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Effects of Forest Fires on the Winter Range of Barren-ground CARIBOU in Northern Saskatchewan

by
George Wilby Scotter

CANADIAN WILDLIFE SERVICE

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GEORGE W. SCOTTER.

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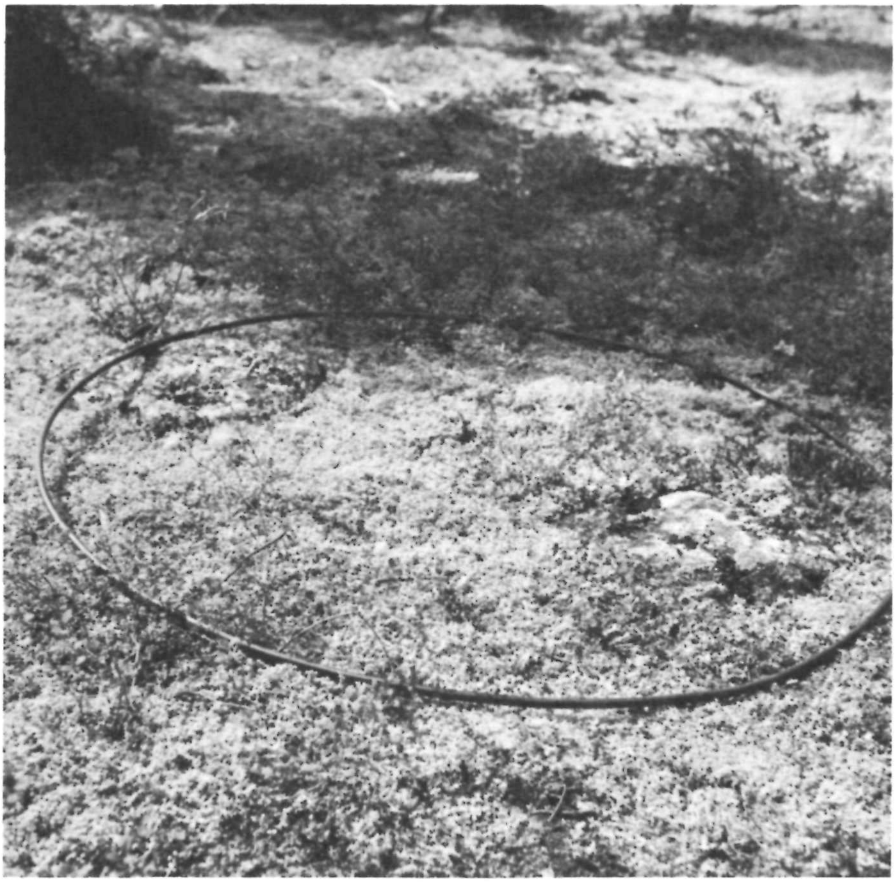

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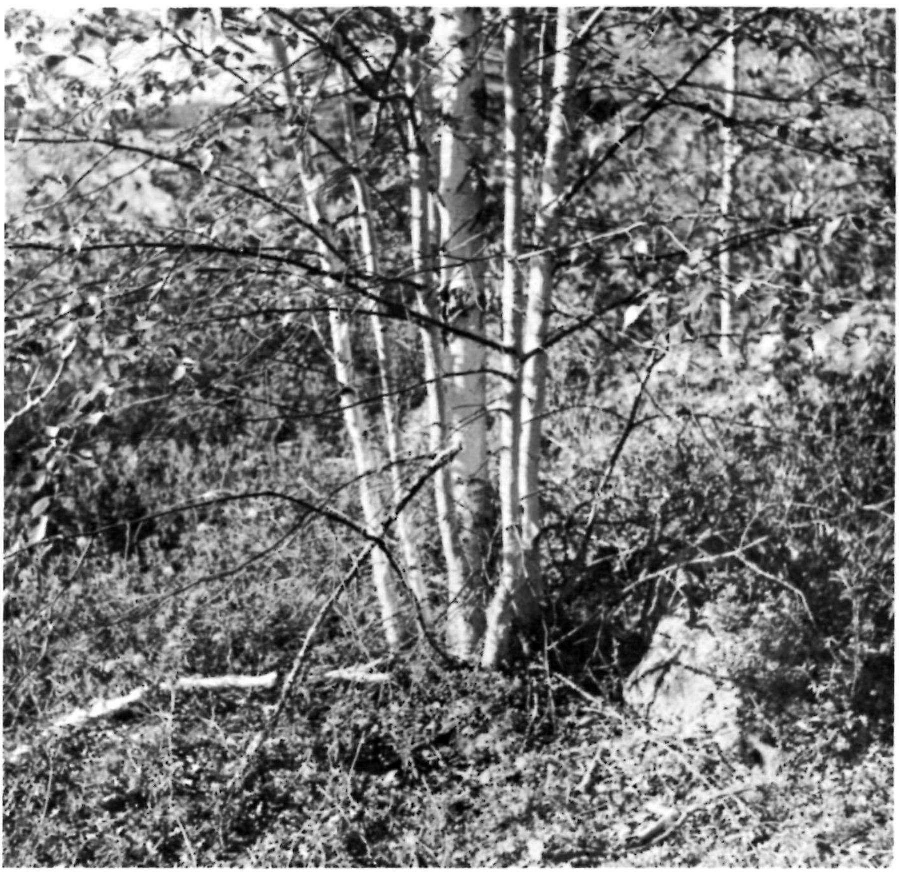

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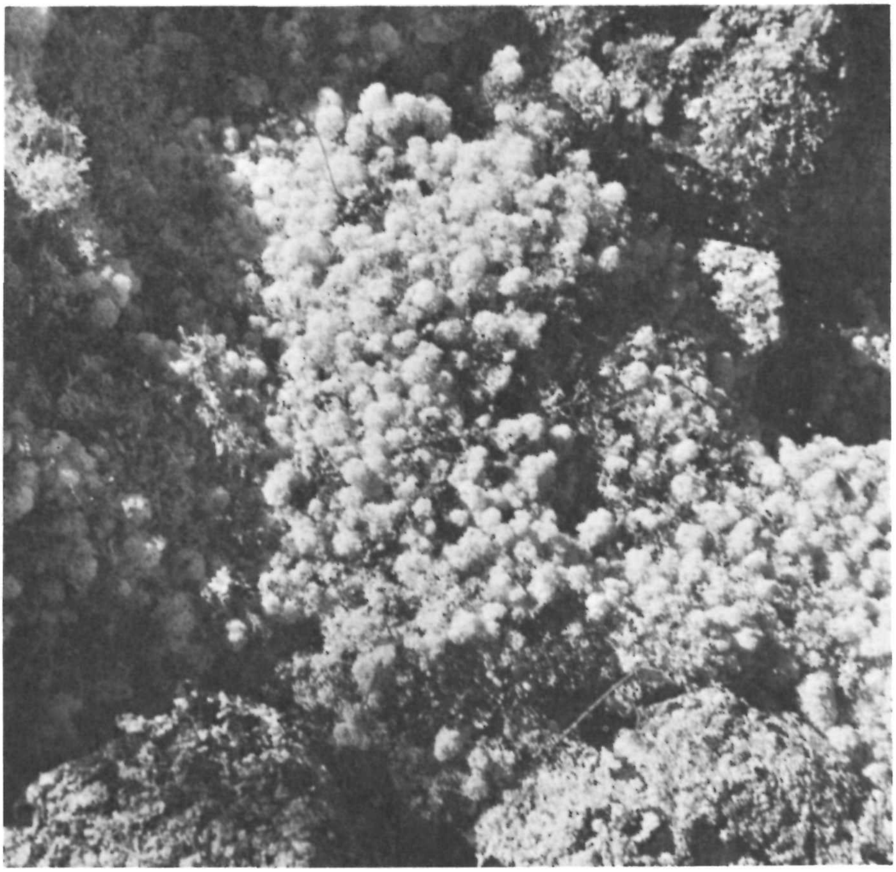

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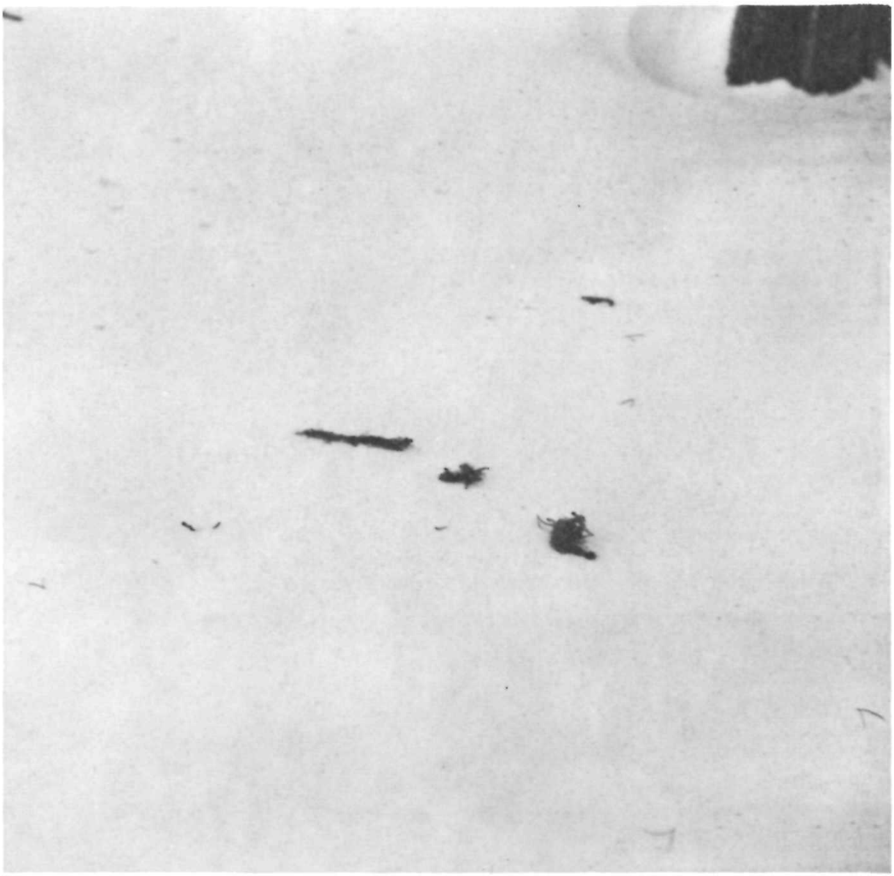

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INTRODUCTION

The numbers of barren-ground caribou (*Rangifer tarandus groenlandicus*) in Northern Canada have decreased during recent years. Hoare (1927, p. 35) quoted Seton, whom he recognized as a leading authority on wildlife in Northern Canada, as stating that "Cutting in half the estimates of explorers who went before me, and making a most conservative estimate there are not less than thirty millions of these caribou letting the wind blow through their whiskers in that northern country." Hoare (1927, p. 39) thought that "It is doubtful if at the present time there are three millions, that is only one-tenth of Seton's 1906 estimate of thirty millions of caribou, left on the mainland in the Northwest Territories." Dr. R. M. Anderson's estimate (Hoare, 1930) agreed with Hoare's. A 1950 estimate based on an aerial census (Banfield, 1954) placed the number at 670,000. A recount during 1955 resulted in an estimate of 277,000 animals, a decline in excess of 50 per cent in 5 years, if the estimates are reliable.

Although barren-ground caribou numbers may have been grossly overestimated in early years, there is ample evidence to indicate a recent and dramatic decline in the population. Such serious depletion has resulted in hardship and famine among Eskimos and Indians who depend on caribou for sustenance.

In 1948 the Canadian Wildlife Service of the Department of Northern Affairs and National Resources started a research program to find causes for the depletion. Most of the field staff involved in those investigations (Banfield, 1954; Kelsall, 1957, 1960; Pruitt, 1959b) have commented on the possible importance of forest fires in the ecology of barren-ground caribou. Dr. W. O. Pruitt (1959b) stated, ". . . I believe that the key to the caribou situation lies in an understanding of the carrying capacity of the winter range and especially in appreciating its drastically reduced carrying capacity due to fires."

During extensive aerial surveys, it was noted that migrating caribou followed green areas and generally avoided large tracts of burned forest. Destruction by fire of slow-growing lichen forage has been suggested as the reason caribou avoided such areas.

The influence of forest fires on barren-ground caribou range in the Northwest Territories was noted earlier by various writers. Pike (1892, p. 47) stated that barren-ground caribou

> . . . seldom come in large quantities to the Mackenzie River, where they used to be particularly numerous in winter. This is in a great measure accounted for by the fact that great stretches of the country have been burnt, and so rendered incapable of growing the lichens so dearly beloved by these animals. The same thing applies at Fort Resolution, where within the last decade, the southern shore of the Great Slave Lake has been burnt and one of the best ranges totally destroyed.

Dogrib Indians told Harper (1932) that caribou had avoided the lower Taltson River for several years because of forest fires. Irregularities of barren-ground caribou migrations were caused by burned-over sections of land, according to Hornby (1934). Referring to barren-ground caribou, Anderson (1938, p. 400) stated that ". . . the destruction of the winter forage of lichens by fire may have been the prime cause of extended movement."

Fire has been mentioned also as a contributing factor in declines of caribou and reindeer (*Rangifer* spp.) in other parts of North America. In Wells Gray Park, British Columbia, the decline of mountain caribou (*Rangifer tarandus caribou*) has been largely attributed to fire (Edwards, 1954). In their study of Alaskan wildlife, Leopold and Darling (1953a, p. 59) commented, "To ignore range limitations for caribou is to ignore the crux of the problem. One fire easily could undo the work of decades in protecting a local caribou population from men and wolves." They concluded that forest fires have eliminated some caribou herds and placed serious restrictions on others. Because the caribou is part of a climax biota, Leopold and Darling (1953b) believed that accelerated burning influenced the species unfavourably. Fire was considered by Palmer (1926) to be the greatest enemy of reindeer herds in Alaska. In two unpublished reports, Palmer (1940, 1941) described the effects of fire on caribou range in interior Alaska. Darling (1954, 1956), Skoog (1956), and Buckley (1958) have commented on the relationship between fire and caribou in that state also. In Manitoba, barren-ground caribou are known to have been deflected by recent burns north of The Pas, which caused them to extend their movements to the southeast. In Ontario, Quebec, and Labrador the effects of fire on caribou have not gone unnoticed (Hind, 1863; Allen, 1942; Manning, 1946; de Vos, 1948; Rousseau, 1951; Moisan, 1955; Cringan, 1957, 1958; Banfield and Tener, 1958).

The problem of providing quantitative and qualitative appraisal of the effects of fire on the winter range of barren-ground caribou was assigned to the writer in July of 1959. The problem was analyzed and separated into the following questions for a preliminary investigation at one important winter range area:

1. What portion of the winter range in the study area has been burned?
2. What effect has fire had on terrestrial forage and arboreal lichen production?
3. What is the successional pattern of vegetation following forest fire?
4. What is the effect of fire on forest soils?
5. What effect does fire have on barren-ground caribou and other wildlife?

DESCRIPTION OF THE STUDY AREA

The winter range of barren-ground caribou is restricted largely to the coniferous forest belt or taiga of Northern Canada. This range, which covers approximately 295,000 square miles, is generally travelled by airplane or boat. Rather than commence an extensive study over such a large expanse, a key wintering range was chosen for intensive study. Presumably, data collected on the study area would be generally applicable to much of the winter range, and would lay groundwork for detailed studies on other wintering areas throughout the coniferous forest of Northern Canada. It was considered desirable that the study area be an important or key winter range and that it contain burns of various ages. In addition it was important that the area be as accessible as possible.

Location

An area in north-central Saskatchewan of approximately 5,000 square miles, extending from 104° to 106° W. longitude and from 59° N. latitude to the Northwest Territories boundary was selected. Sometimes referred to as the world's greatest natural deer pass, this area is one through which barren-ground caribou generally migrate during the early winter and spring and where they sometimes concentrate in large numbers during the winter.

Within this area lie two small communities, Stony Rapids on the Fond-du-Lac River near the western border of the study area, and the other, unnamed, on the northwest shore of Black Lake. Their combined population at the present time is 350 people. Of these, approximately 325 are Chipewyan Indians, often referred to as "Caribou-eaters."

Stony Rapids is approximately 100 miles east of Uranium City, Saskatchewan. Air service from Prince Albert or Uranium City to Stony Rapids was available on irregular schedules. The only road in the area, connecting Stony Rapids and the community at Black Lake, is 16 miles long. Transportation to the study sites was provided by charter aircraft.

