	2247 (95)	1378 (340)
1-50	38	127 (38)	5 (2)	5 (2)	9 (2)	49 (17)	770 (104)	37 (15)	56 (23)	1056 (148)	621 (94)	137 (40)
51-100	60	1065 (75)	34 (4)	63 (8)	47 (4)	282 (18)	860 (60)	642 (166)	90 (16)	3088 (179)	2029 (86)	1162 (75)

¹ *C. stellaris*.

² *Cetraria islandica* and *Cetr. arenaria*.

³ Sum of all species with *Cladonia* spp. reduced by 50% and *Stereocaulon* spp. by 75%.

⁴ Sum of *Cladina mitis*, *C. rangiferina*, and *Cetraria nivalis*.

Appendix 4. Biomass of lichens in forest openings of upland sites at time periods after fire in forests on caribou winter range west of 107°30'W.

Age class (yr)	No. sites	Mean biomass (kg/ha) (SE)										Total lichens	W'ted lichen ³	Caribou lichen ⁴
		<i>Cladina mitis</i> ¹	<i>C. rangif.</i>	<i>Cetraria nivalis</i>	<i>C. island</i> ²	<i>Cladonia uncial.</i>	other	<i>Stereo-caulon</i>	<i>Pelt.-igera</i>					
1-20	10	6 (4)	0	1 (1)	1 (1)	3 (3)	136 (76)	0	15 (9)	162 (77)	92 (40)	7 (5)		
21-40	8	22 (6)	1 (0)	5 (4)	2 (1)	7 (3)	759 (150)	4 (3)	15 (13)	814 (156)	428 (81)	28 (7)		
41-60	23	647 (89)	23 (6)	30 (7)	29 (5)	198 (24)	1132 (134)	270 (120)	159 (45)	2481 (173)	1616 (108)	700 (91)		
61-80	18	1029 (135)	24 (7)	72 (13)	52 (7)	275 (35)	767 (78)	262 (67)	68 (21)	2549 (176)	1831 (140)	1125 (128)		
81-100	9	1353 (271)	60 (15)	75 (23)	35 (6)	359 (46)	569 (100)	346 (193)	85 (23)	2881 (403)	2158 (284)	1488 (247)		
101-150	23	854 (96)	56 (12)	239 (46)	43 (5)	235 (30)	611 (63)	503 (138)	39 (11)	2576 (155)	1775 (138)	1147 (127)		
151-200	26	722 (54)	159 (37)	311 (35)	33 (5)	195 (18)	588 (39)	316 (125)	40 (14)	2366 (134)	1737 (97)	1192 (96)		
201-250	19	544 (64)	208 (45)	314 (64)	29 (5)	172 (20)	516 (49)	943 (387)	44 (16)	2776 (404)	1721 (143)	1066 (119)		
251-300	3	561 (161)	370 (186)	447 (192)	23 (18)	308 (73)	606 (153)	1520 (1400)	5 (5)	3851 (944)	2247 (95)	1378 (340)		
1-50	25	94 (34)	4 (2)	6 (3)	7 (2)	42 (19)	642 (131)	43 (22)	72 (35)	911 (186)	537 (116)	104 (35)		
51-100	43	1011 (92)	33 (5)	59 (8)	41 (4)	274 (21)	846 (74)	302 (78)	95 (20)	2656 (133)	1872 (95)	1103 (91)		

¹ Includes *C. stellaris*.

² *Cetraria islandica* and *Cetr. arenaria*.

³ Sum of all species with *Cladonia* spp. reduced by 50% and *Stereocaulon* spp. by 75%.

⁴ Sum of *Cladina mitis*, *C. rangiferina*, and *Cetraria nivalis*.

Appendix 5. Biomass of lichens in forest openings of upland sites at time intervals after fire on caribou winter range east of 107°30'W.

Age class (yr)	No. sites	Mean biomass (kg/ha) (SE)										Total lichen	W'ted lichen ³	Caribou lichen ⁴
		<i>Cladina mitis</i> ¹	<i>Cladina rangif.</i>	<i>Cetraria nivalis</i>	<i>Cetraria island</i> ²	<i>Cladonia uncial.</i>	other	<i>Stereo- caulon</i>	<i>Pelt.- iger</i>					
1-20	2	12 (11)	0	0	0	1 (1)	48 (47)	10 (10)	12 (5)	81 (64)	50 (33)	12 (7)		
21-40	8	59 (11)	1 (0)	1 (0)	15 (8)	16 (6)	1138 (148)	11 (3)	28 (20)	1258 (153)	678 (79)	61 (10)		
41-60	11	1123 (183)	43 (11)	60 (25)	55 (10)	256 (49)	1205 (116)	421 (217)	52 (31)	3237 (314)	2175 (217)	1226 (186)		
61-80	9	1120 (162)	28 (6)	63 (23)	54 (15)	329 (47)	666 (92)	2345 (836)	86 (34)	4728 (750)	2444 (201)	1211 (151)		
101-150	4	1020 (148)	40 (10)	351 (107)	34 (11)	249 (62)	758 (143)	5227 (1036)	40 (34)	7440 (858)	3250 (191)	1411 (174)		
151-200	11	966 (169)	250 (70)	321 (43)	22 (8)	218 (41)	700 (116)	4777 (904)	25 (9)	7520 (709)	3298 (82)	1537 (201)		
201-250	13	1079 (136)	214 (67)	254 (38)	33 (5)	258 (30)	618 (68)	3286 (516)	10 (5)	5860 (406)	2876 (132)	1547 (193)		

1-50	13	192 (91)	8 (4)	2 (1)	14 (5)	61 (36)	1017 (152)	24 (11)	25 (13)	1336 (236)	782 (157)	201 (92)		
51-100	17	1202 (127)	37 (8)	71 (19)	61 (9)	303 (35)	896 (104)	1501 (502)	75 (26)	4178 (442)	2428 (147)	131 (127)		

¹ Includes *C. stellaris*.

² *Cetraria islandica* and *Cetr. arenaria*.

³ Sum of all species with *Cladonia* spp. reduced by 50% and *Stereocaulon* spp. by 75%.

⁴ Sum of *Cladina mitis*, *C. rangiferina*, and *Cetraria nivalis*.

Appendix 6. Biomass of lichens at paired upland sites, usually across burn edges, in forests of various ages after fire on the winter range of the Beverly herd of caribou.