Geology and topography

Two broad divisions of topography and geology occur in the study area. The region extending south of a line running from the Fond-du-Lac River eastward past Black Lake is largely a monotonous, flat, sandstone plain covered with glacial deposits of sorted sand. The sandstone underlying the region is of the Athabaska series of the Proterozoic era of the late Precambrian. It is composed of rounded to subangular grains of quartz (Blake, 1956). Streams

TABLE 1

Weather data from Beaverlodge Lake, Saskatchewan, 1956

	Temperature (F)						Snow and rain (inches)				
	Mean daily	Mean daily maximum	Mean daily minimum	Mean daily range	Extreme high	Extreme low	Snow	Snow on ground at end of month*	Rain	Greatest precipitation in 24 hours	Total precipitation
January	–11.0	–3.5	–18.5	15.0	14	–44	11.2	—	0	0.42	1.12
February	–10.6	0	–21.3	21.3	14	–45	10.2	—	0	0.30	1.02
March	5.4	16.4	–5.6	22.0	38	–32	3.2	—	0	0.10	0.32
April	22.2	34.3	10.0	24.3	46	–16	2.0	—	T**	0.16	0.20
May	40.8	52.5	29.1	23.4	77	15	0	—	0.53	0.23	0.53
June	57.5	67.2	47.8	19.4	84	34	0	—	1.64	0.50	1.64
July	62.2	71.6	52.8	18.8	82	43	0	—	1.39	0.60	1.39
August	57.5	66.4	48.6	17.8	84	36	0	—	1.68	0.87	1.68
September	41.8	47.9	35.6	12.3	64	26	0.9	—	1.49	0.30	1.58
October	29.6	34.7	24.6	10.1	53	8	1.4	—	1.17	0.35	1.31
November	15.7	22.2	9.2	13.0	42	–18	6.5	—	0.25	0.25	0.90
December	–9.9	–3.1	–16.7	13.6	30	–37	16.3	—	0	0.30	1.63
							51.7		8.15		13.32

*No report
**T = trace

flow northward over the sandstone to Black Lake.

North of this line the rock is generally of an early Precambrian assemblage belonging to the Archean era (Furnival, 1941a, 1941b). Granite, biotite, andesite, basalt, gneiss, and quartzite are the main components of the rocks. Much folding and faulting have occurred, exposing bedrock and forming outcrop ridges. The topography is comparatively rugged, with many elongated valleys separated by steep hills and ridges. The valleys and ridges are oriented in a northeast - southwest direction. Muskegs, lakes, and streams occupy the valley bottoms. Relief from valley bottom to ridge top varies up to 300 feet. Lakes, generally long and narrow, are numerous throughout the area. Approximately 24 per cent of the area is covered by water.

Striations on rocks and water drainage passages indicate that glacial ice moved from a northeast to a southwest direction. Also, the presence of drumlins, eskers, and moraines indicate previous glacial activity.

TABLE 2

Weather data from Brochet, Manitoba, 1956

	Temperature (F)						Snow and rain (inches)				
	Mean daily	Mean daily maximum	Mean daily minimum	Mean daily range	Extreme high	Extreme low	Snow	Snow on ground at end of month	Rain	Greatest precipitation in 24 hours	Total precipitation
January	–15.1	–6.4	–23.8	17.4	6.7	–51.8	7.1	18.2	0	0.35	0.71
February	–14.4	–3.0	–25.9	22.9	22.2	–51.4	2.4	19.6	0	0.08	0.24
March	– 0.6	12.1	–13.3	25.4	37.7	–41.0	4.9	11.0	0	0.31	0.49
April	17.7	29.1	6.3	22.8	47.8	–19.0	6.7	3.2	0	0.21	0.67
May	33.6	44.4	22.8	21.6	67.2	– 1.0	0.2	0	0.49	0.20	0.51
June	54.2	64.1	44.4	19.7	77.9	31.5	T*	0	1.35	0.43	1.35
July	60.7	69.3	52.1	17.2	83.2	37.9	0	0	0.80	0.25	0.80
August	56.2	64.3	48.0	16.3	83.3	37.2	0	0	2.10	0.72	2.10
September	40.4	45.1	35.7	9.4	57.8	25.8	0.5	T*	1.23	0.31	1.28
October	31.5	37.0	26.0	11.0	53.3	8.6	1.8	1.6	0.51	0.13	0.69
November	10.0	19.0	1.1	17.9	39.1	–43.1	13.2	3.8	0.01	0.60	1.33
December	–13.6	–4.7	–22.6	17.9	34.8	–48.1	20.7	19.3	T*	0.43	2.07
							57.5		6.49		12.24

*T = trace

The soil mantle seldom exceeds a few inches in depth except in areas formerly covered by glacial lakes, where thick soil mantles have resulted from water deposition. Podzol soils, peat bogs, and rock outcrops cover the major portion of the region. Soil pH ranged from 4.0 to 6.8. The lower values were found in the mature forests and the higher ones in recently burned areas.

Climate

Prior to 1960, weather data had not been collected in the study area. In general, winters are long and cold. Summers are short and moderately warm. The frost-free period extends over approximately 90 days. Precipitation is light.

Temperature and precipitation data from two weather stations outside the study area are given in Tables 1 and 2. Beaverlodge Lake is 100 miles west of the study area and Brochet is 120 miles southeast. The climate of the study area is thought to be similar to that of Beaverlodge Lake and Brochet. Climatic extremes probably have more influence on food habits and movement of barren-ground caribou than the averages shown in the tables would indicate, since snow, temperature, and wind determine to a large extent where and how much winter forage will be available to these animals.

Flora

The study area is located in a broad forest belt generally referred to as the taiga or boreal forest. This belt extends across Canada and has its counterparts in Alaska and Eurasia. The forest is largely coniferous in character, with deciduous trees occurring in disturbed regions. In order of their abundance, the major tree species are black spruce (*Picea mariana*), jack pine (*Pinus banksiana*), white birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), tamarack (*Larix laricina*), white spruce (*Picea glauca*), and balsam poplar (*Populus balsamifera*).

The forest is not utilized as a source of timber except for local requirements. Jack pine trees are the chief source of lumber for local use. Black spruce, the predominant tree, has little economic value as lumber, but it may be used in the future as a source of pulp and paper.

Unfavourable environmental conditions, such as a short growing season and low precipitation, have limited plant variety. A checklist of plants collected in the field is recorded in Appendix A. More detailed collection lists have been published separately (Scotter, 1961a; Thomson and Scotter, 1961). The vascular plant and lichen flora of the study area was relatively unknown before the present investigation.

Fauna

A checklist of the fauna encountered in the field is found in Appendix B. Since the bird observations were the first recorded in the area, a checklist has been published separately (Scotter, 1961b).

Grazing Use

The study area was lightly browsed by moose (*Alces alces*) the year-round, while light to moderate grazing by caribou was evident during the winter and early spring.

Human use

At the present time trapping, hunting, and fishing are the main occupations of the inhabitants. Several Indian guides are employed at Black Lake during the summer at two fly-in fishing lodges, which cater to sport fishermen. During the winter the Indians hunt and trap.

Gold and uranium prospecting have had flurries of activity. Prospectors have used fire as a quick method of exposing bedrock over relatively large areas, and they no doubt have been responsible for some forest fires in the study area.

EXTENT AND HISTORY OF FOREST FIRES

The relationship between coniferous forest, caribou, and fire is one which existed long before the advent of the white man to the North American continent. The carelessness of both native and white man with fire, however, has been a contributing factor in the increased rate of forest fire destruction apparent over the past decades.

History of fire on caribou ranges in North America

Evidence that coniferous forests of Northern Canada have been devastated by fires for years can be found in muskegs, where charcoal layers are frequent, and in the forest types themselves. Jack pine, white birch, and quaking aspen forests, all of which can be found in the area, are generally regarded as fire subclimaxes.

Journals of early explorers, such as David Thompson, Samuel Hearne, and their modern day counterparts, substantiate the fact that forest fires were prevalent throughout the North. During his third venture in search of copper in 1771-1772, Hearne observed burned areas near the Coppermine and Slave Rivers. Near the Slave River in January 1772, Hearne (Mowat, 1958, p. 132) noted that "During the preceding summer they (Athapuscow Indians) had set fire to the woods, notwithstanding the deep snow, and many months which had elapsed, the fires were still burning in many places. . . ." He also recorded that Indians departed for new camp sites and left fires unattended. In their journals, covering a period from 1774 to 1792, Hearne and Turnor (Tyrrell, 1934) mention forest fires frequently. After spending more than 30 summers in northern forests, Bell (1889, p. 52) stated

> . . . from a very extensive personal knowledge of the conditions of the forests of Northern Canada, I am able to state the fires have become more and more frequent as we approach the present time. . . . The areas of the 'brules' of different dates may be said to be greater in proportion to their recentness.

Low (1897) reported that fires in interior Labrador, which occurred annually and often burned throughout the summer, had destroyed one-half of the forested area during the preceding 25 or 30 years.

Lutz (1956), in reviewing the history of fire in coniferous forests in Alaska, observed that most forests showed evidence of fire. Since the late 1890's an estimated 80 per cent of the forest and range lands in Alaska has been burned (Robinson, 1953). The forest-stands along the southern part of the Alaska Highway which did not show modifications by fire were rare, according to Raup and Denny (1950).

Fire-destroyed forests were recorded by Camsell and Malcolm (1919) in the Mackenzie River basin in the Northwest Territories. Kelsall (1960) calculated that on an important wintering range for barren-ground caribou between Great Bear Lake and Great Slave Lake, 29 per cent of the land area had been burned. Clarke (1940) reported that smoke was so thick from fire on the winter range near Yellowknife during July of 1936 that aerial photography was impossible.

Devastation by fire has not been limited to forests in Northern Canada and Alaska. According to Fernow (1912), of the 5,000,000 acres of forested area in Nova Scotia only 100,000 acres, or 2 per cent, of virgin or semi-virgin timber remained. Fire was largely responsible for this destruction. It may be more than coincidental that about 1912 the last eastern woodland caribou on the mainland of Nova Scotia was reported killed (Anderson, 1938). In the eastern Rocky Mountains of Alberta, Cormack (1953) found disturbances produced by fire a striking and prominent feature of the landscape. According to Anderson (1938), much of this area was formerly within the range of rocky mountain caribou.

The role of man in the destruction by fire of northern forests has been thoroughly reviewed by Lutz (1959). The role of lightning in the creation of fires is well known, but its effect on the study area is uncertain.

Extent of fire in and near the study area

Records of fires in the study area were not kept by the Saskatchewan Department of Natural Resources prior to 1950. A knowledge of the extent of forest fires was gained through a brief review of literature and by determining the amount of forest of various ages from vegetation maps.

In or near the study area, various people noted the presence of burns. In 1796 Thompson (Tyrrell, 1916, p. 137) observed

> . . . the natives are frequently very careless in putting out fires they make, and a high wind kindles it among pines always ready to catch fire; and burn until stopped by some large swamp or lake; which makes many miles of the country appear very unsightly, and destroys many animals and birds especially the grouse, who do not appear to know how to save themselves, but all this devastation is nothing to the Indian, his country is large.

From observations in 1914 and 1920, Harper (1931, p. 28) stated that "Unfortunately a considerable part of the country appears to have been swept time and again, and with disastrous effects, by forest fires, some of which are set purposely by the Indians in order to temporarily improve the hunting." In writing of his experiences as a trapper and prospector in the study area, Munsterhjelm (1953, 1957) made several references to forest fires. Kelsall (1960) reported that of the 16,610 square miles of barren-ground caribou winter range mapped in northern Saskatchewan, only 300 square miles—less than 2 per cent of the area—were unburned.

Vegetation cover maps of the study area were prepared in 1960 by Spartan Air Services Limited while under contract with the Canadian Wildlife Service. The maps are to be used primarily as an aid in determining the

TABLE 3

Average annual rate of forest destruction by fire expressed in acres per year

Age of forest	Acres	Per cent of total	Average annual destruction in acres
Recent burns 1-15 years of age (1945-1959)	311,680	15.4	20,779
Forest 16-30 years of age (1930-1944)	211,200	10.5	14,080
Forest 31-50 years of age (1910-1929)	300,800	14.9	15,040
Forest 51-75 years of age (1885-1909)	357,760	17.7	14,310
Forest 76-120 years of age (1840-1884)	296,960	14.7	6,599
Forest 120 or more years of age (?-1839)	540,160	26.8	—
Totals	2,018,560	100.0	—

carrying capacities of barren-ground caribou winter range. As forest ages were included on the cover maps, they proved useful in determining the acreage of forests in various age classes. Forests and burned areas were classified as 1 to 15 years, 16 to 30 years, 31 to 50 years, 51 to 75 years, 76 to 120 years, or exceeding 120 years of age.

The area of each age class was determined by using a dot grid overlay. Total acreage per age class, per cent of total area, and average annual forest destruction by fire in acres, as determined by dividing the acres per age class by the number of years in the age class is shown in Table 3. Water, muskeg, rock, and other miscellaneous areas, which covered 35.8 per cent of the total area, were excluded from the table.

During the period from 1885 to 1944 the rate of fire destruction was almost constant, although it represents an increase of 2.2 times over the period from 1840 to 1884. In the last 15 years, fire destruction has increased 1.4 times over the 1885 to 1944 period and 3.1 times over the 1840 to 1884 period. These increases are coincident with mining activity and white settlement. The possibility that some forests may have been burned more than once during the interval has not been considered. Multiple burning would increase the area of young forests and reduce the area clothed in more mature forests.

The recent increased destruction of the boreal forest appears even more disastrous when food habits and habitat preferences of caribou are considered. Caribou prefer a climax habitat, or at least a habitat in the advanced stages of succession, where their principle food species are most abundant. In Northern Canada, the recovery period from vegetation on a burn to climax vegetation is a lengthy process. Short summers, low precipitation, and shallow soil all combine to slow plant succession.

FORAGE UTILIZATION AND TERRESTRIAL FORAGE PRODUCTION

One of the most obvious effects of forest fires on the winter range of barren-ground caribou is the reduction of forage. The amount and kind of terrestrial forage available to barren-ground caribou was, therefore, determined in forests at various stages of maturity.

Method

To determine effects of fire on forage productivity, forests were divided into six age classes extending from 1 to 10 years, 11 to 30 years, 31 to 50 years, 51 to 75 years, 76 to 120 years, and in excess of 120 years. Each class was sampled using the weight-estimate method of forage inventory as suggested by Pechanec and Pickford (1937), and Campbell and Cassady (1955).

Forage yield data were obtained from 38 sites distributed among 13 locations. Six of the 38 sites were in jack pine forests. The others were in black spruce forests, or seral stages of white birch which precede the black spruce. Localities from which forage-yield data were collected are Black Lake, Chipman Lake, Dodge Lake, Faraud Lake, Father Lake, Grove Lake, Higginson Lake, Marchant Lake, McKeever Lake, Newnham Lake, Oblate Lake, Offset Lake, and Stony Rapids.

Forage yield was sampled by clipping and weighing, or estimating the grams of forage in temporary circular plots. Each circular plot covered 9.6 square feet. Two 100-foot chains, at right angles to each other at the 50-foot mark, were used in establishing co-ordinates to position 16 randomly selected sample plots. Co-ordinates were established at each ten-foot interval. Samples were stratified so that four plots fell into each quarter of the grid. Five repetitions, or a total of 80 sample plots, were established in each sampling unit. A sampling unit consisted of a black spruce, jack pine, or white birch forest on an upland site within one of the six age classes. When possible, one repetition within a sampling unit was taken on the north, south, east, and west slopes and the fifth was taken on a level area. The positions of the repetitions were chosen so that they were, as nearly as possible, representative of the slope or level area under consideration. Sampling was limited to upland forest stands. Bogs, muskegs, lake shores, drainage channels, and areas with thick peat accumulation were avoided in the sampling process. Repetitions were placed from one-tenth of a mile to 2 miles apart, depending on topography and size of the forest type.

Forage was removed from the circular plots and separated into species or groups before being weighed on a spring scale. Yield and floristic compositions were recorded. Actual and estimated weights were recorded, on the forms shown in Appendix C, to the nearest 5 grams of green weight. Comments on range conditions, utilization, plant vigor, biotic influence, topography, soil, slope, and other features of interest were included.

Weight of the current growth was recorded for forbs, grasses, grass-like plants, and deciduous shrubs. All leaf growth was removed from evergreen shrubs, such as mountain cranberry, (*Vaccinium vitis-idaea* var. *minus*) and common Labrador tea (*Ledum groenlandicum*). Lichen growth was removed to the level where decomposition of the podetia occurs. Decayed portions of podetia have a pungent odor and probably are not preferred by caribou. Bryophytes were not included in forage yield figures since they are probably not eaten by barren-ground caribou except as incidentals with other forage.

The above method of forage inventory was well suited to the low-growing ground vegetation. With the exception of two species, common Labrador tea and green alder (*Alnus crispa*), ground vegetation in mature forests seldom exceeded 6 inches in height. Plants within the study area were distinct and easily recognized as a unit. The method, however, was time consuming.

The green weights obtained in the field were converted to air-dry weights. Daily collections of samples were made from each major forage species; then 100 gram samples were stored at room temperature until no fluctuation in weight could be detected. Lichens, in particular, could only be compared on an air-dry basis since moisture content varied from 20 to 85 per cent, depending on weather conditions. Lichens are well known for their hygroscopic nature.