Site no.	Age (yrs)	Mean biomass (kg/ha)								Total lichen	W'ted lichen ³	Caribou lichen ⁴
		<i>Cladina mitis</i> ¹	<i>Cladina rangif.</i>	<i>Cetraria nivalis</i>	<i>Cetraria island</i> ²	<i>Cladonia uncial.</i>	<i>Cladonia other</i>	<i>Stereo- caulon</i>	<i>Pelt. iger</i>			
1	133	350	0	175	805	99	57	242	173	1902	1230	449
16	71	2160	15	385	1123	33	70	192	0	3979	3080	2208
20	71	881	16	130	378	45	19	168	46	1683	1302	942
2	74	770	5	148	212	16	13	7	1	1171	986	791
4	130	558	134	52	79	30	11	0	5	868	803	722
6	81	901	89	170	185	157	35	0	0	1537	1359	1147
7	81	807	2	369	996	26	20	156	150	2527	1727	835
8	154	580	2	385	779	298	64	111	273	2492	1827	880
9	154	512	7	186	445	106	51	24	49	1381	1047	625
10	168	536	30	219	460	250	39	85	52	1671	1268	816
11	74	716	3	136	470	68	41	633	68	2142	1361	787
17	120	639	27	193	729	203	66	318	103	2277	1578	869
13	73	1349	1	537	982	85	121	628	5	3709	2478	1435
14	154	1113	1	331	992	308	80	1	3	2830	2167	1422
18	61	477	47	211	680	86	26	401	218	2148	1401	610
19	134	626	125	125	640	118	55	992	14	2695	1568	869
21	16	0	0	0	16	0	5	0	0	21	13	0
22	136	1189	18	206	735	248	57	2	9	2464	1992	1455
24	150	792	15	246	949	492	68	0	0	2562	1965	1299
25	55	1497	19	231	1461	63	9	4	0	3283	2434	1579
26	260	553	423	213	669	830	7	0	0	2696	2255	1806
27	166	631	282	246	729	249	12	41	12	2203	1684	1162
28	51	808	49	260	982	55	11	286	4	2276	1508	912
29	164	982	397	114	651	786	24	173	12	3138	2626	2165
43	51	635	11	65	1853	5	40	292	56	2957	1779	651
30	17	1	0	1	84	0	0	0	0	86	43	1
31	210	1301	359	190	581	178	20	20	0	2648	2248	1838
32	111	1115	40	127	374	129	31	53	5	1762	1471	1284
33	27	51	2	22	820	0	1	3	11	909	486	53

(continued)

Appendix 6 (continued)

Site no.	Age (yrs)	Mean biomass (kg/ha)								Total lichens	W'ted lichen ³	Caribou lichen ⁴
		<i>Cladina mitis</i> ¹	<i>Cladina rangif.</i>	<i>Cetraria nivalis</i>	<i>Cetraria island</i> ²	<i>Cladonia uncial</i>	other	<i>Stereo- caulon</i>	<i>Pelt.- iger</i>			
34	187	1153	397	286	970	349	53	0	6	3215	2587	1899
35	41	251	28	131	2706	66	10	0	187	3378	1959	345
36	41	206	57	78	694	1	27	0	824	1887	1501	264
37	28	8	1	3	854	6	2	0	0	874	446	15
38	162	581	193	125	381	158	15	0	3	1455	1202	932
39	108	700	12	283	633	206	77	0	23	1935	1476	918
40	51	598	47	143	497	22	16	152	3	1479	1045	667
41	67	1246	24	203	610	11	18	13	0	2126	1710	1281
42	165	936	328	154	379	210	9	10	0	2026	1751	1474
46	146	623	97	177	602	67	9	704	93	2372	1454	787
47	55	211	48	213	323	3	6	337	592	1734	1213	262
55	55	530	7	273	1158	12	39	102	327	2448	1656	549
48	220	489	336	99	359	165	2	1	21	1472	1242	987
49	60	637	55	242	887	54	18	0	5	1897	1333	746
50	234	480	2	363	1032	52	53	3097	9	5089	2068	534
56	55	855	18	161	390	14	56	2727	77	4299	1977	887
57	103	397	53	158	348	193	68	1352	21	2590	1323	643
51	60	535	13	297	1584	33	44	0	191	2697	1756	581
52	210	478	133	234	400	89	17	13	145	1510	1183	700
53	62	705	23	234	1261	8	26	3	312	2571	1822	736
54	210	427	460	127	188	117	13	0	223	1555	1398	1004
58	189	765	39	133	491	542	39	0	48	2058	1746	1346
59	105	961	10	307	385	33	70	17	23	1806	1447	1004
60	189	833	26	266	512	336	34	100	90	2197	1733	1195
61	66	1013	9	681	671	42	97	776	162	3451	2193	1064
62	160	489	3	206	564	4	51	368	41	1725	1064	496
63	75	785	4	188	711	105	81	176	79	2128	1547	894
64	116	573	30	174	518	99	23	125	171	1714	1274	702
65	75	555	11	203	566	128	61	157	167	1848	1346	694
66	129	859	21	383	542	88	60	416	99	2468	1694	968
67	122	221	15	123	242	36	24	2172	26	2859	1048	272

(continued)

Appendix 6 (continued)

Site no.	Age (yrs)	Mean biomass (kg/ha)								Total lichens	W'ted lichen ³	Caribou lichen ⁴
		<i>Cladina mitis</i> ¹	<i>Cladina rangif.</i>	<i>Cetraria nivalis</i>	<i>Cetraria island</i> ²	<i>Cladonia uncial</i>	other	<i>Stereo- caulon</i>	<i>Pelt.- iger</i>			
68	160	1257	347	266	645	263	8	0	0	2886	2331	1867
69	55	434	3	226	2476	3	31	0	108	3280	1929	440
70	164	688	395	121	537	246	13	20	23	2045	1700	1329
71	101	1191	51	297	576	138	63	128	41	2486	1953	1380
72	155	699	303	248	717	170	24	3	0	2165	1680	1172
73	103	1595	182	378	1418	205	51	55	34	3919	2979	1982
74	243	303	693	141	511	238	11	0	0	1896	1571	1234
76	229	290	36	168	696	238	46	151	3	1628	1083	564
77	76	892	15	305	514	47	70	854	21	2717	1668	954
78	74	626	134	217	1245	209	65	398	4	2896	1867	969
79	260	285	24	452	316	237	60	4317	0	5723	2078	546
80	166	432	58	103	536	517	37	79	0	1763	1383	1007
81	23	5	0	0	760	0	1	0	0	766	386	5
82	62	568	16	306	1269	170	75	20	4	2427	1625	754
83	160	457	23	137	399	316	40	1949	7	3327	1598	796
84	203	666	75	206	495	394	54	1798	0	3688	1989	1135
85	29	35	0	12	723	0	7	24	0	802	417	35
86	162	264	19	126	682	306	11	1522	60	2991	1445	589
87	59	674	8	74	773	31	95	52	0	1707	1244	713
90	225	529	5	314	537	387	43	6427	0	8332	3018	921
91	18	6	0	1	456	0	1	0	0	464	235	6
92	127	277	8	217	289	359	28	1212	0	2390	1227	644
88	267	844	662	259	833	275	3	243	15	3135	2407	1781
89	154	877	101	207	815	201	30	270	35	2536	1823	1179
93	225	309	5	173	614	462	72	1619	1	3255	1647	776
94	236	533	20	138	355	348	21	3293	13	4740	2010	901
95	163	338	11	71	196	216	16	2282	45	3175	1331	565
108	160	585	114	109	464	467	13	2	0	1756	1468	1166
109	65	768	7	102	834	58	40	108	0	1918	1368	833
96	226	479	226	230	422	292	49	0	0	1698	1372	997
106	29	27	2	10	1376	2	1	0	2	1420	727	31