A training period prior to actual field work was held for the purpose of checking estimates against actual weights. Also, field estimates were checked daily throughout the season. Wide fluctuations in lichen weights made this practice particularly important.

When large trees were encountered within the sample plot, the plot frame was placed as close as possible to the trunk and sampling continued. Smaller trees were removed, and the plot frame placed over the stumps.

Forage utilization

Forage-yield data were considered with respect to the barren-ground caribou's winter food habits, which are not well known. Grass and grass-like plants, shrubs, and lichen groups were assigned high, moderate, or low values as caribou winter food, primarily on the basis of information gathered from Loughrey (1952), Banfield (1954), and Kelsall (1957, 1960). This information was supplemented by summer observations of plants which had been grazed during the previous winter, and by limited winter observations. Assigned values were determined by plant abundance and utilization by barren-ground caribou and were not based on nutritive content.

Various grass and grass-like species appeared to be moderately important winter forage. One of these, horsetail (*Equisetum* spp.), appeared to be a highly preferred plant (Loughrey, 1952).

Few forbs, with the exception of those on recently burned areas, were present on the winter range. Forbs as listed in Appendices D and E were considered of low value as forage, as were the liverworts and ferns listed as "other plants".

Barren-ground caribou are grazers primarily, and, except for some evergreen species, browse is of limited importance in their winter diet. Only an occasional white birch, or willow (*Salix* spp.) twig, generally less than 1½ inches in length and 3/16 of an inch in diameter, was found in rumens of 7 barren-ground caribou. Throughout the summer field season, mountain cranberry shrubs were seen with the leaves stripped from the stem. Stripped shrubs were most abundant near well-established caribou trails. Mountain cranberry may be an important source of protein on the winter range in northern Saskatchewan. Unpublished results from recent experiments on reindeer in Scandinavia indicate that lichen digestibility is increased if eaten along with other vegetation higher in protein.

The importance of common Labrador tea is not clear. Kelsall (1960) believed it was actively sought. Common Labrador tea was found in all seven barren-ground caribou rumens analyzed, but since it is a ubiquitous species, it may have been eaten incidentally with more preferred foods. The importance of common Labrador tea, a tall species, may vary with snow depth, the importance being greatest on ranges covered with deep snow. Deciduous shrubs other than willow apparently have limited value as forage.

Lichens are regarded generally as the principal winter food of caribou. Nearly 50 per cent of the winter diet is composed of lichens according to Kelsall (1960). In the present study fruticose lichens, such as *Cladonia alpestris, C. amaurocraea, C. mitis, C. uncialis,* and *C. rangiferina,* were considered of high value. Field separation of the first 4 lichens listed above was too time consuming to be practical, so they were considered as a group. Lichens of moderate value included both fruticose and foliose species. Of these, *Cetraria nivalis* has sometimes been regarded as being of high value, but in northern Saskatchewan it was present in only very small amounts. Lichens in the low value groups were so classified because of their small size, and hence limited accessibility under winter conditions. *Nephroma arcticum* was included in this class since it may not be eaten by barren-ground caribou.

The shrubs and lichens assigned high, moderate, and low values are listed in Appendices D and E. Some changes in the evaluation may be required as additional food habit data are obtained from future studies.

Forage production

Sampling results indicated a close relationship between forest age and forage productivity. Table 4 shows the average production for each age class in black spruce and white birch forests. Average air-dry yield ranged from 290 pounds per acre in the 1 to 10 year class to 942 pounds per acre in the oldest age class.

Definite trends in forage production were indicated. Total average productivity was consistently higher with increased age of the tree class. Grass and grass-like plants and forbs yielded 63 and 122 pounds of forage per acre respectively in the 1 to 10 year age class. Average combined productivity in subsequent age classes never exceeded 14 pounds per acre and it was reduced to 5 pounds per acre in the class older than 120 years. Shrub productivity was low in the first age class, but was reasonably consistent throughout the remaining age classes. Yields of lichens increased consistently from 5 pounds per acre to 482 pounds per acre. More important than the increase in total lichen yield was the increase of high value lichens. Average yield of high value lichens varied from 1 pound per acre in the 1 to 10 year old forest to an average yield of 264 pounds per acre in the class exceeding 120 years of age. Moderate value lichens reached their highest yield during the 51 to 75 year age class, and low value lichens attained dominance in the 11 to 30 year age class. Although there were variations within each age class (Appendix D), lichen abundance was clearly related to maturity of the forest. An older forest sometimes produced less forage than a younger forest of the same age class because of variations in tree density, soil type, and other factors.

Forage production in jack pine forests did not show the same consistency as did that of black spruce and white birch forests (Table 5). Two reasons for this inconsistency can be suggested. Because jack pine forest covered only a small percentage of the study area, few samples fell in that forest type.

TABLE 4

Average productivity in pounds per acre of air-dry forage by age classes in black spruce and white birch forests

	Age of forests by age classes					
	1–10	11–30	31–50	51–75	76–120	120 +
Grass and grass-like plants	63	9	1	1	4	2
Herbs	122	5	7	9	1	3
Shrubs						
High value	18	234	289	226	356	334
Moderate value	18	10	8	3	4	6
Low value	60	159	106	119	110	115
	(96)	(403)	(403)	(348)	(470)	(455)
Lichens						
High value	1	12	61	66	205	264
Moderate value	2	16	88	183	125	179
Low value	2	47	44	34	25	39
	(5)	(75)	(193)	(283)	(355)	(482)
Others	4	—	—	—	—	—
Average pounds of forage per acre	290	492	604	641	830	942

TABLE 5

Average productivity in pounds per acre of air-dry forage in jack pine forests

	Age of forests in years					
	5	15	16	35	43	65
Grass and grass-like plants	21	18	T	0	0	0
Herbs	33	66	1	T	T	4
Shrubs						
High value	24	35	96	309	69	344
Moderate value	—	21	—	—	—	4
Low value	7	139	290	302	187	25
	(31)	(195)	(386)	(611)	(256)	(373)
Lichens						
High value	—	5	31	55	203	33
Moderate value	2	138	—	4	9	82
Low value	—	60	55	122	65	15
	(2)	(203)	(86)	(181)	(277)	(130)
Others	T*					
Average pounds of forage per acre	87	482	473	792	533	507

*T = Trace

Then too, understory vegetation in jack pine forests appeared to be partly determined by soil type. Jack pine forests on sandy soil supported primarily mountain cranberry and a thick carpet of lichens. The same forest on glacial till supported understory vegetation consisting of common Labrador tea, green alder, bryophytes, and lichens which increased the yield of low value forage. Such wide variations related to soil type were not apparent in the spruce forests.

The effects of increased forest fire destruction in recent years, considered in the light of yield data, are obvious. Forage available to barren-ground caribou on the winter range is being reduced, both in amount and quality, at the fastest rate within approximately the last 150 years. Average rate of destruction in the recent age class, as determined by dividing the number of years in the recent age class into the total acreage burned during the period was 20,779 acres per year (Table 3). Theoretically the average forage yield on recent burns was 290 pounds per acre or 3,013 tons on the 20,779 acres. A mature black spruce forest, assuming an average production of 942 pounds per acre, would produce 9,787 tons of forage on the same acreage. On the same acreage, the so-called "reindeer lichens" or high value lichens would produce 2,743 tons of forage in the mature forest and only 10 tons in the 1 to 10 year old age class. In recent burns compared with mature forests, the total yield of forage was reduced more than three times, while high value lichen yield was reduced more than 270 times. When compared with forage yield in mature stands, other age classes also show reduced forage yield, but in smaller proportions. The foregoing data clearly show that fire on barren-ground caribou winter ranges will drastically reduce the quantity of forage and the proportion of high quality plant species.

There may have been periods when the boreal forest received extensive fire damage, and intervals of few fires and little damage to barren-ground caribou range. Population levels may have fluctuated accordingly throughout the history of the species.

ARBOREAL LICHEN PRODUCTION

North American literature contains casual mention only of caribou or reindeer feeding upon arboreal lichens, yet it is generally agreed that they are an important source of food for these animals. Sir John Richardson was perhaps the first to report use of arboreal lichens by caribou in Canada. Richardson (1829, p. 242-3) stated, "The barren-ground caribou which resort to the coast of the Arctic Sea, in summer, retire in winter to the woods . . . where they feed on the usneae, alectoriae, and other lichens, which hang from the trees. . . ." In Northern Canada, Pike (1892), Tyrrell (1894), Banfield (1954), and Harper (1955) considered arboreal lichens to be constituents of the winter diet of caribou. In Newfoundland, Dugmore (1913) and Ahti (1959) recognized the importance of arboreal lichens during periods when accessibility to ground lichen stands was difficult. Referring to caribou, Dugmore (1913, p. 39) wrote

> . . . during the very heavy falls of snow all ground food is hidden from them, they must then turn to the tree-growing mosses (lichens), such as *Sticla pulmonaria,* (sic) and the common *Usnea* or Old Man's Beard, which hangs from the trees in graceful wind-blown festoons as though arranged especially for the hunger-driven creatures—a manna in the time of greatest need.

Arboreal lichens were assigned varying degrees of importance on winter ranges of caribou on the Gaspé Peninsula (Moisan, 1955), in western Ontario (Cringan, 1957), and in Wells Gray Park, British Columbia (Edwards and Ritcey, 1960). Edwards and Ritcey (1960, p. 5, 7) stated, "In winter the food of caribou is mainly arboreal lichens. . . . These lichens appear to be essential for survival of caribou in winter." Cringan's investigation suggested that arboreal lichens may be as important a food source as the common terrestrial lichens.

Use of arboreal lichens was noted in Alaska by Lutz (1956) and in Labrador by Hustich (1951). Utilization by reindeer was noted by Porsild (1954) in Arctic Canada and by Perez-Llano (1944) in Lapland. Apparently arboreal lichens are important food sources for caribou, particularly as emergency food during periods of deep or ice-crusted snow.

Forest fires on the winter range of barren-ground caribou destroy not only terrestrial vegetation, but also arboreal lichens. An attempt was made, therefore, to measure the average productivity of arboreal lichens per acre of mature black spruce and jack pine forests in certain parts of the study area.

Method

Four black spruce and four jack pine trees, each representative of its forest type, were selected at various locations as sample trees. After felling and measuring, the trunks were divided into 10-foot sections. Lichens were painstakingly removed by hand from the trunk and branches of each section, and the relative abundance of different species noted. The masses of lichens were placed in cotton bags, air-dried at approximately 72 F and weighed. The resulting data on lichen productivity may not be completely accurate because of variable conditions of slope, soil, tree age, exposure, and vegetation cover. However, they provide an idea of the potential food source.

In a study of epidendric lichens Edwards *et al.* (1960) removed the lichens (*Alectoria* spp.) from two branches at each 10-foot interval of tree height. In the present study, greater accuracy seemed obtainable by removing all lichens from an entire tree that was representative of a particular forest type.

An estimate of the number of trees per acre was made at each site by taking five wedge prism readings and measuring the diameter of all trees viewed in each 360° horizontal sweep. The techniques of sampling were outlined by Kendall and Sayn-Wittgenstein (1959).

Of the eight trees from which lichens were removed, all but one were from upland sites. Black spruce sample trees 1, 3, and 4 were 128, 103, and 108 years of age and 37, 26, and 30 feet tall respectively. Tree age was determined by counting annual growth rings at a stump height of 6 inches. The location of sample tree 2 represented a black spruce physiographic climax. The soil in that area was water saturated, but it could not be classified as a muskeg since peat accumulation was not characteristic. The tree was 18 feet tall and 135 years old. Depauperate stands of this kind were encountered on flat areas where drainage was retarded and permafrost was near the surface. The four jack pine sites were characterized by sandy soils and generally little relief. The ages of the trees were 61, 104, 112, and 101 years, and the heights were 41, 34, 31, and 32 feet respectively. The forests from which these pine trees were selected occurred near Black Lake. Those forests have been subjected to frequent fires, and mature stands exist in isolated areas only.

Lichen production and availability

Arboreal lichens present on the black spruce and the jack pine trees were *Alectoria jubata, A. nadvornikiana, A. nidulifera, Cetraria ciliaris, C. sepincola, Evernia mesmorpha, Parmelia olivacea, P. saxatilis, P. sulcata, Usnea dasypoga, U. glabrescens,* and *U. hirta.* Of these only the fruticose species of *Alectoria jubata, Evernia mesomorpha,* and *Usnea hirta* were present in sufficient abundance to be important forage for barren-ground caribou. The other lichens on the branches and trunks of these trees would be insignificant as caribou food because of their small size or infrequent occurrence.

Tables 6 and 7 show the weights in grams, and per cent of total lichen weight for each section of the individual sample tree. Nearly 50 per cent of the arboreal lichens occurring on spruce trees were within 10 feet of the ground, compared with only 20 per cent on pine trees. This variation was due to a difference in tree form. Branches were present near the base of spruce

TABLE 6

Air-dry weight of arboreal lichens removed from black spruce trees

Tree number	Grams of lichens per tree	Grams of lichens and per cent of total lichen weight per tree in four height intervals			
		0–10 ft.	10–20 ft.	20–30 ft.	30 + ft.
1	1,011	94 (9.3%)	438 (43.3%)	416 (41.2%)	63 (6.2%)
2	477	440 (92.2%)	37 (7.8%)	—	—
3	566	359 (63.4%)	205 (36.2%)	2 (0.4%)	—
4	434	264 (60.8%)	146 (33.7%)	24 (5.5%)	—
Total	2,488	1,157 (46.5%)	826 (33.2%)	442 (17.8%)	63 (2.5%)

trees, while pine trunks were almost limbless for the first few feet above ground.

The average weights per acre of arboreal lichens occurring in spruce forests and pine forests were calculated as 485 kilograms or 1069 pounds, and 830 kilograms or 1830 pounds (Tables 8 and 9). However, only part of these lichens would be available to the barren-ground caribou. It was arbitrarily decided that all lichens within 10 feet of the ground were within reaching distance of the barren-ground caribou. This may be an excessive height except under conditions of deep and drifted snow. The lower lichen-bearing limbs of the spruce generally made more lichens accessible because they droop low from the bases of attachment. On the lower 10-foot section, mature spruce forests provided approximately 275 kilograms or 606 pounds of arboreal lichens per acre, compared with 154 kilograms or 340 pounds of arboreal lichens per acre in mature pine forests. Both species were devoid of lichens on approximately the top 3 feet of growth. The age of this growth interval and its exposure appear to inhibit lichen colonization.

From observations over a period of four years, it would appear that arboreal lichen production as measured in northern Saskatchewan is near the maximum for the taiga region inhabited by barren-ground caribou. Production

TABLE 7

Air-dry weight of arboreal lichens removed from jack pine trees

Tree number	Grams of lichens per tree	Grams of lichens and per cent of total lichen weight per tree in four height intervals			
		0–10 ft.	10–20 ft.	20–30 ft.	30 + ft.
1	490	98 (20.0%)	288 (58.8%)	99 (20.2%)	05 (1.0%)
2	671	60 (8.9%)	375 (55.9%)	236 (35.2%)	—
3	1,276	323 (25.3%)	688 (53.9%)	265 (20.8%)	—
4	1,147	218 (19.0%)	701 (61.1%)	228 (19.9%)	—
Total	3,584	699 (19.5%)	2,052 (57.3%)	828 (23.1%)	05 (0.1%)

TABLE 8

Productivity of arboreal lichens per acre of mature black spruce forest (air-dry weight)

Tree number	Number of trees per acre	Grams of lichens per tree	Kilograms of lichens per acre	Grams of lichens present on the 0–10 ft. section	Kilograms of lichens present per acre on the 0–10 ft. section	Grams of lichens present above the 10 ft. section	Kilograms of lichens present per acre above the 10 ft. section
1	521	1,011	527	94	49	917	478
2	1,200	477	572	440	528	37	44
3	635	566	359	359	228	207	131
4	1,111	434	482	264	293	170	189
Total			1,940		1,098		842
Average weight of lichens per acre in kilograms			485		275		210
Average weight in lichens per acre in pounds			1,069		606		463

in the Gordon Lake and Taltson River regions of the Northwest Territories and in northwestern Manitoba appeared to be greatly reduced.

Edwards *et al.* (1960) suggested that more of the total lichen load was accessible periodically because of the lichens present on fallen trees and those dislodged by wind or snow. This additional availability was demonstrated at Offset Lake in the study area. During the winter, either the weight of snow or a strong wind had broken off a 140-year-old spruce and the foliage was still green in June. Lichens from this tree had been so meticulously removed by barren-ground caribou during their northern migration that even fragments were difficult to find. Arboreal lichens from the nearest erect tree of similar age and height weighed 477 grams.

The importance of fallen trees in making formerly out-of-reach lichens accessible to barren-ground caribou appears rather limited. Assuming a theoretical mortality rate of 1 per cent per year of trees in forest stands, an additional .44 to 8.72 kilograms, or 1 to 19 pounds, of arboreal lichens would be made available per acre per year. This is a small contribution to the food supply and may be of little importance except under the most critical conditions.