(continued)

Appendix 6 (continued)

Site no.	Age (yrs)	Mean biomass (kg/ha)								Total lichens	W'ted lichen ³	Caribou lichen ⁴
		<i>Cladina mitis</i> ¹	<i>Cladina rangif.</i>	<i>Cetraria nivalis</i>	<i>Cetraria island</i> ²	<i>Cladonia uncial</i>	other	<i>Stereo- caulon</i>	<i>Pelt.- igera</i>			
98	171	871	6	219	391	369	108	0	0	1965	1660	1246
99	24	1	0	0	79	0	1	0	0	81	42	1
100	212	664	259	146	517	240	19	343	8	2197	1608	1163
101	61	768	23	317	1079	74	33	164	74	2532	1711	865
102	195	488	72	121	501	608	33	0	0	1823	1513	1168
103	30	34	1	8	283	29	2	2	0	359	211	64
104	45	97	4	6	495	0	39	332	8	982	483	101
105	137	275	16	97	168	142	8	2122	8	2836	1112	433
112	76	1690	42	340	850	55	70	13	23	3082	2477	1787
113	97	718	37	302	815	66	56	38	57	2089	1502	821
114	52	972	6	243	1037	103	66	907	107	3442	2121	1081
115	155	779	11	420	919	199	40	1099	266	3732	2238	989
116	55	574	113	213	1169	25	28	23	495	2640	1931	712
117	89	622	144	303	689	196	65	874	197	3090	1938	962
118	84	617	94	252	385	11	37	272	120	1787	1265	722
119	225	419	283	132	612	252	20	304	99	2122	1522	954
120	53	1682	11	395	614	132	27	118	62	3041	2848	1825
121	139	1792	128	341	703	439	40	123	4	3572	2957	2359
122	146	633	23	192	1011	518	48	667	13	3104	2003	1174
123	43	266	1	101	940	37	10	200	28	1583	913	304
124	85	1452	7	426	201	58	45	3	37	2229	1913	1517
125	43	491	3	208	1209	1	39	1	210	2162	1453	495
126	43	115	1	26	1690	0	9	411	29	2280	1114	116
127	232	1096	304	307	931	392	50	258	64	3402	2589	1792
128	58	1440	8	391	1761	6	13	0	0	3620	2544	1454
129	127	1458	18	752	826	211	22	99	0	3386	2523	1687
130	44	687	8	414	879	8	14	104	260	2375	1650	703
131	94	2797	47	348	355	29	28	65	35	3705	3305	2873

(continued)

Appendix 6 (continued)

Site no.	Age (yrs)	Mean biomass (kg/ha)								Total lichens	Wted lichen ³	Caribou lichen ⁴
		<i>Cladonia mitis</i> ¹	<i>Cladonia rangif.</i>	<i>Cetraria nivalis</i>	<i>Cetraria island</i> ²	<i>Cladonia uncial</i>	other	<i>Stereo- caulon</i>	<i>Pelt.- iger</i>			
132	77	2545	40	302	350	58	13	12	36	3356	3021	2643
133	140	1538	196	231	683	952	26	0	0	3625	3168	2686
134	133	1278	69	178	792	505	34	771	22	3649	2586	1852
137	220	887	344	148	583	1027	4	0	0	2993	2628	2258
135	84	2199	50	667	627	1	12	0	22	3577	2930	2250
136	29	14	0	1	1178	0	1	0	104	1298	709	14
138	84	2067	69	396	869	131	13	1702	143	5391	3482	2267
139	169	1293	742	102	670	566	7	54	2	3437	3010	2601
140	76	1098	23	271	759	22	12	5092	41	7040	2915	1143
141	194	604	373	55	244	216	0	4923	25	7083	2758	1193
142	180	760	41	238	1142	353	21	5509	27	8092	3270	1154
143	76	327	29	305	463	119	14	7240	107	9107	2916	475
144	14	1	0	0	1	0	0	0	16	17	17	1
145	126	1136	21	234	539	82	11	4653	7	6569	2693	1239
146	56	1809	40	188	442	40	42	24	0	2586	2253	1889
147	193	1657	370	170	336	176	3	3889	1	6875	3500	2203
148	57	2000	114	253	1371	91	109	50	29	4017	3167	2205
149	200	489	34	182	603	182	11	9877	0	10957	3473	705
150	180	892	223	288	1417	274	94	2632	85	5906	3079	1389
151	57	1376	55	554	1307	90	86	464	348	4280	3002	1521
152	206	1034	527	222	494	382	15	3122	11	5863	3121	1943
153	50	901	42	472	1431	2	14	155	73	3091	2023	945
154	218	341	165	440	627	99	39	6142	40	8079	2799	605
155	16	22	0	1	95	0	0	19	7	144	82	22
156	163	1429	516	466	1189	357	1	840	0	4798	3341	2302
157	127	706	52	350	998	276	31	7035	2	9149	3529	1034
158	73	1512	30	400	551	25	71	2664	95	5349	2876	1567
159	200	681	43	449	562	192	18	7169	50	10425	3597	916

(continued)

Appendix 6 (continued)

Site no.	Age (yrs)	Mean biomass (kg/ha)								Total lichens	W'ted lichen ³	Caribou lichen ⁴
		<i>Cladina mitis</i> ¹	<i>Cladina rangif.</i>	<i>Cetraria nivalis</i>	<i>Cetraria island</i> ²	<i>Cladonia uncial</i>	other	<i>Stereo- caulon</i>	<i>Pelt.- iger</i>			
160	170	405	15	71	462	590	19	7907	0	10256	3469	1010
161	77	1657	20	626	978	16	44	495	322	4158	2985	1693
162	31	57	4	34	1229	2	3	24	154	1429	816	63
163	127	1376	61	333	1010	534	64	2545	10	5471	3320	1971
164	36	27	1	4	1364	0	11	14	65	1487	792	28
165	226	947	19	247	411	115	32	3046	5	5652	2416	1081
166	43	149	8	51	1478	6	33	23	0	1749	967	163
167	235	801	45	211	325	449	58	2005	0	3894	2122	1295
168	180	1292	440	157	414	468	22	1794	22	4633	2988	2200
169	36	43	0	4	880	2	5	23	0	958	498	45
170	197	776	34	117	578	236	51	6904	4	8771	3192	1046
171	56	1226	20	319	1330	14	50	665	21	3545	2220	1260
172	34	67	1	43	1491	0	18	4	0	1624	855	68
173	123	861	24	79	483	513	28	6676	142	8573	3459	1398
174	201	877	27	184	494	195	34	4828	1	6640	2680	1099
175	71	917	5	192	448	81	28	3263	65	5109	2259	1003
176	210	791	213	87	437	503	10	2652	8	4700	2449	1507
177	50	949	38	144	1144	10	14	30	0	2299	1648	997
180	54	633	19	170	718	134	74	94	0	1843	1328	786
181	227	1280	190	351	922	168	56	2315	4	5286	2914	1638
190	55	351	11	159	1219	5	46	2453	2	4469	1773	367
182	79	1232	65	228	594	215	121	4	0	2459	2045	1512
183	212	1123	69	216	727	155	61	2916	1	5266	2608	1347
191	80	1225	31	259	383	69	132	48	0	2046	1689	1325
184	30	12	0	0	674	0	7	2	0	696	357	12
185	204	1234	60	352	568	146	22	4406	0	6951	3065	1440
186	77	492	8	225	602	9	48	1795	10	3189	1429	509
187	225	477	10	221	630	205	28	5130	0	7347	2590	692

(continued)

Appendix 6 (continued)

Site no.	Age (yrs)	Mean biomass (kg/ha)								Total lichen	Wted lichen ³	Caribou lichen ⁴
		<i>Cladina mitis</i> ¹	<i>Cladina rangif.</i>	<i>Cetraria nivalis</i>	<i>Cetraria island</i> ²	<i>Cladonia uncial.</i>	<i>Cladonia other</i>	<i>Stereo-caulon</i>	<i>Pelt. igera</i>			
188	54	1238	102	432	1856	262	98	649	29	4666	3036	1602
189	235	1161	423	215	718	171	42	5041	0	8136	3615	1755
132	77	2545	40	302	350	58	13	12	36	3356	3021	2643
192	33	91	2	27	1777	0	2	0	1	1901	999	93
193	217	2138	812	155	445	416	2	119	50	4138	3748	3366
194	222	1819	226	455	1231	303	29	165	3	4230	3263	2348
195	31	71	0	12	1135	0	6	2	4	1230	655	71
196	176	1636	653	208	757	489	5	1106	63	4918	3606	2778
197	61	1720	38	455	1220	7	18	502	132	4093	2879	1765

¹ Includes *C. stellaris*.² *Cetraria islandica* and *Cetr. arenaria*.³ Sum of all species with *Cladonia* spp. reduced by 50% and *Stereocaulon* spp. by 75%.⁴ Sum of *Cladina mitis*, *C. rangiferina*, and *Cetraria nivalis*.

Appendix 7. Biomass of major vascular plant species in forest openings at 197 upland sites at time periods after fire on the winter range of the Beverly herd of caribou.

Age class (yr)	No. of sites	Mean biomass (kg/ha) ¹ (SE)							
		<i>Vaccinium vitis-idaea</i>	"Other <i>Vaccinium</i> " spp.	<i>Ledum</i> spp.	<i>Empetrum</i> sp.	<i>Arcto-staph.</i>	<i>Lois-eularia</i>	Grasses/ sedges	<i>Geo-caulon</i>
1-20	12	166.3 (34.0)	12.6 (8.4)	60.4 (33.1)	0	15.4 (11.5)	0	10.5 (8.0)	1.5 (1.2)
21-40	16	172.4 (41.0)	11.9 (6.9)	34.0 (6.2)	13.0 (7.3)	5.0 (3.3)	1.3 (1.2)	2.1 (0.9)	0
41-60	34	315.8 (37.7)	9.6 (3.1)	37.6 (7.1)	17.3 (6.1)	20.2 (9.7)	2.4 (1.4)	1.0 (0.7)	4.5 (2.7)
61-80	26	209.7 (23.9)	12.4 (3.7)	36.7 (7.8)	33.2 (12.0)	6.1 (3.7)	0.1 (0.1)	1.0 (0.5)	1.3 (0.5)
81-100	19	160.3 (39.5)	1.8 (1.3)	25.2 (10.7)	9.1 (7.9)	0.5 (0.4)	0	0.3 (0.2)	2.8 (1.0)
101-150	25	168.8 (21.5)	14.8 (5.1)	22.1 (3.6)	10.9 (4.8)	1.4 (1.4)	6.0 (6.0)	0.9 (0.5)	4.7 (1.2)
151-200	37	202.9 (21.8)	6.7 (2.2)	23.5 (5.2)	30.1 (9.1)	0.5 (0.5)	8.2 (4.8)	0.4 (0.2)	4.0 (1.1)
201-250	31	190.1 (22.3)	11.8 (3.0)	21.8 (4.9)	18.1 (5.3)	4.4 (3.0)	18.0 (8.6)	0.3 (0.2)	3.4 (1.0)
251-300	3	221.3 (124.7)	12.3 (12.3)	39.3 (19.7)	0	0	0	1.0 (1.0)	0.7 (0.5)
1- 50	38	206.2 (28.1)	9.6 (4.0)	42.0 (11.1)	7.2 (3.4)	20.0 (9.4)	0.9 (0.6)	4.2 (2.6)	2.6 (1.5)
51-100	59	246.6 (23.5)	10.9 (2.4)	36.2 (5.2)	24.9 (6.4)	6.2 (2.4)	1.2 (0.8)	1.0 (0.5)	2.2 (0.6)

¹ Leaves and current-year woody tissues of shrubs.

Appendix 8. Biomass of major vascular plant species in forest openings of upland sites at time periods after fire on caribou winter range west of 107°30'W.

Age class (yr)	No. of sites	Mean biomass (kg/ha) ¹ (SE)							
		<i>Vaccinium vitis-idaea</i>	"Other <i>Vaccinium</i> " spp.	<i>Ledum</i> spp.	<i>Empetrum</i> sp.	<i>Arctostaph.</i>	<i>Loiseularia</i>	Grasses/sedges	<i>Geocaulon</i>
1-20	10	158.1 (35.5)	9.8 (9.0)	66.0 (39.5)	0	5.2 (5.2)	0	11.2 (9.7)	1.8 (1.5)
21-40	8	227.8 (74.2)	6.9 (6.5)	22.9 (7.7)	10.0 (10.0)	10.0 (6.2)	2.5 (2.5)	2.9 (1.5)	0
41-60	23	316.0 (50.9)	9.4 (4.3)	30.1 (8.1)	7.8 (5.1)	25.6 (14.5)	1.2 (1.2)	1.4 (1.0)	5.4 (2.6)
61-80	18	196.4 (24.8)	7.8 (2.8)	34.5 (9.6)	32.8 (17.9)	3.7 (2.7)	0	0.1 (0.1)	0.9 (0.6)
81-100	8	160.3 (39.5)	1.8 (1.3)	25.2 (10.7)	9.1 (8.0)	0.5	0	0.3 (0.2)	2.8 (1.6)
101-150	21	175.2 (25.2)	14.5 (5.9)	19.2 (3.5)	9.2 (5.3)	1.7 (1.6)	7.1 (7.1)	0.7 (0.4)	4.7 (1.3)
151-200	26	193.7 (28.5)	8.0 (3.1)	19.5 (5.6)	17.4 (8.7)	0.8 (0.7)	11.7 (6.7)	0.6 (0.3)	5.0 (1.4)
201-250	18	184.2 (32.2)	6.4 (2.4)	14.6 (6.0)	12.9 (6.3)	0.8 (0.8)	7.0 (7.0)	0.5 0.3	4.4 (1.5)
251-300	3	221.3 (124.8)	12.3 (12.3)	39.3 (19.7)	0	0	0	1.0 (1.0)	0.7 (0.5)
1- 50	25	210.9 (33.4)	6.1 (4.1)	39.7 (16.4)	5.0 (3.6)	25.0 (13.2)	0.8 (0.8)	5.4 (3.9)	4.0 (2.3)
51-100	42	242.4 (30.6)	8.7 (2.6)	32.3 (5.9)	18.4 (8.0)	4.0 (2.1)	0.6 (0.6)	0.9 (0.6)	1.9 (0.7)

¹ No biomass was obtained at sites 1 - 4.