In Northern Scandinavia and Finland, Hustich (1951) reported that reindeer herders cut lichen-covered trees to make emergency food available for their animals. Trappers in the Iosegun Lake area of Alberta have cut down conifers so that mule deer (*Odocoileus hemionus*) could feed on the arboreal lichens during periods of deep snow.

Wind and snow dislodge small quantities of lichens during the winter season. The importance of fallen lichens to barren-ground caribou is unknown, although the yield may exceed that from fallen trees.

The accumulated arboreal lichen production exceeded one-half ton per acre in mature spruce, and approached 1 ton per acre in mature pine stands. The situation is reversed when availability is considered. Amounts of lichens within the animals' reach on standing trees, those on fallen trees, and those dislodged were roughly approximated at 285 kilograms or 628 pounds per acre for mature spruce and 170 kilograms or 375 pounds per acre for mature pine. However, barren-ground caribou may not be able to remove all the available arboreal lichens which are woven among the needles. Lichens "stockpile" their growth from year to year, so these data represent cumulative weights rather than annual production.

Lichen utilization

The growth form of the trees made it difficult to determine the degree of lichen utilization because of varying lichen densities within and beyond the reach of caribou. Caribou utilization may have accounted for the relatively small amount of lichens present on the lower 10 feet of black spruce sample tree 1.

Several trappers familiar with wintering conditions in the area were questioned about the use of arboreal lichens by barren-ground caribou. Without exception they had observed animals eating lichens and believed them to

TABLE 9

Productivity of arboreal lichens per acre of mature jack pine forest (air-dry weight)

Tree number	Number of trees per acre	Grams of lichens per tree	Kilograms of lichens per acre	Grams of lichens present on the 0–10 ft. section	Kilograms of lichens present per acre on the 0–10 ft. section	Grams of lichens present above the 10 ft. section	Kilograms of lichens present per acre above the 10 ft. section
1	442	490	217	98	44	392	173
2	1,351	671	906	60	81	611	825
3	915	1,276	1,168	323	296	953	872
4	897	1,147	1,029	218	196	929	833
Total			3,320		617		2,703
Average weight of lichens per acre in kilograms			830		154		676
Average weight of lichens per acre in pounds			1,830		340		1,490

be important in the winter diet. According to information received by Hustich (1951) from the Indians at Fort George, Quebec, *Evernia mesomorpha* was well-liked by caribou during the winter.

Rumen samples from seven barren-ground caribou were analyzed in an attempt to establish the relative importance of arboreal lichens. Two samples showed traces of arboreal lichens. As the animals were taken in early winter, the results may not represent the food habits under more critical conditions. Also, lichens are fragile and may be subject to rapid digestion. Work by Norris (1943) indicated that rumen contents are an inaccurate measure of the forage eaten.

Under critical conditions, and perhaps throughout the winter, arboreal lichens may contribute substantially to the diet of barren-ground caribou. The availability of these lichens is an important measure of their potential significance when compared with terrestrial food plants. Investigations by Pruitt (1959a, p. 177) indicated that "Caribou appear to have a threshold of sensitivity to the hardness, density, and thickness of the snow cover." As the threshold of sensitivity is exceeded caribou may no longer be able to obtain the required amount of food from terrestrial plants. Arboreal lichens may be increasingly important as that threshold is approached.

Lichen ecology

Arboreal lichen abundance apparently depends on tree age, density, species, and moisture conditions. With trees of similar age, there appeared to be an inverse relationship between tree density and lichen productivity per tree. Lichen productivity per tree increased with reduced tree density. Since lichen growth is cumulative it was expected that productivity would vary roughly with age. The youngest jack pine produced the smallest amount of lichens in its group (Table 7) and the oldest spruce and pine, excluding the depauperate specimen, produced the largest amount of lichens in their respective groups (Tables 6 and 7). Although data and observations were limited, it appeared that the more mesic spruce sites were more productive than the upland sites. The mesic sites seemed to favour the growth of *Alectoria jubata* over *Evernia mesomorpha* and *Usnea hirta.*

There were variations in the species distribution of lichens on the two tree types. *Alectoria jubata* was the most abundant lichen on both spruce and pine. *Evernia mesomorpha* and *Usnea hirta* were more abundant on pine than on spruce and also more abundant on the lower than the upper tree sections. *Usnea hirta* would probably be the least important, and *Alectoria jubata* the most important of the three lichens because of its relative abundance and accessibility.

Arboreal lichens are apparently important sources of forage during critical periods and perhaps throughout the entire winter season. Destruction of these extremely slow-growing plants by fire must be considered a serious loss of winter caribou food.

PLANT SUCCESSION FOLLOWING FOREST FIRES

Plant succession following forest fires is dependent on several factors including site potential, size of the burned area, intensity of the fire, climate for several years following the burn, seral stage of vegetation at the time of the burn, and seed available for dispersal. The influence of these factors on the cycle of recovery is often difficult to determine.

Method

The seral stages, for descriptive purposes, were grouped in three major divisions or stages of succession. The description of the liverworts and mosses, lichens, tree species, and other vascular plants within those three stages were based on observations made throughout the study.

Bryophytes

Lower forms of plant life, such as bryophytes, are rapid colonizers in the first successional stage. The liverwort, *Marchantia polymorpha,* and the mosses *Polytrichum juniperinum,* P. *piliferum,* and *Ceratodon purpureus,* were the first post-fire plants to appear.

Marchantia polymorpha appeared to be a temporary species. Profuse growth of this species occurred only in shaded spots or in moist depressions. About 5 years after a fire, this liverwort was present only in moist depressions or as impoverished individuals scattered at the bases of various mosses. Spores of *Marchantia polymorpha* may be wind disseminated over large areas since plants were not found in the periphery of mature forests encompassing recent burns.

Polytrichum juniperinum, P. *piliferum,* and *Ceratodon purpureus,* which displace *Marchantia polymorpha,* have greater longevity than the liverwort, although abundance of the first two mosses listed decreased 10 to 15 years after fire. *Ceratodon purpureus* was a characteristic member of both the first and second stage of development. *Polytrichum juniperinum* and *Ceratodon purpureus* were found in drier habitats. *Polytrichum piliferum* was most abundant in moist habitats. The first years following forest fires are evidently the most advantageous period for growth of those mosses.

The second stage of bryophyte succession was generally dominated by *Aulacomnium palustre, Ceratodon purpureus, Hedwigia ciliata, Pleurozium schreberi,* and *Polytrichum commune.* Those bryophytes play an important role in the accumulation of litter on exposed mineral soils and rocks which supported plant growth previously.

TABLE 10

Dominant bryophytes present in three successional stages following forest fires

First stage (1 to 10 years)	
Ceratodon purpureus	*Polytrichum piliferum*
Polytrichum juniperinum	*Marchantia polymorpha*
Polytrichum juniperinum var. *alpestre*	
Second stage (11 to 50 years)	
Aulacomnium palustre	*Pleurozium schreberi*
Ceratodon purpureus	*Polytrichum commune*
Hedwigia ciliata	
Third stage (51 or more years)	
Dicranum elongatum	*Ptilium crista-castrensis*
Dicranum rugosum	*Sphagnum capillaceum*
Hylocomium splendens	*Sphagnum capillaceum* var. *tenellum*
Pleurozium schreberi	*Ptilidium ciliare*
Polytrichum commune	

Dicranum elongatum, D. rugosum, Hylocomium splendens, Pleurozium schreberi, Polytrichum commune, Ptilium crista-castrensis, Sphagnum spp., and the liverwort, *Ptilidium ciliare,* were constituents of an almost continuous bryophyte carpet in mature spruce stands. Whether or not such dense stands of bryophytes have a thinning effect on important caribou food lichens, such as *Cladonia alpestris* and *C. rangiferina,* was not determined. The more abundant bryophytes present in the three successional stages are listed in Table 10.

Lichens

When fires occur, destruction of fire-susceptible lichens is generally complete except for patches in moist sites. Rate of lichen recovery depends on the extent of destruction, but it is a very slow process. Lichens are perennials, which are characterized by slow growth and a long life span. Fire appeared to be more destructive to lichens than to other plants because of the much slower growth rate of the lichens.

Crustose lichens, such as *Lecidea cuprea,* L. *granulosa,* and *Baeomyces rufus,* comprise the earliest stages of succession. *Peltigera canina* var. *spuria* is generally the first foliose lichen to appear. Displacement of *Marchantia polymorpha* and *Polytrichum* spp. by *Peltigera canina* var. *spuria* starts gradually about 5 years after a fire.

Cup lichens belonging to the genus *Cladonia,* such as *Cladonia coccifera,* C. *deformis, and C. pyxidata,* are present occasionally late in the first successional stage, but are more characteristic of the second. Other lichens which reached their best development in the second stage of succession are listed in Table 11. The lichens in that stage are eaten by barren-ground caribou, but are of little significance since they are generally small in size and do not form clumps. Exceptions are *Cladonia amaurocraea, C. mitis, Peltigera canina,* and *Stereocaulon spp.* which are important forage lichens.

TABLE 11

Dominant lichens present in three successional stages following forest fires

	First stage (1 to 10 years)	
Crustose		
	Baeomyces rufus	*Lecidea granulosa*
	Lecidea cuprea	
Foliose		
	Peltigera canina var. *spuria*	
	Second stage (11 to 50 years)	
Crustose		
	Baeomyces rufus	*Lecidea granulosa*
	Lecidea cuprea	*Ochrolechia frigida*
Foliose		
	Peltigera canina	*Peltigera canina* var. *spuria*
	Peltigera canina var. *rufescens*	
Fruticose		
	Cetraria crispa	*Cladonia cornuta*
	Cetraria nivalis	*Cladonia cristatella*
	Cladonia alpicola	*Cladonia deformis*
	Cladonia amaurocraea	*Cladonia gracilis*
	Cladonia bacillaris	*Cladonia mitis*
	Cladonia botrytes	*Cladonia pyxidata*
	Cladonia carneola	*Cladonia pyxidata* var. *neglecta*
	Cladonia coccifera	*Cladonia verticillata*
	Third stage	
	First phase (51 to 120 years)	
Foliose		
	Peltigera aphthosa	
	Peltigera canina	
Fruticose		
	Cetraria crispa	*Cladonia rangiferina*
	Cladonia alpestris	*Cladonia turgida*
	Cladonia amaurocraea	*Cladonia uncialis*
	Cladonia gracilis	*Stereocaulon alpinum*
	Cladonia mitis	*Stereocaulon tomentosum*
	Cladonia multiformis	
	Second phase (120 or more years)	
Foliose		
	Nephroma arcticum	*Peltigera canina* var. *ulorrhiza*
	Peltigera aphthosa	*Peltigera malacea*
	Peltigera canina	*Peltigera pulverulenta*
Fruticose		
	Cladonia alpestris	*Cladonia rangiferina*
	Cladonia mitis	

In the third stage of succession, two phases were clearly recognized. Large numbers of diverse lichen species were present in the first phase. In the second phase *Peltigera* spp. and "reindeer lichens", such as *Cladonia alpestris* and *C. rangiferina*, which are preferred food species, were most abundant in the lichen flora.

"Reindeer lichens" reach their best development in the second phase of the third stage. These important food sources are particularly vulnerable to destruction by forest fires. Recovery is slow because of the low rate of growth, and because of unfavourable ecological conditions. It has been estimated that recovery requires 30 years (Manning, 1946), 30 to 40 years (Sarvas, 1937), 30 to 40 years (Itkonen, 1948). Palmer (1940, p. 2) believed that "A burned-over lichen range may require as much as 40 or more years for recovery." In northern Saskatchewan it would appear that complete recovery of two "reindeer lichens", (*Cladonia alpestris* and C. *rangiferina*), to their former abundance may take from 90 to 120 years. In fact, fire appeared to have been as destructive to important food lichens as to the forest itself. In black spruce forests it was unusual to find *Cladonia alpestris* and *C. rangiferina* in areas burned within 30 years, except for small relic areas which had escaped fire. Lichen recovery in jack pine forests appeared to be somewhat more rapid.

Succession in jack pine forests was similar to that described in black spruce forests. However, bryophyte carpets appeared to be considerably reduced in mature stands. *Peltigera* spp. and *Cladonia rangiferina* were seldom encountered. Other lichens were much more abundant, but their height seemed considerably restricted when compared with the lichens of black spruce forests.

Annual growth rates of "reindeer lichens" have been of great interest for several years. After considerable research Russian scientists have developed an acceptable procedure for lichen growth rate research (Andreev, 1954).

In studying fruticose species of *Cladonia,* the Russians recognize three periods of growth (Andreev, 1954). During the first interval, which is called the growth period, length of the podetium or stalk increases continuously for a number of years. Branching occurs at the top of the podetium so each joint is 1 year younger than the joint below, or in other words, the age of joints increase as they near the base of the podetium. The intervals between lateral branches on the main stalk, called joints, also increase in length during the period of growth. Annual lichen growth comprises the increase in length of the joints as well as the addition of a new joint.

In the second period of growth, which is referred to as the period of renewal, the base of a podetium decomposes at approximately the same rate as the top of the podetium is growing.

The period of renewal is followed by a period of degeneration. During this period the rate of decomposition at the base of podetia exceeds the rate of addition at the top. Finally podetia perish.

The period of growth or formation of podetia may last for 25 years, but a 10-year growth period is average. The renewal period may extend over several decades, but the period of degeneration is similar to the period of growth. The lifespan for *Cladonia alpestris* and *C. rangiferina* appears to be lengthy in northern Saskatchewan. At Dodge Lake, where forests were approximately 170 years old, *Cladonia alpestris* and *C. rangiferina* with completely decomposed podetia could not be found. In northern Saskatchewan lichens which showed decay along the whole length of the podetia were noted only in muskegs that had escaped fire for a long period of time.

Russian scientists, working on management problems on reindeer ranges, have accepted as fact that podetia of *Cladonia* branch but once a year. They have suggested that the growth rate is equal to the height of the living portion of the podetium, under moist conditions, divided by the number of joints on the podetium. The measurements are taken under moist conditions because the plant is extremely fragile and because it shrinks when dry.

The following formula was used in measuring 48 podetia of *Cladonia alpestris* and 48 podetia of C. *rangiferina* at each of four locations in northern Saskatchewan:

$$\frac{\text{Height of the living podetium}}{\text{Number of joints on the living podetium}} = \text{Average annual linear growth rate of the podetium}$$

Separation of living portions of the podetia from decaying portions was possible because a colour change occurs when decay is initiated. The colour change was more distinct in *Cladonia rangiferina* than in *C. alpestris.*

Of the two *Cladonia* species studied, *C. rangiferina* had a faster growth rate than *C. alpestris.* However, *Cladonia rangiferina* had fewer years of growth before reaching the period of renewal (Table 12).

TABLE 12

Annual linear growth rates of Cladonia alpestris and C. rangiferina at four locations in black spruce forests of northern Saskatchewan.

Location	Annual average growth rate	Growth rate extremes	Length of growth period
		Cladonia alpestris	
Dodge Lake	4.3 mm.	3.6–4.9 mm.	10–14 yrs.
McKeever Lake	4.7 mm.	3.2–6.1 mm.	8–14 yrs.
Newnham Lake	3.4 mm.	3.0–4.2 mm.	8–13 yrs.
Chipman Lake	3.9 mm.	3.1–5.1 mm.	8–12 yrs.
Average and range	4.1 mm.	3.0–6.1 mm.	8–14 yrs.
		Cladonia rangiferina	
Dodge Lake	4.8 mm.	3.0–6.7 mm.	6–12 yrs.
McKeever Lake	5.7 mm.	4.1–7.3 mm.	6– 9 yrs.
Newnham Lake	4.7 mm.	3.4–5.6 mm.	7–11 yrs.
Chipman Lake	4.4 mm.	3.0–5.5 mm.	6–12 yrs.
Average and range	4.9 mm.	3.0–6.7 mm.	6–12 yrs.

Growth rates of lichens in northern Saskatchewan, Russia (Andreev, 1954), and Newfoundland (Ahti, 1957), seem to be fairly similar. The growth rate of *Cladonia rangiferina* in Newfoundland was similar to that in northern Saskatchewan, but less than that in Russia. The growth rate of *Cladonia alpestris* in Newfoundland was greater than in northern Saskatchewan or Northern Russia (Table 13). Habitats from which these data were assembled vary widely. Growth of *Cladonia alpestris* in Newfoundland may be favoured by the oceanic climate.

TABLE 13
Annual linear growth of Cladonia as reported by various workers.