Appendix 9. Biomass of major vascular plant species in forest openings of upland sites at time periods after fire on caribou winter range east of 107°30'W.

Age class (yr)	No. of sites	Mean biomass (kg/ha) ¹ (SE)							
		<i>Vaccinium vitis-idaea</i>	"Other <i>Vaccinium</i> " spp.	<i>Ledum</i> spp.	<i>Empetrum</i> sp.	<i>Arcto-staph.</i>	<i>Lois-eularia</i>	Grasses/ sedges	<i>Geo-caulon</i>
1-20	2	207.0 (132.0)	26.5 (26.5)	32.5 (32.5)	0	66.5 (66.5)	0	7.0 (7.0)	0
21-40	8	117.1 (28.6)	16.9 (12.5)	45.1 (8.2)	16.0 (11.1)	0	0	1.3 (1.1)	0
41-60	11	315.5 (50.8)	10.2 (4.1)	53.1 (13.3)	37.3 (14.2)	9.0 (6.2)	4.9 (3.8)	0.2 (0.1)	2.7 (1.5)
61-80	9	234.8 (51.9)	21.2 (8.9)	41.0 (14.2)	34.1 (8.9)	10.9 (9.9)	0.3 (0.3)	2.7 (1.3)	2.1 (0.6)
101-150	4	135.3 (23.5)	16.5 (9.0)	37.0 (11.7)	19.5 (11.9)	0	0	2.0 (2.0)	4.5 (3.6)
151-200	11	224.5 (29.8)	3.8 (2.0)	32.8 (11.1)	60.0 (20.9)	0	0	0	1.5 (0.6)
201-250	13	198.2 (30.2)	19.2 (5.8)	31.9 (7.5)	25.4 (9.1)	9.2 (6.7)	33.3 (17.7)	0	2.0 (1.2)
1-50	13	197.1 (52.9)	16.4 (8.4)	46.3 (8.3)	11.5 (7.0)	10.2 (10.2)	1.0 (1.0)	2.0 (1.2)	0
51-100	17	257.2 (32.1)	16.4 (5.3)	45.7 (10.6)	40.9 (9.5)	11.6 (6.4)	2.6 (2.4)	1.4 (0.8)	2.9 (1.0)

Appendix 10. Estimated cover of lichens at periods after fire at 197 upland sites on the winter range of the Beverly herd of caribou.

Age class (yr)	No. of sites	Mean cover (%) (SE)										
		<i>Cladina mitis</i> ¹		<i>Cetraria rangif. nivalis</i>		<i>Cladonia island</i> ²		<i>Cladonia uncial.</i>	<i>Stereo- other</i>	<i>Stereo- caulon</i>	<i>Peltig- iger</i>	Total lichen
1-20	12	0.8 (0.3)	0	0.2 (0.1)	0	0.2 (0.1)	4.2 (2.2)	0	1.3 (0.8)	6.6 (2.6)	1.0 (0.3)	2.3 (1.0)
21-40	16	3.0 (0.4)	0	0.1 (0.1)	0.6 (0.3)	0.6 (0.2)	17.8 (1.8)	0.6 (0.3)	1.1 (0.5)	23.7 (2.2)	3.1 (0.6)	4.2 (0.8)
41-60	34	21.4 (1.9)	0.9 (0.2)	1.7 (0.4)	1.3 (0.2)	3.8 (0.5)	15.7 (1.4)	4.4 (1.2)	3.7 (1.1)	52.9 (2.0)	24.0 (2.0)	27.7 (2.0)
61-80	27	29.6 (2.2)	1.1 (0.3)	3.6 (0.6)	2.7 (0.4)	4.9 (0.6)	11.7 (1.3)	10.0 (2.7)	1.5 (0.4)	65.1 (2.1)	34.3 (2.2)	35.8 (2.1)
81-100	9	35.9 (4.1)	2.9 (1.4)	3.6 (1.1)	1.6 (0.5)	5.6 (1.4)	9.4 (0.4)	4.0 (1.9)	2.2 (0.6)	65.1 (2.4)	42.4 (3.8)	44.6 (3.3)
100-150	27	24.7 (1.9)	2.4 (0.5)	10.5 (1.7)	1.9 (0.3)	4.4 (0.7)	9.9 (0.8)	12.8 (3.3)	1.3 (0.4)	67.8 (2.0)	37.6 (2.0)	37.9 (2.9)
151-200	37	22.5 (1.4)	5.2 (1.0)	12.7 (1.1)	1.3 (0.3)	2.3 (0.3)	9.6 (0.9)	14.3 (3.2)	0.9 (0.2)	68.9 (1.8)	40.4 (1.9)	41.3 (2.4)
201-250	32	20.3 (1.4)	5.7 (0.9)	10.2 (1.2)	1.8 (0.3)	3.0 (0.5)	7.9 (0.7)	20.8 (3.6)	0.7 (0.3)	70.4 (2.1)	36.2 (1.9)	36.9 (2.4)
251-300	3	16.7 (4.9)	7.0 (4.0)	17.7 (5.7)	1.7 (1.2)	4.0 (2.3)	10.0 (2.6)	16.0 (14.5)	2.3 (2.3)	75.3 (4.3)	41.4 (8.1)	43.7 (11.4)

1-50	38	5.1 (2.1)	0.1 (0.1)	0.2 (0.1)	0.5 (0.2)	1.1 (0.3)	14.0 (1.7)	0.6 (0.3)	2.4 (0.9)	24.0 (2.9)	5.4 (1.2)	7.8 (1.7)
51-100	60	28.6 (1.5)	1.4 (0.3)	3.0 (0.4)	2.0 (0.2)	4.7 (0.4)	12.3 (0.9)	7.3 (1.4)	2.2 (0.4)	61.4 (1.4)	33.0 (2.2)	35.2 (1.5)

¹ Includes *C. stellaris*.

² Includes *Cet. arenaria*.

³ *C. mitis*, *C. rangiferina* and *Cet. nivalis*.

Appendix 11. Estimated cover of vascular plants and other surface elements at intervals after fire at 197 upland sites on the winter range of the Beverly herd of caribou.

Age class (yr)	No. of sites	Mean cover (%) (SE)											
		<i>Vacc. vitis-idaea</i>	"Other <i>Vacc.</i> " spp.	<i>Ledum</i> spp.	<i>Empetrum</i> spp.	<i>Arctostaphylos</i> spp.	<i>Loiseleuria</i> spp.	Grass/ sedge	<i>Geocaulon</i>	Moss	Litter ¹	Gd/ rock	Crustose lichens
1-20	12	7.3 (1.4)	0.7 (0.5)	1.8 (0.9)	0 (0.3)	0.5 0	0	0.9 (0.6)	0.1 (0.1)	21.8 (6.0)	10.8 (6.4)	50.2 (8.1)	3.4 (1.2)
21-40	16	7.9 (1.4)	1.0 (0.7)	1.8 (0.3)	0.6 (0.3)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0	14.1 (4.2)	10.8 (2.2)	24.4 (2.3)	12.4 (2.8)
41-60	34	12.3 (1.2)	1.0 (0.3)	1.7 (0.3)	0.6 (0.2)	0.4 (0.2)	0.1 (0.1)	0	0.4 (0.1)	4.8 (1.1)	11.9 (1.7)	10.8 (1.1)	2.4 (0.7)
61-80	27	9.7 (0.7)	0.8 (0.3)	1.7 (0.3)	1.0 (0.4)	0.2 (0.1)		0	0.3 (0.1)	3.1 (0.6)	7.7 (4.7)	8.6 (1.4)	2.2 (0.7)
81-100	9	8.6 (0.9)	0.1 (0.1)	1.1 (0.4)	0.4 (0.4)	0	0	0	0.4 (0.2)	6.4 (1.5)	11.0 (2.2)	4.8 (1.1)	1.3 (0.6)
101-150	27	8.6 (1.0)	1.1 (0.4)	1.3 (0.2)	0.5 (0.2)	0	0.1 (0.1)	0	0.4 (0.1)	6.1 (1.4)	5.3 (1.0)	6.7 (0.8)	1.4 (0.4)
151-200	37	9.6 (0.6)	0.8 (0.3)	1.2 (0.2)	0.8 (0.2)	0	0.1 (0.1)	0	0.4 (0.1)	5.5 (1.1)	4.2 (0.6)	6.6 (0.7)	1.7 (0.4)
201-250	32	8.1 (0.8)	0.9 (0.2)	1.2 (0.2)	0.7 (0.2)	0.1 (0.1)	0.3 (0.2)	0	0.4 (0.1)	6.0 (1.0)	4.7 (0.6)	6.4 (0.6)	0.8 (0.2)
251-300	3	11.3 (4.4)	0.7 (0.6)	3.0 (1.6)	0	0	0	0	0.3 (0.3)	1.3 (0.4)	1.3 (0.9)	6.0 (1.5)	1.0 (0.6)
<hr/>													
1-50	38	8.8 (0.9)	0.7 (0.3)	1.7 (0.3)	0.3 (0.2)	0.4 (0.2)	0	0.3 (0.2)	0.1 (0.1)	14.7 (2.8)	12.9 (2.4)	28.5 (3.8)	7.2 (1.5)
51-100	60	10.6 (0.7)	0.9 (0.2)	1.6 (0.2)	0.8 (0.2)	0.2 (0.1)	0.1 (0)	0	0.3 (0.1)	3.9 (0.5)	8.9 (0.9)	9.2 (0.9)	2.0 (0.4)

¹ Needles, dead leaves and twigs.

Appendix 12. Percent cover of lichens at 20-year periods after fire at 148 upland sites on the winter range of the Beverly herd of caribou as estimated from 1000 line intercepts at each site.

Age class (yr)	Mean lichen cover (%)			<i>n</i>
	Mean	Standard deviation	Standard error	
1 - 20	16.9	25.6	10.5	7
21 - 40	29.6	22.0	6.1	14
41 - 60	55.0	19.9	4.0	26
61 - 80	66.0	14.9	3.5	19
81 - 100	67.9	18.9	7.7	7
101 - 120	78.2	9.4	4.7	5
121 - 140	73.7	11.3	3.4	12
141 - 160	78.2	10.5	3.7	9
161 - 180	74.9	7.6	2.4	11
181 - 200	77.6	9.2	3.5	8
201 - 220	76.3	13.5	4.1	12
221 - 240	79.7	8.0	2.2	15
241 - 260	58.0	27.0	27.0	2
261 - 280	83.0	0	0	1

Appendix 13. Frequency of occurrence of lichens with measurable biomass in 25 x 50 cm quadrats at 50-year periods after fire at sites located west and east of 107°W and at combined sites on the winter range of the Beverly herd of caribou.

Age class (yr)	No. of quadrats	Mean frequency of occurrence (%)							
		<i>Cladina mitis</i> ¹	<i>rang.</i>	<i>Cetraria nivalis</i>	<i>island.</i> ²	<i>Cladonia uncial.</i>	other	<i>Stereo-caulon</i>	<i>Peltigera</i>
West									
1-50	322	64.6	17.7	16.8	41.3	39.1	74.8	19.9	26.7
51-100	411	97.6	62.3	67.9	89.3	97.8	99.0	47.7	47.4
101-150	226	100.0	75.3	95.6	92.5	97.4	100.0	58.6	37.0
151-200	257	100.0	79.8	96.5	88.3	98.8	99.2	35.8	26.1
201-250	198	100.0	77.8	96.5	80.3	88.9	99.5	51.5	26.8
251-300	30	100.0	86.7	96.7	63.3	93.3	100.0	43.3	10.0
All	1444	92.0	60.1	70.4	77.2	83.5	93.9	41.5	33.8
East									
1-50	179	87.7	37.4	15.1	72.1	53.9	93.9	29.1	21.2
51-100	175	99.4	83.4	70.9	95.4	99.4	98.9	70.3	38.3
101-150	40	100.0	85.0	82.5	85.0	100.0	100.0	94.9	37.5
151-200	115	100.0	91.3	96.5	66.1	98.3	100.0	91.3	23.5
201-250	130	100.0	95.4	99.2	83.1	99.2	100.0	93.1	16.9
All	639	96.4	74.5	67.0	80.4	86.5	98.0	68.7	26.4
West and east									
1-50	501	72.9	13.4	16.2	52.3	44.4	81.6	23.2	79.7
51-100	586	96.6	68.6	68.8	91.1	98.3	99.0	54.4	44.7
101-150	267	100.0	76.8	95.1	91.4	97.7	100.0	63.8	37.1
151-200	372	100.0	83.3	96.5	81.5	98.7	99.5	53.0	25.3
201-250	328	100.0	84.8	97.6	81.4	93.0	99.7	68.0	22.9
251-300	30	100.0	86.7	96.7	63.3	93.3	100.0	43.3	10.0
All	2084	93.4	64.5	69.4	78.2	84.4	95.2	49.8	31.5

¹ Includes *C. stellaris*.

² *Cetraria islandica* and *Cet. arenaria*.

Appendix 14. Frequency of occurrence of vascular plants with measurable biomass in 25 x 50 cm quadrats at 50-year periods after fire at sites located west and east of 107°W and at combined sites on the winter range of the Beverly herd of caribou.