		Annual growth rate in mm.	
Worker	Place	*C. alpestris*	*C. rangiferina*
Scotter	N. Saskatchewan	4.1	4.9
Ahti	Newfoundland	6 to 7	4.8
Andreev	Russia (sub-tundra forest)	4.4	5.9

Vascular Plants

After a fire, the successional pattern of grass, grass-like plants, herbs, and shrubs depended largely on the seeding and sprouting habits of the species involved. Hardy and prolific invaders after fire were fireweed (*Epilobium angustifolium*), pale corydalis (*Corydalis sempervirens*), sedges (*Carex aenea, C. deflexa, C. canescens*), bluejoint (*Calamagrostis canadensis*), hairgrass (*Agrostis scabra*), woodland horsetail, and willows. Fire removed thick mantles of litter from seedbeds and made such invasions successful.

Fireweed colonized new burns rapidly and contributed from 25 to 60 per cent of the total forage production on recent burns. However, this ubiquitous herb was abundant for only a short period of time. Fireweed disappeared, except for scattered individuals, presumably because of the increased competition for sunlight.

Only a few other herbs were generally present. Pale corydalis plants, although few in number, were always present. In contrast, willow herb (*Epilobium glandulosum*) was present in only one burn and then in considerable abundance. Typical grass and grass-like invaders reached their maximum abundance about 5 years after a fire. Bluejoint was occasionally present in mature forest stands, but the plants were generally sterile. Moist depressions were occupied by woodland horsetail stands of varying densities. Two common sedges present on recent burns were *Carex aenea* and *C. deflexa*, although *C. brunnescens, C. canescens* and *C. foenea* were occasionally present in this seral stage. Raspberries (*Rubus idaeus* var. *aculeatissimus*) were seldom present in burns older than 20 years of age. Invasion of this plant is so rapid following a fire that seed must lie dormant in the soil for years waiting for fire to reduce competition and make conditions favourable for germination. The seeds appear too large for wind dissemination and the plant is sometimes so abundant that animal or bird dissemination seems improbable.

Following fires, plants such as fireweed, bluejoint, and sedges renew the humus layer which favours lichen growth. Important forage lichens, however, are unable to compete successfully with these plants.

Wind is an important agent in the seed dissemination of postfire species. Airborne seeds of fireweed, which bloomed from late June to September, are dispersed by the wind over large areas. Some sedge and grass species reproduce by rhizomes and through seed dissemination by wind, birds, and mammals. Undestroyed riparian vegetation within burned areas, and peripheral vegetation bordering burned areas, are potential seed sources.

Mountain cranberry, which has a wide ecological amplitude, was one of the most abundant shrubs in black spruce forests 10 years after a fire. Its density was equaled by common Labrador tea in some regions. As the forests neared maturity common Labrador tea decreased in abundance, while mountain cranberry remained the same or decreased slightly. Subterranean runners of mountain cranberry survived forest fires and were the organs responsible for re-establishment of this shrub. Dense carpets of the low-growing shrub were formed.

Common Labrador tea was an abundant shrub in muskegs and the more moist upland sites throughout the coniferous forests. Leaf cover was not as dense, the plant was not as numerous, and total forage weight was not as great as that of mountain cranberry. Because of its height, however, common Labrador tea sometimes dominated the aspect. In mature forest the yield of common Labrador tea was reduced because this plant is intolerant of shade.

Generally, grass, grass-like plants, and herbs were encountered infrequently in second and third stages of succession, not only for reasons of shade intolerance, but also because of competition from bryophytes and shrubs. Of the species present, bunchberry (*Cornus canadensis*) and northern comandra (*Geocaulon lividum*) were the most abundant.

Willows, raspberries, skunk currant (*Ribes glandulosum*), and pin cherry (*Prunus pensylvanica*) occurred in an early seral stage. Various willows occurred in most of the more recent burns. Long-beaked willow (*Salix bebbiana*) was characteristic of drier upland sites, while grayleaf willow (*S. glauca*) and flat-leaved willow (*S. planifolia*) were more common on moist upland sites. In the study area willow was sparse and only light regeneration following fire was noted. Even as members of riparian vegetation, willows were not abundant.

Berry-producing shrubs composed the majority of shrub vegetation in the second stage of succession. Many of these species are reproduced vegetatively and many of the underground parts escape destruction by fire. Fleshy fruits of some shrubs survive fire, and the viability of certain shrubs' seeds may be increased by heat from fire. Black crowberry (*Empetrum nigrum* var. *hermaphroditum*) was restricted to mature forest sites and its occurrence was sporadic. Small cranberry (*Vaccinium oxycoccus*), bog bilberry (*V. uliginosum*), northern Labrador tea (*Ledum palustre* var. *decumbens*), and cloudberry (*Rubus chamaemorus*) were occasionally present.

One shrub, green alder, was present in all stages of succession in both jack pine and black spruce forests. The shrub produces a voluminous quantity of leaves which appear to be resistant to decay. The leaf accumulation suppressed other plant growth directly under the shrub. Table 14 lists the plants generally present in the three stages of black spruce forest succession.

TABLE 14
Dominant vascular plants in three successional stages following fire in black spruce forests

First stage (1 to 10 years)	
Agrostis scabra	*Equisetum sylvaticum*
Calamagrostis canadensis	*Poa glauca*
Carex aenea	*Prunus pensylvanica*
Carex canescens	*Ribes glandulosum*
Carex deflexa	*Rubus idaeus* var. *aculeatissimus*
Corydalis sempervirens	*Salix* spp.
Epilobium angustifolium	
Epilobium glandulosum	
Second stage (11 to 30 years)	
Alnus crispa	*Lycopodium annotinum*
Arctostaphylos uva-ursi	*Lycopodium complanatum*
Cornus canadensis	*Lycopodium obscurum*
Geocaulon lividum	*Ribes oxyacanthoides*
Juniperus communis	*Salix* spp.
Ledum groenlandicum	*Vaccinium uliginosum*
	Vaccinium vitis-idaea var. *minus*
Final stage (30 or more years)	
Alnus crispa	*Ledum palustre* var. *decumbens*
Cornus canadensis	*Rubus chamaemorus*
Empetrum nigrum	*Salix bebbiana*
Geocaulon lividum	*Vaccinium oxycoccus*
Ledum groenlandicum	*Vaccinium vitis-idaea* var. *minus*

Succession of tree species

Three species, black spruce, jack pine, and white birch, were the most abundant trees on the study area. On one frequently burned area aspen had gained a foothold. Tamarack was common in muskegs, and balsam poplar was present along some sandy lake shores. White spruce may be the ultimate climax species in view of its presence on some areas protected from fire.

Jack pine. Forest fires are essential in the maintenance and perpetuation of jack pine in the study area. Jack pine forests occur commonly in nearly pure stands following fire and are good indicators of sandy soil. Fire appears to prepare an excellent seed bed for the jack pine. Fire eliminates competitors for nutrients, light, and moisture. Also, ashes from fires may increase the amount of nutrients available. Because of extensive and repeated fires, the southern region of the area supported subclimax stands of jack pine. The serotinous cones of this species resist destruction by fire and at the same time the heat of the fire aids in opening the cones and in releasing their seeds. The early age at which jack pine bears cones, together with the fire resistance of the cones, enables it to spread rapidly in fire-disturbed regions of the study area. Cones were noted on jack pine trees which were only 7 years old.

Jack pine forests are intolerant of shade and as the stands mature black spruce intrudes to make an admixture. The latter species gradually becomes the dominant. Jack pine forests resist fire better than black spruce forests. Fire-scarred jack pine trees were encountered frequently, while black spruce trees apparently succumb even to low-intensity fires.

White birch. Fire in black spruce stands favours the invasion of white birch as the pioneer tree species. Leaves from these shade-intolerant hardwood trees contribute substantially to the renewal of litter on the forest floor. Improved litter conditions aid in the re-establishment of an understory of lichens.

Following forest fires in the study area, exposed mineral soil provided suitable areas for white birch regeneration. On some burns young trees reached such densities that they impeded walking.

White birch is easily killed by fire, partly because its bark is flammable. Sprouting of dormant buds on the enlarged base of the bole was common in fire-destroyed white birch forests, but such sprouting was insignificant in the rapid invasion of white birch in former black spruce forests. The dense stands of young white birch were established as a result of wind-disseminated seeds. Mineral soil and exposure of seeds to sunlight aided white birch regeneration. The comparatively short-lived white birch trees dominated for 50 to 75 years and were then overtopped, suppressed, and eliminated by black spruce. White-birch forest boundaries were very distinct and clearly marked peripheries of burns.

Black spruce. Thin bark and flammable foliage near the ground make black spruce trees very susceptible to destruction by forest fires. Tinder-dry ground lichens and arboreal lichens, along with hot, dry summer weather add to the fire hazard. Few black spruce, outside of muskegs, escape destruction during a forest fire.

Black spruce are able to grow on wet, peaty soils as well as on drier upland sites. Most black-spruce muskeg forests contain a sprinkling of tamarack, and an occasional white birch is present in upland sites. The nearly pure stands of black spruce on rock outcrop formations were shallow-rooted and often were found growing in litter cover rather than in mineral soil. Black spruce seeds remain viable after maturity, not unlike those of jack pine trees. Undoubtedly, this is important in perpetuation of the species. The cones, which are serotinous and persistent, are situated near the tree tops where they are less likely to be destroyed by fire. Seeds are dispersed later onto exposed surfaces where reduced vegetative competition and other favourable conditions for reproduction are met. Black spruce seedlings are overtopped by white birch or jack pine, and then make a gradual entry into the forest canopy until they gain dominance. Black spruce, a small and slow-growing but moderately long-lived species, propagates by layering as well as by seed. This results in uneven-aged stands. Black spruce trees, similar to jack pine trees, produce seed cones at an early age. Seed cones were found on 15-year-old trees.

As the age of black spruce stands increased, there was a decrease in the number of lichen species present, although lichens, such as *Cladonia alpestris* and *C. rangiferina,* increased. The latter are important sources of forage for barren-ground caribou. Plants in the upland black spruce sites exhibited a low degree of diversity. A ground cover of bryophytes was concomitant with mature black spruce forests.

Whether or not black spruce can be considered a member of the climax forest on upland sites is difficult to determine. It is capable of self-perpetuation and has a high degree of stability. White spruce, however, may be the ultimate climax if given protection from fires for a lengthy period of time. A relic area at Faraud Lake, which is isolated by two small streams, supported white spruce. That suggested the surrounding area may have been forested with white spruce.

EFFECTS OF FOREST FIRES ON SOIL PROPERTIES

Previous studies show that the effects of fire on soil properties vary widely with soil type, climate, vegetation, and severity of the burn. Few definite conclusions could be reached from the literature. An investigation by Lutz in Alaska is the only known study in North America made at a comparable latitude and in similar forest types. From his study Lutz (1956, p. 78) concluded, in part, "No possible justification for uncontrolled wildfires can be found in the realm of soil science. Such fires can never be justified or even excused on the basis of beneficial effects on the soil, despite the fact that fires may have favorable effects on certain properties."

In this investigation influences of fire on forest soils have been divided into effects on physical properties of soil, on chemical properties of soil, and on unincorporated organic matter. Data on edaphic changes wrought by forest fires are important considerations in understanding the ecology of lichens and other plant life which reclothe the devastated area.

Description of sample sites

Sample sites were selected in mature black spruce forests, mature jack pine forests, and on burned-over sites which formerly supported those forests. Mature-forest sample sites were chosen as comparable as possible to adjacent burned-over sites in slope, topography, drainage, and soil parent material. For example, at Marchant Lake soil properties under a 155-year-old black spruce forest were compared with an adjacent 5-year-old burn. Soils supporting a 130-year-old black spruce forest stand were compared with those on a burn approximately 13 years of age at Dodge Lake. Ages of the two burns at Newnham Lake were 5 and approximately 22 years. Those areas had been covered with jack pine forests and were compared with a mature jack pine and black spruce forest with similar conditions of slope, topography, and drainage. Soil under the burned-over areas was medium sand of a pale brown colour, compared with grayish coloured, medium loamy sand under the jack pine and black spruce forest.

Soil in the northern section of the study area was shallow, seldom exceeding a few inches in depth on upland sites. At Newnham Lake, sandy soil, which resulted from water deposition, exceeded four feet in depth. Soil horizons were indistinct.

Since pedologists have not worked in the region, soil classification and description will be limited to colour and texture as given in Table 15. Records of texture of the soil, determined by feel, and colour of the soil, determined with a Munsell soil-colour chart, were made in co-operation with the Soil Survey Research Branch of the Canada Department of Agriculture at Edmonton, Alberta.

Methods

Data on physical and chemical soil properties were obtained from the same sample sites. Sampling procedures were not random since boulders and thin soil mantles sometimes precluded random sampling. However, six sample sites were distributed as well as possible on each area.

Physical properties. Information was obtained on soil temperature, water infiltration rate, and soil erosion. To determine soil temperature, six readings were taken during August between the hours of 10:30 a.m. and 1:00 p.m., using a Weston soil thermometer at depths of 1 and 3 inches. Notes on erosion were made from observations on the ground and while flying at low altitude in airplanes.

TABLE 15

Description of soil colour and texture at sample sites

Site	Munsell Colour Description	Texture
5-year-old burn at Marchant Lake	Brown	Coarse sandy loam
Mature black spruce forest at Marchant Lake	Brown	Coarse sandy clay loam
13-year-old burn at Dodge Lake	Light yellow-brown	Medium sandy loam
Mature black spruce forest at Dodge Lake	Pale brown	Medium sandy loam
5-year-old burn at Newnham Lake	Pale brown	Medium sand
22-year-old burn at Newnham Lake	Pale brown	Medium sand
Mature jack pine and black spruce forest at Newnham Lake	Gray	Medium loamy sand

Methods used by Burns (1952) and Beaton (1959) were employed to determine water infiltration rates. A steel cylinder 20 centimeters high, with a cross-sectional area of 100 square centimeters, was driven 10 centimeters into mineral soil. After the unincorporated organic matter inside the cylinder was removed, muslin was placed over the soil to prevent disturbance of soil particles. The time required for one liter of water to pass into the soil was observed to the nearest 15 seconds. Replications at two different locations in the burned-over and mature forest areas were made at Dodge Lake.

Chemical properties. Eighteen soil cores, 3 from each of 6 sites, were collected from the 0-to-3 inch depth of mineral soil for chemical analyses. Changes in chemical composition of soils attributable to fire have seldom been detected below the upper soil layers, and for this reason sampling was limited to the 0-to-3 inch depth. Plastic bags were used for storing the air-dried soil. The Soil Survey Research Branch of the Canada Department of Agriculture in co-operation with the Research Council of Alberta made chemical analyses and laboratory pH determinations on the mineral soil cores.

Extractions were as outlined by the Association of Official Agricultural Chemists (1955). Calcium, magnesium, sodium, and potassium were determined using the Beckman DU flame spectrophotometer with a model 9200 flame attachment and line-operated power supply unit as outlined by Baker (1956). The modifications suggested by Mathieu and Burtch (1961), Mathieu and Carson (1961), and Carson *et al.* (1962) were incorporated. A cleaning solution as proposed by Choinière (1956) was used. Total nitrogen was determined with the Kjeldahl method of Prince (1945), using mercury as a catalyst. Available phosphorus was measured by extracting 5 grams of soil with 25 ml. of 0.03 normal sulfuric acid and 0.03 normal ammonium fluoride. Available phosphorus was determined calorimetrically by using a Fisher Model No. A electrophotometer.

Composite soil samples, taken from the first 3 inches of mineral soil, were tested for pH in the Soil Survey Research Branch laboratory with a Beckman Model H-2 pH meter. A soil paste consisting of distilled water and dry, sieved soil was allowed to stand 15 minutes before pH values were determined. Field and laboratory pH meters used in this study were compared before the field season so that similar results could be expected. Field determinations of pH were made with a Beckman Model 180 pocket pH meter by inserting a glass electrode into mineral soil at the desired depth.

Unincorporated organic matter. Changes wrought by fire in the unincorporated organic matter were determined by observation.

Effect on physical properties

Destruction of trees, ground vegetation, and organic matter exposes mineral soil to the elements, and changes in physical soil properties could therefore be anticipated.

Soil temperature. Soil temperatures in burned-over areas were consistently higher than in unburned areas (Table 16). On the four study plots, temperature on recent burns averaged 10.5 F. higher at 1-inch depths, and 9.7 F. higher at 3-inch depths than temperatures under mature forests. Temperatures were consistently higher at 1-inch levels than at 3-inch levels. As the age of burns increased, differences in temperatures were reduced. Removal of unincorporated organic matter, which acted as an insulator, and absence of shade from the forest canopy and other vegetation, were largely responsible for increased soil temperature. The increased capacity of the blackened soil surface to absorb heat in recently burned-over areas also contributed to a rise in soil temperature. Following a fire, the addition of charcoal to soil has been suggested by Bauer (1936) in California, and Lutz (1956) in Alaska as a factor in the increase of soil temperature. The capacity of charcoal to absorb heat was commented on by Tryon (1948). Isaac and Hopkins (1937) also felt that fire increased the capacity of soil to absorb heat.