Age class (yr)	No. of quadrats	Mean frequency of occurrence (%)							
		<i>Vaccinium vitis-idaea</i>	"Other <i>Vaccinium</i> " spp.	<i>Ledum</i> spp.	<i>Empetrum</i> spp.	<i>Arctostaphylos</i> spp.	<i>Loiseleuria</i> spp.	Grasses and sedges	<i>Geocaulon</i> spp.
West									
1-50	322	78.3	3.4	19.9	0.6	6.2	0.6	11.5	5.3
51-100	401	91.0	9.0	17.9	5.2	2.2	0.2	2.2	7.0
101-150	208	76.1	16.3	19.7	5.3	1.4	1.0	1.9	12.0
151-200	257	95.7	14.0	21.4	6.2	1.2	5.4	2.3	13.2
201-250	188	87.2	10.6	21.3	5.3	0.5	1.6	2.1	11.2
251-300	30	90.0	6.7	16.7	0	0	0	3.3	6.7
All	1406	87.1	9.9	12.5	4.3	2.6	1.6	4.3	9.0
East									
1-50	179	89.9	12.8	45.3	3.9	2.2	0.6	8.9	0
51-100	175	97.1	23.4	38.4	19.4	4.6	1.1	5.1	10.3
101-150	40	95.0	42.5	37.5	17.5	0	0	7.5	10.0
151-200	115	87.4	11.3	33.9	20.9	0	0	0.9	7.8
201-250	130	98.4	26.9	30.0	20.0	2.3	8.5	0	6.9
All	639	95.3	20.2	37.9	15.3	2.3	2.2	4.5	6.3
West and east									
1-50	501	82.4	6.8	28.9	1.8	4.8	0.6	10.6	3.4
51-100	576	91.3	13.4	31.2	9.5	3.0	0.5	3.1	8.0
101-150	248	87.5	20.6	22.6	7.3	1.2	0.8	2.8	11.7
151-200	372	93.5	13.2	25.3	10.8	0.8	3.8	1.9	11.6
201-250	318	91.8	17.3	24.8	11.3	1.3	4.4	1.3	9.4
251-300	30	90.0	6.7	16.7	0	0	0	3.3	6.7
All	2045	89.6	13.1	17.3	7.7	2.5	1.8	4.4	8.2

Appendix 15. Densities of caribou pellet groups at 50-year periods after fire at upland sites at five locations on the winter range of the Beverly herd of caribou.

Year class	Mean number of pellet groups/ha with SE (below) and (n)				
	Nonacho	Porter	Thekulthili	Beauvais	Selwyn
1-50	5	38	0	0	3
	3	33	0	0	4
	(11)	(6)	(5)	(1)	(9)
51-100	67	165	7	8	6
	27	92	7	5	4
	(30)	(5)	(7)	(6)	(9)
101-150	53	250	15		6
	11	0	10		6
	(16)	(1)	(5)	(0)	(4)
151-200	134	142	0		18
	44	43			8
	(17)	(6)	(1)	(0)	(10)
201-250	147	107	13	25	17
	54	49	13	19	17
	(9)	(7)	(2)	(5)	(6)
251-300	125	50			
	0	50			
	(1)	(2)			
All	79	111	8	15	10
	15	25	4	8	4
	(84)	(27)	(20)	(12)	(38)

Appendix 16. Densities of moose pellet groups at 50-year periods after fire in upland sites at five locations on the winter range of the Beverly herd of caribou.

Age class (yr)	Mean number moose pellet groups/ha, SE (below mean), and (n)					
	Nonacho	Porter	Thekulthili	Beauvais	Selwyn	Nonacho/ Porter area
1-50	64	167	115	0	94	99
	13	104	23			33
	(11)	(6)	(5)	(1)	(9)	(20)
51-100	37	55	32	17	17	43
	7	13	14	12		8
	(30)	(5)	(7)	(6)	(9)	(36)
101-150	8	25	10		25	8
	3	0	3			3
	(16)	(1)	(5)	(0)	(4)	(18)
151-200	15	25	0		13	19
	6	9				5
	(17)	(6)	(1)	(0)	(10)	(25)
201-250	31	25	13	15	8	26
	8	14	13	10		7
	(9)	(7)	(2)	(5)	(6)	(17)
251-300	0	25				17
	0	25				17
	(1)	(2)				(3)
All	29	62	44	15	34	39
	4	25	15	7	11	7
	(84)	(27)	(20)	(12)	(38)	(119)

Appendix 17. Densities of hare pellet groups at 50-year periods after fire at upland sites at five locations on the winter range of the Beverly herd of caribou.

Age class (yr)	Mean number hare pellet groups/ha, SE (below mean), and (n)					
	Nonacho	Porter	Thekulthili	Beauvais	Selwyn	Nonacho/ Porter area
1-50	2	4	215	0	47	9
	2	4	77		21	6
	(11)	(6)	(5)	(1)	(9)	(20)
51-100	18	0	43	17	6	15
	5	0	15	17	4	4
	(30)	(5)	(7)	(6)	(9)	(36)
101-150	9	0	20		75	10
	6	0	6		75	5
	(16)	(1)	(5)	(0)	(4)	(18)
151-200	6	4	0		15	5
	3	4			15	2
	(17)	(6)	(1)	(0)	(10)	(25)
201-250	19	0	13	5	8	10
	9	0	13	5	5	5
	(9)	(7)	(2)	(5)	(6)	(17)
250-300	25	0				8
	0	0				8
	(1)	(2)				(3)
All	12	2	75	10	26	10
	2	5	40	8	10	2
	(84)	(27)	(20)	(12)	(38)	(119)

Appendix 18. Densities of ptarmigan/grouse pellet groups at 50-year periods after fire at upland sites at five locations on the winter range of the Beverly herd of caribou.

Age class (yr)	Mean ptarmigan/grouse pellet groups/ha, SE (below mean), & (n)					
	Nonacho	Porter	Thekulthili	Beauvais	Selwyn	Nonacho/ Porter area
1-50	20	54	130	0	47	54
	7	36	21			18
	(11)	(6)	(5)	(1)	(9)	(20)
51-100	144	210	293	13	6	153
	36	83	103	9		33
	(30)	(5)	(7)	(6)	(9)	(36)
101-150	41	25	110		75	47
	14	0	33			15
	(16)	(1)	(5)		(4)	(18)
151-200	76	38	300		15	64
	25	14	0			17
	(17)	(6)	(1)		(10)	(25)
201-250	8	32	13	15	8	34
	6	17	13	15		17
	(9)	(7)	(2)	(5)	(6)	(17)
251-300	0	0				0
	0	0				
	(1)	(2)				(3)
All	78	69	179	13		81
	15	26	45	7	7	12
	(84)	(27)	(20)	(12)	(38)	(119)

Appendix 19. Average numbers of spruce and pine trees in five diameter-at-breast-height (DBH) classes in 10 x 10 m plots grouped in 20-year intervals at 138 upland sites west of 107°W on winter range of the Beverly herd of caribou.

Age class (yr)	No. of sites	Mean number of trees in DBH (cm) class												Grand total
		Black spruce						Jack pine						
		1-5	6-10	11-15	16-20	>20	Total	1-5	6-10	11-15	16-20	>20	Total	
1-20	10	4.7	0	0	0	0	4.7	3.8	0	0	0	0	3.8	8.5
21-40	8	18.6	0.5	0	0	0	19.1	1.8	1.5	0.1	0	0	3.4	22.5
41-60	23	38.5	2.2	0	0	0	40.7	12.7	8.2	0.3	0	0	21.2	61.9
61-80	18	21.8	4.1	0.8	0.2	0	26.9	1.5	2.7	1.1	0.3	0	5.6	32.5
81-100	9	11.0	5.3	0.7	0.1	0	17.1	0.8	6.4	2.1	0.2	0.1	9.6	26.7
101-120	8	40.3	8.8	2.4	0.1	0	51.6	0	0.3	0.6	0.3	0	1.2	52.8
121-140	12	7.6	6.3	1.2	0.8	0.9	16.8	0.3	0.4	0.4	0.2	0.2	1.5	18.3
141-160	13	12.3	11.2	2.3	0.1	0.1	26.0	0.2	0	0.2	0.1	0	0.5	26.5
161-180	12	12.0	13.2	3.0	0.2	0.1	28.5	0	0.2	0.6	0.3	0	1.1	29.6
181-200	4	20.5	20.0	3.3	0.3	0	44.1	0	0	0	0.3	0	0.3	44.4
201-220	8	9.5	11.0	3.3	0	0.1	23.9	0	0.1	0	0	0	0.1	24.0
221-240	9	12.7	5.7	1.3	0	0	19.7	0	0.1	0	0	0	0.1	19.8
241-260	3	3.7	3.3	3.7	0	0	10.7	0	0	0	0	0	0	10.7
261-280	1	11.0	1.0	0	0	0	12.0	0	0	0	0	0	0	12.0

Appendix 20. Average numbers of spruce and pine trees in five diameter-at-breast-height (DBH) classes in 10 x 10 m plots grouped in 20-year intervals after fire at 58 upland sites on caribou winter range east of 107°W.

Age class (yr)	No. of sites	Mean number of trees in DBH (cm) class												Grand total
		Black spruce						Jack pine						
		1-5	6-10	11-15	16-20	>20	Total	1-5	6-10	11-15	16-20	>20	Total	
1-20	2	0	0	0	0	0	0	4.5	0	0	0	0	4.5	0
21-40	8	33.0	0.3	0	0	0	33.3	0	0	0	0	0	0	33.3
41-60	11	27.2	6.4	0.1	0	0	33.7	5.9	1.1	0	0	0	7.0	40.7
61-80	9	16.1	6.0	0.6	0	0	22.7	0	0	0	0	0	0	22.7
121-140	4	15.8	6.3	2.3	0	0	24.4	0	0	0	0	0	0	24.4
161-180	6	20.2	12.5	1.7	0	0	34.4	0	0	0	0	0	0	34.4
181- 200	5	17.6	6.6	3.4	0	0	27.6	0	0	0	0	0	0	27.6
201-220	7	17.6	12.0	1.3	0.4	0	31.3	0	0	0	0	0	0	31.3
221-240	6	9.3	6.7	1.0	0.2	0	17.2	0	0	0	0	0	0	17.2

Appendix 21. Calculated total diameter-at-breast-height (DBH) values in five DBH size classes and in 20-year age classes of forests at 138 upland sites on caribou winter range west of 107°W.

Age class (yr)	No. of sites	Mean total DBH values ¹ in size classes (cm)													Grand total
		Black spruce						Jack pine							
		1-5	6-10	11-15	16-20	>20	Total	1-5	6-10	11-15	16-20	>20	Total		
1-20	10	14.1	0	0	0	0	14.1	11.4	0	0	0	0	11.4	25.5	
21-40	8	55.8	4.0	0	0	0	59.8	5.4	12.0	1.3	0	0	18.7	78.5	
41-60	23	115.5	17.6	0	0	0	133.1	38.1	65.6	3.9	0	0	107.6	240.7	
61-80	18	65.4	32.8	10.4	3.6	0	112.2	4.5	21.6	13.0	5.4	0	44.5	156.7	
81-100	9	33.0	42.4	9.1	1.8	0	86.3	2.4	51.2	27.3	3.6	2.2	86.7	170.3	
101-120	8	120.9	70.4	31.2	1.8	0	224.3	0	2.4	7.8	5.4	0	15.6	239.9	
121-140	12	22.8	50.4	15.6	14.4	19.8	123.0	0.9	3.2	5.2	3.6	4.4	17.3	140.3	
141-160	13	36.9	89.6	29.9	1.8	2.2	160.4	0.6	0	2.6	1.8	0	5.0	165.4	
161-180	12	36.0	105.6	39.0	3.6	2.2	186.4	0	1.6	7.8	5.4	0	14.8	201.2	
181-200	4	61.5	160.0	42.9	5.4	0	269.8	0	0	0	5.4	0	5.4	275.2	
201-220	8	28.5	88.0	42.9	0	2.2	161.6	0	0.8	0	0	0	0.8	162.4	
221-240	9	38.1	45.6	16.9	0	0	100.6	0	0.8	0	0	0	0.8	101.4	
241-260	3	11.1	26.4	48.1	0	0	85.6	0	0	0	0	0	0	85.6	
261-280	1	33.0	8.0	0	0	0	41.0	0	0	0	0	0	0	41.0	

¹ Product of average number of trees in DBH size class and the mid-point of size class.

Appendix 22. Calculated total diameter-at-breast-height (DBH) values in five DBH size classes and in 20-year age classes of forests at 58 upland sites east of 107°W.

Age class (yrs)	No. of sites	Mean total DBH values ¹ in size classes (cm)												Grand total
		Black spruce						Jack pine						
		1-5	6-10	11-15	16-20	>20	Total	1-5	6-10	11-15	16-20	>20	Total	
1-20	2	0	0	0	0	0	0	13.5	0	0	0	0	13.5	13.5
21-40	8	99.0	2.4	0	0	0	101.4	0	0	0	0	0	0	101.4
41-60	11	81.6	51.2	1.3	0	0	134.1	17.7	8.8	0	0	0	26.5	160.6
61-80	9	48.3	48.0	7.8	0	0	104.1	0	0	0	0	0	0	104.1
121-140	4	47.4	50.4	29.9	0	0	127.7	0	0	0	0	0	0	127.7
141-180	6	60.6	100.0	22.1	0	0	182.7	0	0	0	0	0	0	182.7
181-200	5	52.8	52.8	44.2	0	0	149.8	0	0	0	0	0	0	149.8
201-220	7	52.8	96.0	16.9	7.2	0	172.9	0	0	0	0	0	0	172.9
221-240	6	27.9	53.6	13.0	3.6	0	98.1	0	0	0	0	0	0	98.1

¹ Average number of trees in DBH size class times the mid-point of the size class.