TABLE 16
Temperatures in burned-over and unburned soil with differences tested by means of a t-test

Description	Temperature at 1″ depth (average of 6 readings) F	Difference in temp. F	Temperature at 3″ depth (average of 6 readings) F	Difference in temp. F
5-year-old burn at Marchant Lake	79.2	12.7**	69.7	14.2**
Mature black spruce forest at Marchant Lake	66.5		55.5	
13-year-old burn at Dodge Lake	82.0	11.8**	64.5	6.5**
Mature black spruce forest at Dodge Lake	70.2		58.0	
5-year-old burn at Newnham Lake	66.3	11.6**	65.0	14.2**
Mature jack pine and black spruce forest at Newnham Lake	54.7		50.8	
22-year-old burn at Newnham Lake	60.7	6.0*	55.0	4.2*
Mature jack pine and black spruce forest at Newnham Lake	54.7		50.8	

*Significant at 5 per cent
**Significant at 1 per cent

Kittredge (1938) found a 20 F. temperature difference between forested and burned-over areas at a 1-inch depth. Most workers, with the exception of Shirley (1932), found increased soil temperature on burned-over areas. Shirley reported no difference in jack pine forests.

A soil temperature inversion, with burned areas being colder and forested areas warmer, may be expected in winter because of reduced amounts of unincorporated organic matter to act as an insulating agent. Greater fluctuation in daily diurnal and nocturnal soil temperatures in recent burns is also probable. The changes in the amounts of radiation, insulation, wind, and humidity, in burned-over and forested areas should influence the soil temperatures.

The influence of extreme soil temperatures on lichen regeneration is unknown, although it is generally believed that lichens can endure extremes of temperature without harmful effects. However, it can be assumed that the higher temperature of summer soil, and increased wind action caused by removal of vegetal cover will increase water evaporation, which in turn may result in desiccation of lichen stands. Lichens are strongly influenced by abundance or lack of moisture. Smith (1921) reported that lichens, most of which are hygroscopic, are capable of enduring desiccation, but functions of active metabolism, respiration, and assimilation are impossible without water.

The rise in surface-soil temperature following fire was ecologically favourable for germination and growth of some plants. Many of the fire-induced species in the early seral stages of succession may benefit from the increased soil temperature.

Exfoliation of rocks, caused by the rapid expansion of the outer surfaces during fires, was noted at Marchant and Dodge Lakes. This may indicate the extreme temperature generated by forest fires in this region.

Infiltration rate. Data on infiltration rates were collected at Dodge Lake. Results, as given in Table 17, indicate that infiltration rates on burned-over soil were more rapid than on unburned soil. Infiltration rates for 1 liter of water were 13.5 and 15.5 minutes on burned-over soil, and 17.0 and 18.25 minutes in unburned soil. The sample was too small to permit the application of statistical tests of significance.

TABLE 17
Water infiltration rates on burned-over and unburned soil

Description	Infiltration rate of 1 liter of water in minutes	
	1st Site	2nd Site
13-year-old burn at Dodge Lake	15.5	13.5
Mature black spruce forest at Dodge Lake	17.0	18.25

Veihmeyer and Johnston (1944) found that infiltration capacities of soil in burned-over chaparral areas of northern California were not changed by fire. In contrast, Johnson (1940) found infiltration rates on burned-over soil were reduced 40 per cent when compared with unburned soil. Kittredge (1938), Burns (1952), and Beaton (1959), also found slower infiltration rates on burned-over areas than on undisturbed soil.

Erosion. Erosion following forest fires in northern Saskatchewan is not serious. Destruction of plant cover, litter, and organic matter does not appear to result in more than light sheet erosion. Lack of erosion is explainable because of the light intensity of summer rainstorms, the soil's being frozen during a seven-month period, and the rapid colonization, following fire, of *Marchantia polymorpha* and mosses such as *Polytrichum piliferum, P. juniperinum,* and *Ceratodon purpureus.* In addition, soils in the northern section are thin, seldom exceeding a few inches in depth. Water infiltration rates on burns in the study area, which appear to be increased, would also reduce the threat of erosion. Gully erosion was noted only twice. In both cases, it was confined to sandy soils in southern regions of the study area.

On two occasions the writer was present on recent burns during rainstorms. Little or no surface runoff resulted from rain pelting on exposed

TABLE 18
Chemical soil properties on burned-over and unburned soil

Site Description	Exchangeable cations in millequivalents per 100 grams of dry soil					Sum of cations	Total exchange capacity	Total nitrogen P.P.M.	Available phosphorus P.P.M.
	H	Na	K	Ca	Mg				
5-year-old burn at Marchant Lake	4.1	.1	T*	.4	.2	4.8	7.3	50	8.5
Mature black spruce forest at Marchant Lake	7.0	.1	T	.2	.4	7.7	11.8	100	1.0
13-year-old burn at Dodge Lake	3.4	.2	T	.2	.1	3.9	4.8	40	26.5
Mature black spruce forest at Dodge Lake	3.9	.1	T	.2	.1	4.3	4.9	40	14.5
5-year-old burn at Newnham Lake	1.9	.1	T	.4	.1	2.5	4.4	50	13.5
Mature jack pine and black spruce forest at Newnham Lake	2.4	.2	T	.2	.1	2.9	3.2	30	T
22-year-old burn at Newnham Lake	1.2	.1	T	.4	.1	1.8	2.9	20	37.0
Mature jack pine and black spruce forest at Newnham Lake	2.4	.2	T	.2	.1	2.9	3.2	30	T

*T = Trace

surfaces. Any loss of soil from these thin mantles would be serious. In Alaska, Lutz (1956) also found erosion "surprisingly small". Wind erosion resulted in small sand dunes on two recent burns in southern sections of the study area.

Effect on chemical properties

Determinations for nitrogen, available phosphorus, total exchange cation capacity, and exchangeable hydrogen, sodium, potassium, calcium, magnesium, and pH were made on samples from seven areas. Soil pH values were determined in the field and laboratory.

Soil nutrients. Total exchange capacity was decreased in three of the four burned-over areas (Table 18). A 5-year-old burn showed a slight increase in total exchange capacity.

Of the individual cations, exchangeable hydrogen was reduced on each burn. Exchangeable calcium increased on three sites and remained the same on the fourth. Little difference was noted in exchangeable potassium, sodium, or magnesium. Increased calcium was recorded by Garren (1943) in his summary on effects of fire on soils in southeastern United States. In Alaska, Lutz (1956) found that a several-fold increase in exchangeable calcium accompanied burning. Reduced hydrogen ion concentration following burning on Vancouver Island was suggested by Godwin (1938).

While studying effects of slash burning on soil, Tarrant (1956) observed that light burning increased exchangeable potassium and had little appreciable effect on cation exchange capacity, while severe burns greatly increased exchangeable potassium and reduced cation exchange capacity. Burning of logging slash increased soluble or available forms of potassium, calcium, and magnesium in investigations by Austin and Baisinger (1955).

Total nitrogen abundance, as determined by the Kjeldhal method, did not follow any apparent trend. It increased on one burn, was reduced on two others, and remained the same on a fourth. Contradictory results were also reported in the literature. Barnette and Hester (1930), Isaac and Hopkins (1937), and Austin and Baisinger (1955) reported decreases in nitrogen, but Heyward and Barnette (1934) and Garren (1943) reported increases.

Lutz (1956) reported an immediate reduction in total nitrogen, but increased available nitrogen following forest fires. Nitrogen in forest soils, LeBlanc (1954) believed, is the limiting factor in tree growth since it conditions the utilization of other nutrients. Nitrogen levels in both mature-forest soils and burned-over soils of the study area were considerably less than the 200 to 250 parts per million suggested by Bensend (1943) as optimum for growth of jack pine seedlings. Plants such as *Epilobium angustifolium* and *Rubus idaeus* var. *aculeatissimus,* which are generally regarded as nitrophilous species, were frequent to abundant on burned areas. Members of the nitrophilous Leguminosae family were entirely absent on both undisturbed and fire-destroyed areas.

In each of the four burned-over soils studied, phosphorus was more abundant than in unburned forest soils. Following fire in Alaska, an increase in the amount of available phosphorus in upper mineral layers was reported by Lutz (1956). Austin and Baisinger (1955) found more than a two-fold increase in phosphorus on burned-over plots in Washington and Oregon.

Immediately following fire an increased supply of nutrients may be made available for plant growth. The possibility of the nutrients being leached from unprotected soil is increased also. Several years after a fire the soil might be no more, or perhaps less fertile than before the fire. Research by Sampson (1944) in California showed that the effect of fire on soil constituents is largely nullified by the second year and disappears in subsequent years.

Ahlgren (1959) suggested that high concentrations of salts released from ash may kill or retard growth of seedlings by causing plasmolysis of root hairs and young roots. Toxic concentration levels would vary with the tolerance of certain plants. Spruce seedlings are damaged more easily than pine seedlings, according to Heikinheimo (1915). The general increase of nutrients resulting from ash would be expected to stimulate the growth of some plant species and inhibit others. Ahlgren (1960) found that oats and sunflowers showed increased vigor and size when grown in a certain soil which had been subjected to fire. Oats grown in soil subjected to a more severe summer fire, which resulted in more ash, showed no increase in size.

Higher concentrations of many of the elements reported in Table 18 could have been expected in burned areas, if sampling had been extended to more recent forest fires.

TABLE 19
Soil pH in burned-over and unburned soils

Description	pH laboratory sample 0–3 inch depth	pH field sample 1-inch depth (median of 6 readings)	pH range	pH field sample 3-inch depth (median of 6 readings)	pH range
5-year-old burn at Marchant Lake	4.7	6.45	5.2–6.8	6.15	5.7–6.8
Mature black spruce at Marchant Lake	4.4	5.00	4.2–6.3	5.60	4.5–6.8
13-year-old burn at Dodge Lake	4.6	5.45	5.2–6.2	5.65	5.2–6.1
Mature black spruce at Dodge Lake	4.5	5.15	4.7–5.2	5.35	5.0–5.5
5-year-old burn at Newnham Lake	4.7	5.50	5.4–6.4	5.30	5.2–6.2
Mature jack pine and black spruce stand at Newnham Lake	4.0	5.10	5.0–5.3	5.20	5.2–5.5
22-year-old burn at Newnham Lake	5.2	5.90	5.4–6.2	5.80	5.2–5.9
Mature jack pine and black spruce stand at Newnham Lake	4.0	5.10	5.0–5.3	5.20	5.2–5.5

Soil pH. Field tests revealed that soils in burned-over areas gave increased pH values when compared with unburned forests (Table 19). Increases were greater at the 1-inch depth than at the 3-inch depth. Soil samples measured in the laboratory, although lower in pH value than field samples, showed the same trend of increased soil pH on recent burns.

Variations in field and laboratory pH measurements of soil from northern Alberta were reported by the Soil Survey Research Branch. Staff members suggested that aluminium in the dried soil is changed, and the capacity of the soil to reabsorb water is reduced. The phenomenon, however, has not been explained thoroughly.

Decreased acidity probably results from destruction of unincorporated organic material and addition of alkalis from wood ash to the soil. A similar decrease has been reported by other workers. Marshall and Averill (1928), Barnette and Hester (1930), Lutz (1956), Beaton (1959), and others have reported increased pH values on burned-over soil. Garren (1943), in reviewing the literature on effects of fire on vegetation in southeastern United States, found that reduced soil acidity was reported.

In Sweden, Uggla (1958) reported pH values were higher on burns than on adjacent unburned areas for about 25 years. The severity of the burn would influence the period of years over which higher pH values would be retained.

Wilde (1958) gave pH range of 4.7 to 6.5 as optimum for white spruce growth. Increased soil pH may affect black spruce growth unfavorably for a period following forest fires since expected optimum values for black spruce growth would be lower than those for white spruce.

Trumpener (1926) maintained that pH is an ecological factor of prime importance in the distribution of lichens. The growth and functioning of other plants are influenced by the hydrogen ion concentration also.

Effect on unincorporated organic matter

Forest fires in the study area, which appear to be generally severe, destroyed unincorporated organic matter on the forest floor, resulting in the exposure of as much as 35 to 50 per cent of the mineral-soil surface area or bedrock. In other parts of the burns, thickness of unincorporated organic matter was much reduced. Organic matter tended to be unincorporated in most of the region.

In Washington, Isaac and Hopkins (1937) found that slash fires destroyed as much as 89 per cent of the organic matter. Fowells and Stephenson (1934), Arend (1941), and many others have noted the destruction of unincorporated organic matter following forest fires.

Soils in parts of the region studied were composed largely of organic matter. Fires that destroy organic matter in such areas are serious since bare rock is often exposed. Lengthy periods of time are required before organic matter will accumulate on exposed surfaces and support important food plants. Organic matter layers may be important sources of nutrients and may be closely related to the productivity of a site (Gagnon *et al.*, 1958).

Fires which destroy unincorporated layers of organic matter would be expected to increase nutrients available for plant growth, at least temporarily. Any increase may be temporary since leaching can occur more readily on the exposed soils in burned-over areas.

In Oregon and Washington, Austin and Baisinger (1955) regarded removal of organic matter by fire as a major loss, probably having more significance than other effects combined. They noted that unincorporated organic matter was a beneficial agent in: (1) improving soil aeration (2) storing plant nutrients (3) reducing moisture losses through evaporation (4) improving soil structure (5) inhibiting compaction and crusting (6) checking erosion (7) increasing water-holding capacities.

Unincorporated matter acts as an insulator also, reducing temperature changes from day to day and diminishing seasonal fluctuations. Reduced frost penetration and delayed freezing of soil could be expected under a covering of unincorporated organic matter.

The effects of fire on forest soils are favourable to certain soil properties and unfavourable to others. Whether or not the beneficial effects exceed the deleterious effects can be determined only after detailed studies of lichen and vascular plant ecology are made. Little is known about the effects of increased or reduced nutrient supplies on most of the lichens and vascular plants of the boreal forests.

EFFECTS OF FIRE ON WILDLIFE

Effects of forest fires on wildlife are both direct and indirect. Direct effects involve destruction or injury of wildlife. Early in the fire season, young birds and mammals are victims of the ravages of forest fires. Although no charred carcasses were found in the study area, some animals may have succumbed.

An important indirect effect is the change of a climax community—with its cover of trees, shrubs, bryophytes, and lichens—into a tangle of fallen snags and exposed soil, and later into a fireweed-grass-shrub community. Fire alters plant cover both in kind and quantity. These changes subsequently modify wildlife populations.

Method

Fecal pellet-group counts were made in each age class in each black spruce forest and jack pine forest sampled to determine the habitat preference of moose and barren-ground caribou. Within each 9.6-square-foot circular plot used for calculating vegetation production, moose and caribou pellets were counted. If six or more winter pellets of one type were found in a plot, they were recorded as a pellet group. Kelsall (1957) regarded six or more pellets as a group because barren-ground caribou generally drop their pellets while moving, leaving a point of concentration and several widely scattered pellets. Each pile of summer moose droppings was considered a pellet group. Pellet groups per plot were converted to pellet groups per acre. Effects of fire on other wildlife were determined by observation.

Big game animals

Replacement of fire-destroyed climax communities with subclimax vegetation results in subsequent changes in populations of barren-ground caribou and moose. Pellet group counts (Table 20) on six age classes in black spruce and white birch forests indicate that barren-ground caribou prefer the older forests, whereas moose favour the younger types. In forests over 120 years old, 586 caribou pellet groups per acre were found, compared with only 41 per acre on the 1 to 10 year age class. In contrast, 49 moose pellet groups per acre were present on the 1 to 10 year age class and only 9 were present in forests over 120 years old. Moose apparently prefer habitats less than 50 years old, but barren-ground caribou favour those exceeding 50 years of age.

No moose pellet groups were found in jack pine forests (Table 21). Caribou pellets were found in older stands, but caribou's avoidance of young stands was evident. In a 65-year-old forest 1,702 caribou pellet groups per acre were recorded. The large number of pellet groups in this forest indicates

TABLE 20
Average number of caribou and moose pellet groups per acre in six black spruce and white birch age classes

	Forest age class in years					
	1–10	11–30	31–50	51–75	76–120	120 +
Caribou pellet groups	41	28	199	510	331	586
Moose pellet groups	49	85	57	19	9	9

a caribou concentration area during a previous winter.

Barren-ground caribou feeding patterns were noted during the winter by aerial observations of transects on the study area. Feeding craters, which were dug in the snow by barren-ground caribou, were easily observed from the air. These observations agreed closely with the pellet-group counts. Such craters were confined largely to mature forests. Occasional trails and feeding craters were observed in recent burns where migrating animals crossed from one mature forest to another.

TABLE 21
Average number of caribou and moose pellet groups per acre in jack pine forests of various ages

	Forest age in years					
	5	15	16	35	43	65
Caribou pellet groups	0	0	0	57	0	1,702
Moose pellet groups	0	0	0	0	0	0

In some recently burned areas the tangle of fallen snags and wind-throws made human movement difficult. Barren-ground caribou may experience similar difficulty. It is likely that young over-stocked birch stands impede caribou movement and lessen utilization of some areas. Crusted snow was another physical obstacle which may have induced barren-ground caribou to avoid recent burns. Snow depths were similar on burned-over and mature forests on the study area during March 1961, but crusted snow was encountered on recent burns. Crusted snow probably resulted from greater exposure to sunlight and reduced shelter from winds. Snow density and hardness, according to Pruitt (1959a), influence caribou movements and feeding patterns.

In some areas of North America, such as the Kenai Peninsula of Alaska, forest fires have resulted in improved moose ranges and subsequently higher moose populations. A large moose population, however, was not evident in the study area. Only three moose were seen in more than three months of ground observation and several hours of observation from aircraft. Nearly 523,000 acres, or 26 per cent, of the total area have been burned in the last 30 years. The reason for such a small moose population is apparent from the forage productivity tables in Appendices D and E. Preferred moose browse in the post-fire vegetation was present in only small amounts. For example, willow (*Salix* spp.) was scarce in upland foersts. In Alaska, Leopold and Darling (1953a) also suggested that passage of fire through forests did not always create optimum moose range.

Effects of forest fire on wildlife may be good or bad, depending on animal utilization of the vegetation before and after the fire. In considering only two big-game species, fire appears to reduce the quality and quantity of winter range for barren-ground caribou and improve it only slightly for moose on upland forests of the study area. Carrying capacity per acre of mature forest for barren-ground caribou appears higher than that of early subclimax forests for moose. It appears that in terms of meat production, the area would be best managed for barren-ground caribou by protecting it from fire.

A moderate black bear (*Euarctos americanus*) population found burned-over areas an excellent source of berries. Droppings and observations indicated frequent and widespread use of such areas by bears. Their feces appeared to be important in the distribution of seeds on recent burns.

Fur-bearing animals

Fur bearing animals are affected by fire also, since they are dependent on vegetative cover for food and shelter. The red squirrel (*Tamiasciurus hudsonicus*) was eliminated over much of the area. Squirrel populations were generally noted only in forest stands older than 50 years. Since squirrels are an item in the food chain of marten (*Martes americana*) and fisher (*Martes pennanti*), populations of these animals likewise may have been adversely affected. Forest fires may also destroy marten habitat since the species is regarded as a climax or near climax species (Miller, *et al.,* 1955).

At least one, and possibly two fur-bearers benefited from post-fire vegetation. Snowshoe hare (*Lepus americanus*) frequented younger forests in much larger numbers than they did mature forests. Persistent fires north of Stony Rapids have gradually allowed quaking aspen to invade small areas. This food source may allow for a gradual increase in the present small population of beavers (*Castor canadensis*).

Birds

One example of a population change due to fire in the study area was provided by the presence of sharp-tailed grouse (*Pedioecetes phasianellus*) on a recent burn and the confinement of numerous spruce grouse (*Canachites canadensis*) to mature black spruce forests. Spruce grouse were encountered almost daily throughout the summer field season in mature forests. The only other birds which demonstrated a habitat preference were slate-colored juncos (*Junco hyemalis*) and white-crowned sparrows (*Zonotrichia leucophrys*). Observations of the slate-colored juncos were confined to coniferous forests, and white-crowned sparrows were generally found in birch or mixed birch and black spruce forests.

The few generalizations discussed in the preceeding paragraphs are the most obvious ones. Future studies might include detailed attention to the succession of animals following the alteration of habitat by forest fire.

SUMMARY AND CONCLUSIONS

The number of barren-ground caribou inhabiting the coniferous forests and tundra of Northern Canada has declined rapidly in recent years. This reduction has placed hardships on many Indians and Eskimos who rely on barren-ground caribou for food and various other provisions. In an effort to arrest the decline, the Canadian Wildlife Service of the Department of Northern Affairs and National Resources began intensive barren-ground caribou investigations in 1948. Since the destruction of climax biota by forest fires had been suggested as one cause for the decline of barren-ground caribou, the Service started a preliminary study to evaluate the effects of fire on a key wintering area in northern Saskatchewan in July, 1959.

Comments on forest fires in the journals of early explorers, and the presence of charcoal in soil profiles indicate that the relationship between forest fires and caribou is not a recent one. Vegetation maps of the study area, however, indicate that the acreage burned per year by forest fires has increased 1.4 times in the last 15 years compared with the previous 60 years and 3.1 times when compared with the period extending from 1840 to 1884.

One of the most obvious effects of forest fires on the winter range of barren-ground caribou is reduction of forage in both quantity and quality. Forage production was determined for six forest age classes. Black spruce and seral white birch stands produced an average of 290, 492, 604, 641, 830, and 942 pounds of air-dry forage per acre in the 1 to 10, 11 to 30, 31 to 50, 51 to 75, 76 to 120, and over 120 year age classes respectively. Accumulated production of high value lichens, which are the preferred winter food of barren-ground caribou, was 1, 12, 61, 66, 205, and 264 pounds per acre, air-dry weight, in the six age classes, respectively. Grass, grass-like plants, and herbs produced 185 pounds of forage per acre in the 1 to 10 year age class, but less than 15 pounds per acre in subsequent age classes. Shrub production was low during the first post-fire age class and was fairly constant at approximately 400 pounds per acre throughout the others. Production in jack pine forest may follow the same general trend as in black spruce forest, but the type was too limited in extent to draw any definite conclusions.

Burning of the winter range results in only a temporary reduction in range productivity, with the exception of high value "reindeer lichens". In northern Saskatchewan, a century or more is required for fire-destroyed "reindeer lichens" to reach their former abundance. Annual growth rates of *Cladonia alpestris* and *C. rangiferina* were approximated at 4.1 and 4.9 millimetres respectively. The two lichens were found infrequently in forests younger than 30 years of age.

In mature coniferous forests, arboreal lichens may make substantial contributions to the winter diet of barren-ground caribou, particularly under severe weather conditions. Approximately 628 pounds of accessible arboreal lichens per acre were present in mature black spruce forests compared with 375 pounds per acre of accessible arboreal lichens in mature jack pine forests. A quantity of those lichens is not available to barren-ground caribou since the lichens are interwoven with the needles and branches of the conifers. Lichens on fallen trees, lichens dislodged by wind or snow, and lichens growing within 10 feet of the ground were considered accessible to the animals. As a food source, *Alectoria jubata* is thought to be the most important arboreal lichen in the study area.

The first, second, and third stages of secondary plant succession following forest fires are described. The first stages of succession were characterized by rapid changes in species composition. Floristic changes were less rapid as the stages of succession advanced.

The results of investigations of soil properties indicated that several changes were wrought by forest fires. Fire increased water infiltration rates on soils in one area which formerly supported a black spruce forest. Summer temperatures of exposed mineral soils in burned-over areas were higher at 1-inch and 3-inch depths than in unburned areas. Soils on burned areas may be subject to greater daily and seasonal temperature extremes than soils supporting mature forests. Soil erosion appeared to be a minor problem. On recent burns, acidity of soil was reduced for several years. Exchangeable calcium increased and total exchange capacity decreased on three of four burned-over soils. Amounts of exchangeable hydrogen were reduced, while amounts of available phosphorus increased in each of the burned-over soils. No trends were indicated for total nitrogen, or exchangeable potassium, magnesium, and sodium following forest fires. Destruction of unincorporated organic matter by forest fires was a serious loss. The full effect of these changes in soil properties on plant life will not be fully understood until ecological studies on plant requirements have been made.

Pellet-group counts and aerial surveys indicate that barren-ground caribou prefer climax forests and advanced successional stages of forest growth. Moose showed a preference for early successional stages of forest growth, particularly the post-fire stage 10 to 30 years after a fire. Neither species, however, limited itself to any one age class. Other mammals and birds were influenced by changes in habitat following forest fires.

From the results of this preliminary study on only one winter range area, it is impossible to determine the extent to which forest fires have influenced the decline of the barren-ground caribou population. But, if the effect of fire on plant productivity, plant succession, and growth rates of "reindeer lichens" are similar throughout the winter range, then there would be little doubt that forest fires have been one of the principal causes of the decline. Regardless of the reason for the decline, the present winter range, with its vast fire-destroyed areas, will place a restriction on caribou numbers for at least a few decades.

SOMMAIRE ET CONCLUSION

Le nombre de rennes arctiques habitant les forêts de conifères et la toundra du Nord canadien a rapidement diminué au cours des dernières années. Cette réduction a causé des privations à un grand nombre d'Indiens et d'Esquimaux qui comptent sur le renne arctique pour leur nourriture et divers autres besoins. Dans un effort pour arrêter cette diminution, le Service canadien de la faune du ministère du Nord canadien et des Ressources nationales a entrepris, en 1948, des recherches intensives sur le renne arctique. Etant donné qu'on a supposé que la destruction de la faune et de la flore climacique par les incendies de forêt était une des causes de la diminution du nombre de rennes arctiques, le Service a entrepris, en juillet 1959, une étude préliminaire afin d'estimer les effets des incendies dans une importante région d'hivernage du nord de la Saskatchewan.

Les commentaires sur les incendies de forêt qu'on trouve dans les notes des premiers explorateurs et la présence de charbon dans les coupes de sols indiquent que le rapport entre le nombre de rennes et les incendies de forêt n'est pas un phénomène récent. Cependant, les cartes de la flore de la région étudiée indiquent que la superficie dévastée chaque année par les incendies de forêt a augmenté de 1.4 fois au cours des 15 dernières années en comparaison des 60 années précédentes, et de 3.1 fois en comparaison de la période s'étendant de 1840 à 1884.

Un des effets les plus évidents des incendies de forêt sur l'habitat d'hiver du renne arctique est une réduction à la fois de la quantité et de la qualité du fourrage. On a déterminé la production de fourrage dans des forêts réparties en six classes selon leur âge. Les peuplements d'épinette noire et les peuplements de succession de bouleau à papier ont produit une moyenne de 290, 492, 604, 641, 830 et 942 livres de fourrage séché à l'air à l'acre dans les classes de 1 à 10, 11 à 30, 31 à 50, 51 à 75, 76 à 120 et plus de 120 ans, respectivement. La production accumulée de lichens à grande valeur nutritive, qui constituent la nourriture d'hiver préférée du renne arctique, a été de 1, 12, 61, 66, 205 et 264 livres à l'acre (séché à l'air) respectivement dans les six classes d'âge. Les herbacées et les plantes qui leur sont apparantées ont produit 185 livres de fourrage à l'acre dans la forêt de 1 à 10 ans, mais moins de 15 livres à l'acre dans les autres classes de forêt. La production arbustive a été faible dans la première classe, mais assez constante à environ 400 livres à l'acre dans les autres. Il se peut que la production des forêts de pin gris suive la même tendance générale que celle des forêts d'épinette noire, mais le peuplement avait une étendue trop limitée pour qu'on puisse tirer des conclusions précises.

Le brûlage des pâturages d'hiver ne cause qu'une diminution temporaire de leur productivité, sauf en ce qui concerne le précieux "lichen des caribous". Dans le nord de la Saskatchewan, il faut un siècle ou plus aux "lichens des caribous" détruits par le feu pour retrouver leur ancienne abondance. On a calculé que *Cladonia alpestris* et *C. rangiferina* ont une croissance annuelle d'environ 4.1 et 4.9 millimètres, respectivement. On trouve rarement ces deux lichens dans des forêts de moins de 30 ans.

Dans les forêts de conifères adultes, les lichens corticoles peuvent contribuer sensiblement à la nourriture d'hiver du renne arctique, surtout lorsqu'il fait mauvais temps. Il y avait environ 628 livres de lichens corticoles accessibles à l'acre dans les forêts d'èpinettes noires adultes, en comparaison de 375 livres dans les forêts de pins gris adultes. Une partie des lichens n'est pas accessible au renne arctique, car ils sont entrelacés avec les aiguilles et les branches des arbres. On a considéré comme accessibles aux animaux les lichens poussant sur les arbres tombés, ceux qui ont été détachés par le vent ou la neige et ceux qui poussent sur les arbres jusqu'à dix pieds du sol. On croit que, comme source de nourriture, *Alectoria jubata* est le lichen corticole le plus important de la région étudiée.

Une description est donnée des premier, deuxième et troisième stades de la succession secondaire des plantes à la suite d'un incendie de forêt. Les premiers stades de la succession étaient caractérisés par des changements rapides d'espèces. Les changements floristiques devenaient moins rapides à mesure qu'on avançait dans les stades de succession.

Les résultats des recherches sur les propriétés des sols indiquent que les incendies de forêt leur ont apporté plusieurs changements. Le feu a augmenté le taux d'infiltration de l'eau dans le sol dans une région recouverte auparavant d'épinettes noires. En été, la température du sol minéral dénudé dans les aires brûlées était plus élevée à une profondeur de 1 et de 3 pouces que dans les aires non brûlées. Il se peut que le sol des aires brûlées soit soumis à de plus grands écarts de température journalière et saisonnière que le sol des forêts adultes. L'érosion du sol a semblé n'être qu'un problème d'importance secondaire. Dans les brulis récents, l'acidité du sol a été plus faible durant plusieurs années. Le teneur en calcium échangeable a augmenté, tandis que la capacité totale d'échange a diminué dans trois terrains brûlés sur quatre. La quantité d'hydrogène échangeable a diminué, alors que la quantité de phosphore assimilable a augmenté dans chacun des brûlis. Aucun changement n'a été décelé en ce qui concerne l'azote total, ni le potassium, le magnésium et le sodium échangeables à la suite d'incendies de forêt. La destruction par le feu de matières organiques non incorporées au sol a été bien désastreuse. Tout l'effet de ces changements de propriétés du sol sur la vie des plantes ne pourra être bien compris qu'après des études écologiques sur les besoins des plantes.

Le dénombrement de petits groupes et des relevés aériens indiquent que le renne arctique préfère les forêts climaciques et celles qui sont parvenues à un stade avancé de succession. Les orignaux, eux, montrent une certaine préférence à l'endroit des forêts aux premiers stades de succession, en particulier le stade qu'on trouve entre 10 et 30 ans après un incendie de forêt. Aucune des espèces, cependant, ne se limite à une seule des classes d'âge. Les autres mammifères et les oiseaux ont aussi subi l'influence des changements d'habitat qu'ont entraînés les incendies de forêt.

Les résultats de cette étude préliminaire d'un seul pâturage d'hiver ne permettent pas de déterminer dans quelle mesure la diminution de la population de rennes arctiques est attribuable aux incentries de forêt. Cependant, si les effets de l'incendie sur la productivité végétale, sur la succession de plantes et sur la croissance des "lichens des caribous" sont les mêmes dans tout l'habitat d'hiver, on ne peut guère douter que les incendies de forêt aient été une des principales causes de cette diminution. Quelle que soit la raison de cette dernière, l'habitat d'hiver actuel, avec ses vastes brûlis, va restreindre le nombre de rennes pour au moins quelques décennies.

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APPENDICES

Appendix A

CHECKLIST OF THE FLORA ON THE BARREN-GROUND CARIBOU WINTER RANGE OF NORTHERN SASKATCHEWAN

LICHENES

CALICIACEAE
- *Chaenotheca chrysocephala* (Turn.) Th. Fr.

CYPHELIACEAE
- *Cyphelium tigillare* Ach.

PANNARIACEAE
- *Pannaria pezizoides* (Web.) Trev.
- *Massalongia carnosa* (Dicks.) Korber

PELTIGERACEAE
- *Nephroma arcticum* (L.) Torss.
- *Nephroma bellum* (Spreng.) Tuck.
- *Peltigera aphthosa* (L.) Willd.
- *Peltigera canina* (L.) Willd.
- *Peltigera canina* var. *rufescens*
- *Peltigera canina* var. *spuria*
- *Pelltigera canina var. ulorrhiza*
- *Peltigera malacea* (Ach.) Funck
- *Peltigera pulverulenta* (Tayl.) Nyl.

GYALECTACEAE
- *Microphiale diluta* (Pers.) Zahlbr.

LECIDEACEAE
- *Lecidea alaiensis* Vainio
- *Lecidea assimilata* Nyl.
- *Lecides auriculata* Th. Fr.
- *Lecidea berengeriana* (Mass.) Th. Fr.
- *Lecidea cuprea* Sommerf.
- *Lecidea granulosa* (Ehrh.) Ach.
- *Lecidea lapicida* Ach. var. *ochracea* (Nyl.) Vainio
- *Lecidea macrocarpa* (D.C.) Th. Fr.
- *Lecidea* (Psora) *ostreata* (Hoffm.) Schaer.
- *Mycoblastus sanguinarius* (L.) Norm.
- *Rhizocarpon grande* (Florke) Arn.
- *Rhizocarpon lindsayanum* Ras.
- *Rhizocarpon obscuratum* (Ach.) Mass.

CLADONIACEAE
- *Baeomyces rufus* (Huds.) Rabenh.
- *Cladonia alpestris* (L.) Rabenh.
- *Cladonia alpicola* (Flot.) Vain.
- *Cladonia amaurocraea* (Florke) Schaer.
- *Cladonia bacillaris* (Ach.) Nyl.
- *Cladonia botrytes* (Hag.) Willd.

CLADONIACEAE (continued)

Cladonia cariosa (Ach.) Spreng.
Cladonia carneola Fr.
Cladonia cenotea (Ach.) Schaer.
Cladonia coccifera (L.) Zopf
Cladonia cornuta (L.) Schaer.
Cladonia crispata (Ach.) Flot.
Cladonia cristatella Tuck.
Cladonia deformis (L.) Hoffm.
Cladonia gracilis (L.) Willd.
Cladonia gracilis var. *dilatata* (Hoffm.)
Cladonia mitis Sandst.
Cladonia multiformis Merr. f. *finkii* (Vainio) Evans
Cladonia pyxidata (L.) Fr.
Cladonia pyxidata var. *neglecta* (Flk.)
Cladonia rangiferina (L.) Web.
Cladonia turgida (Ehrh.) Hoffm.
Cladonia uncialis (L.) Web.
Cladonia verticillata (Hoffm.) Schaer.
Stereocaulon alpinum Laur.
Stereocaulon dactylophyllum Florke
Stereocaulon paschale (L.) Hoffm.
Stereocaulon tomentosum Fr.

UMBILICARIACEAE

Actinogyra muhlenbergii (Ach.) Scholander
Lasallia papulosa (Ach.) Llano
Umbilicaria hyperborea (Ach.) Hoffm.
Umbilicaria vellea (L.) Ach.

LECANORACEAE

Haematomma lapponicum Ras
Icmadophila ericetorum (L.) Zahlbr.
Lecanora pachythallina Lynge
Lecanora rubina (Vill.) Ach.
Ochrolechia frigida (Sw.) Lynge
Ochrolechia inaequatula (Nyl.) Zahlbr.
Candelariella vitellina (Ehrh.) Mull. Arg.

PARMELIACEAE

Parmeliopsis ambigua (Wulf.) Nyl.
Parmeliopsis hyperopta (Ach.) Vain.
Parmelia centrifuga (L.) Ach.
Parmelia olivacea (L.) Ach.
Parmelia omphalodes (L.) Ach.
Parmelia physodes (L.) Ach.
Parmelia rudecta Ach.
Parmelia saxatilis (L.) Ach.
Parmelia separata Th. Fr.
Parmelia sinuosa Nyl.
Parmelia subobscura Vainio
Parmelia sulcata Tayl.
Cetraria ciliaris Ach.
Cetraria commixta (Nyl.) Th. Fr.
Cetraria crispa (Ach.) Nyl.
Cetraria cucullata (Bell.) Ach.
Cetraria glauca (L.) Ach.
Cetraria hepatizon (Ach.) Vain.
Cetraria islandica (L.) Ach.
Cetraria nivalis (L.) Ach.
Cetraria pinastri (Scop.) S. Gray
Cetraria sepincola (Ehrh.) Ach.

USNEACEAE

Alectoria jubata (L.) Ach.
Alectoria nadvornikiana Gyel.
Alectoria nidulifera Norrl.
Evernia mesomorpha Nyl.
Ramalina pollinaria (Westr.) Ach.
Usnea dasypoga (Ach.) Rohl.
Usnea glabrescens (Nyl.) Vainio spp. *glabrella Mot.*
Usnea hirta (L.) Wigg.

CALOPLACACEAE

Caloplaca cerina (Ehrh.) Th. Fr.
Caloplaca elegans (Link.) Th. Fr.
Caloplaca flavovirescens (Wulf.) D. T. & S.
Caloplaca ulmorum (Fink) Fink

TELOSCHISTACEAE

Xanthoria candelaria (L.) Arn.
Xanthoria fallax (Hepp) Arn.

BUELLIACEAE

Rinodina lecideoides (Nyl.) Vain.
Rinodina oreina (Ach.) Mass.

PHYSCIACEAE

Physcia dubia (Hoffm.) Lett.

LICHENES IMPERFECTI

Crocynia membranacea (Dicks.) Zahlbr.
Crocynia neglecta (Nyl.) Hue

HEPATICAE

Ptilidium ciliare (L.) Hampe
Marchantia polymorpha L.

SPHAGNA

Sphagnum capillaceum (Weiss.) Schrank
Sphagnum capillaceum var. *tenellum* (Schimp.) Andr.

MUSCI

Andreaea rupestris Hedw.
Ceratodon purpureus (Hedw.) Brid.
Dicranum elongatum Schwaegr.
Dicranum rugosum (Hoffm.) Brid.
Aulacomnium palustre (Hedw.) Schwaegr.
Hedwigia ciliata (Hedw.) P. Beauv.
Neckera pennata Hedw.
Pleurozium schreberi (Brid.) Mitt.
Ptilium crista-castrensis (Hedw.) DeNot.
Hylocomium splendens (Hedw.) B.S.G.
Polytrichum commune Hedw.
Polytrichum juniperinum Hedw.
Polytrichum juniperinum var. *alpestre* B.S.G.
Polytrichum piliferum Hedw.

VASCULAR PLANTS

POLYPODIACEAE

Woodsia ilvensis (L.) R. Br. .... Rusty fern
Dryopteris disjuncta (Ledeb.) C. V. Morton .... Oak fern
Dryopteris fragrans (L.) Schott. .... Fragrant cliff fern
Cryptogramma crispa (L.) R. Br.
var. *acrostichoides* (R. Br.) C. B. Clarke .... Mountain parsley

EQUISETACEAE

Equisetum sylvaticum L. .... Woodland horsetail
Equisetum sylvaticum L.
var. *multiramosum* (Fern.) Wherry
Equisetum fluviatile L. .... Water horsetail
Equisetum scirpoides Michx. .... Dwarf scouring rush

LYCOPODIACEAE

Lycopodium annotinum L. var. pungens (La Pyl.) Desv.	Pungent stiff club-moss
Lycopodium obscurum L.	Tree club-moss
Lycopodium complanatum L.	Running club-moss

PINACEAE

Picea glauca (Moench) Voss	White spruce
Picea mariana (Mill.) BSP.	Black spruce
Larix laricina (Du Roi) Koch	Tamarack
Pinus banksiana Lamb.	Jack pine
Juniperus communis L. var. *depressa* Pursh	Ground juniper

GRAMINEAE

Festuca saximontana Rydb.	Rocky mountain fescue
Poa pratensis L.	June grass
Poa interior Rydb.	Inland bluegrass
Poa palustris L.	Fowl meadow grass
Poa glauca Vahl	Blue-green meadow grass
Agropyron trachycaulum (Link) Malte	Rough-stemmed grass
Hordeum jubatum L.	Squirrel-tail grass
Deschampsia caespitosa (L.) Beauv.	Tufted hairgrass
Calamagrostis purpurascens R. Br.	Purplish reed-bentgrass
Calamagrostis canadensis (Michx.) Beauv.	Bluejoint
Agrostis scabra Willd.	Hairgrass
Alopecurus aequalis Sobol.	Water foxtail
Beckmannia syzigachne (Steud.) Fern.	Slough-grass

CYPERACEAE

Eriophorum spissum Fern.	Hare's-tail
Eriophorum angustifolium Honck.	Narrow-leaved cotton grass
Scirpus caespitosus L. var. *callosus* Bigel.	Callous bulrush
Scirpus hudsonianus (Michx.) Fern.	Hudson Bay bulrush
Carex foenea Willd.	Hay-like sedge
Carex loliacea L.	
Carex brunnescens (Pers.) Poir.	Brownish sedge
Carex canescens L.	Hoary sedge
Carex aenea Fern.	Hay sedge
Carex deflexa Hornem.	Deflexed sedge
Carex paupercula Michx.	Bog sedge
Carex media R. Br.	
Carex aquatilis Wahl.	Water sedge
Carex rostrata Stokes	

JUNCACEAE

Juncus vaseyi Engelm.	
Juncus balticus Willd.	Wire rush
Luzula multiflora (Retz.) Lej.	Wood rush

LILIACEAE

Smilacina trifolia (L.) Desf.	False Solomon's seal

ORCHIDACEAE

Spiranthes romanzoffiana Cham. & Schl.	Hooded ladies' tresses

SALICACEAE

Populus tremuloides Michx.	Quaking aspen
Populus balsamifera L.	Balsam poplar
Salix glauca L.	Grayleaf willow
Salix myrtillifolia Anderss.	Myrtle-leaved willow
Salix pseudomonticola Ball	False mountain willow
Salix pyrifolia Anderss.	Balsam willow
Salix bebbiana Sarg.	Long-beaked willow
Salix planifolia Pursh	Flat-leafed willow
Salix arbusculoides Anderss.	

MYRICACEAE

Myrica gale L.	Sweet gale

BETULACEAE

Betula papyrifera Marsh .... White birch
Betula papyrifera Marsh
var. *humilis* (Regel) Fern & Raup
Betula glandulosa Michx. .... Dwarf birch
Alnus crispa (Ait.) Pursh .... Green alder
Alnus tenuifolia Nutt. .... River alder

SANTALACEAE

Geocaulon lividum (Richards.) Fern. .... Northern comandra

POLYGONACEAE

Rumex occidentalis S. Wats. .... Dock

NYMPHAECEAE

Nuphar variegatum Engelm. .... Bullhead lily

RANUNCULACEAE

Anemone patens L. .... Pasque flower
Ranunculus lapponicus L.
Ranunculus abortivus L. .... Kidney leaf buttercup

FUMARIACEAE

Corydalis sempervirens (L.) Pers. .... Pale corydalis

CRUCIFERAE

Draba nemorosa L.
Lepidium bourgeauanum Thell. .... Pepperwort

SAXIFRAGACEAE

Saxifraga tricuspidata Rottb.
Ribes oxyacanthoides L.
Ribes hudsonianum Richardson
Ribes glandulosum Grauer .... Skunk currant

PARNASSIACEAE

Parnassia palustris L. var. *neogaea* Fern. .... Grass of Parnassus

ROSACEAE

Amelanchier alnifolia Nutt. .... Saskatoon-berry
Rubus idaeus L.
var. *aculeatissimus* Regel & Tiling .... Raspberry
Rubus chamaemorus L. .... Cloudberry
Rubus acaulis Michx. .... Dwarf raspberry
Fragaria vesca L. .... Woodland strawberry
Potentilla norvegica L. .... Norwegian cinquefoil
Potentilla palustris (L.) Scop. .... Marsh cinquefoil
Potentilla tridentata Ait. .... Three-toothed cinquefoil
Geum perincisum Rydb. .... Avens
Rosa bourgeauiana Crep. .... Prickley rose
Prunus pensylvanica L. f. .... Pin cherry

EMPETRACEAE

Empetrum nigrum L.
var. *hermaphroditum* (Lange) Sorensen .... Black crowberry

ELAEAGNACEAE

Shepherdia canadensis (L.) Nutt. .... Soapberry

ONAGRACEAE

Epilobium angustifolium L. .... Fireweed
Epilobium glandulosum Lehm.
var. *adenocaulon* (Haussk.) Fern. .... Willow herb

ARALIACEAE

Aralia nudicaulis L. .... Wild sarsaparilla

CORNACEAE

Cornus canadensis L. .... Bunchberry

PYROLACEAE

Moneses uniflora (L.) A. Gray .... Wintergreen (one flowered)
Pyrola secunda L. .... One-sided wintergreen
Pyrola virens Schweigger
Pyrola asarifolia Michx. .... Pink Pyrola

ERICACEAE

Ledum groenlandicum Oeder	Common Labrador tea
Ledum palustre L. var. *decumbens* Ait.	Northern Labrador tea
Loiseleuria procumbens (L.) Desv.	Alpine azalea
Kalmia polifolia Wang.	Pale laurel
Andromeda polifolia L.	Bog rosemary
Chamaedaphne calyculata (L.) Moench	Leather leaf
Arctostaphylos uva-ursi (L.) Spreng	Common bearberry
Vaccinium uliginosum L.	Bog bilberry
Vaccinium myrtilloides Michx.	Velvet-leaf blueberry
Vaccinium vitis-idaea L. var. *minus* Lodd.	Mountain cranberry
Vaccinium oxycoccus L.	Small cranberry

GENTIANACEAE

Menyanthes trifoliata L.	Three-leaved buckbean

SCROPHULARIACEAE

Pedicularis labradorica Wirsing	Lousewort

LENTIBULARIACEAE

Pinguicula villosa L.	Butterwort

RUBIACEAE

Galium trifidum L.	Three-cleft bedstraw

CAPRIFOLIACEAE

Viburnum edule (Michx.) Raf.	Squashberry
Linnaea borealis L. var. *americana* (Forbes) Rehd.	Twinflower

CAMPANULACEAE

Campanula rotundifolia L.	Harebell

COMPOSITAE

Solidago spathulata DC.	Goldenrod
Aster laevis L.	Smooth aster
Aster ciliolatus Lindl.	Aster
Achillea sibirica Ledeb.	Siberian yarrow
Achillea lanulosa Nutt.	Woolly yarrow
Matricaria matricarioides (Less.) Porter	Wild chamomile
Petasites palmatus (Ait.) A. Gray	Palmate sweet coltsfoot
Petasites vitifolius Greene	Grape-leaved sweet coltsfoot
Petasites sagittatus (Pursh) A. Gray	Arrow-shaped sweet coltsfoot
Senecio pauperculus Michx. var. *flavovirens* (Rydb.) Boivin	Poor groundsel
Taraxacum dumentorum Greene	Dandelion
Taraxacum officinale Weber	Common dandelion
Hieracium scabriusculum Schw.	Hawkweed

Appendix B

CHECKLIST OF VERTEBRATE FAUNA ON THE BARREN-GROUND CARIBOU WINTER RANGE OF NORTHERN SASKATCHEWAN

Class *OSTEICHTHYES* (nomenclature based on Scott, 1958)

Salvelinus namaycush (Walbaum)	Lake trout
Esox lucius (Linnaeus)	Northern pike
Stizostedion vitreum vitreum (Mitchill)	Walleye
Thymallus arcticus (Pallas)	Arctic grayling
Catostomus sp.	Sucker
Coregonus clupeaformis (Mitchill)	Lake whitefish

Class *AVES* (nomenclature based on American Ornithologists' Union Check-list, 1957)

Gavia immer (Brunnich)	Common loon
Branta canadensis (Linnaeus)	Canada goose
Anas platyrhynchos Linnaeus	Mallard
Anas acuta Linnaeus	Pintail
Anas carolinensis Gmelin	Green-winged teal
Aythya affinis (Eyton)	Lesser scaup
Bucephala clangula (Linnaeus)	Common goldeneye
Bucephala albeola (Linnaeus)	Bufflehead
Melanitta perspicillata (Linnaeus)	Surf scoter
Mergus merganser Linnaeus	Common merganser
Accipiter gentilis (Linnaeus)	Goshawk
Buteo jamaicensis (Gmelin)	Red-tailed hawk
Haliaeetus leucocephalus (Linnaeus)	Bald eagle
Pandion haliaetus (Linnaeus)	Osprey
Falco columbarius Linnaeus	Pigeon hawk
Falco sparverius Linnaeus	Sparrow hawk
Canachites canadensis (Linnaeus)	Spruce grouse
Lagopus lagopus (Linnaeus)	Willow ptarmigan
Pedioecetes phasianellus (Linnaeus)	Sharp-tailed grouse
Actitis macularia (Linnaeus)	Spotted sandpiper
Tringa solitaria Wilson	Solitary sandpiper
Totanus flavipes (Gmelin)	Lesser yellowlegs
Larus philadelphia (Ord)	Bonaparte's gull
Sterna hirundo Linnaeus	Common tern
Chordeiles minor (Forster)	Common nighthawk
Megaceryle alcyon (Linnaeus)	Belted kingfisher
Colaptes auratus (Linnaeus)	Yellow-shafted flicker
Picoides arcticus (Swainson)	Black-backed three-toed woodpecker
Hirundo rustica Linnaeus	Barn swallow
Perisoreus canadensis (Linnaeus)	Gray jay
Corvus corax Linnaeus	Common raven
Parus atricapillus Linnaeus	Black-capped chickadee
Parus hudsonicus Forster	Boreal chickadee
Turdus migratorius Linnaeus	Robin
Hylocichla guttata (Pallas)	Hermit thrush
Regulus calendula (Linnaeus)	Ruby-crowned kinglet
Dendroica petechia (Linnaeus)	Yellow warbler
Dendroica coronata (Linnaeus)	Myrtle warbler
Seiurus noveboracensis (Gmelin)	Northern waterthrush
Euphagus carolinus (Muller)	Rusty blackbird
Loxia leucoptera Gmelin	White-winged crossbill
Junco hyemalis (Linnaeus)	Slate-colored junco
Spizella passerina (Bechstein)	Chipping sparrow
Zonotrichia leucophrys (Forster)	White-crowned sparrow
Melospiza melodia (Wilson)	Song sparrow

Class *MAMMALIA* (nomenclature based primarily on Beck, 1958)

Euarctos americanus Pallas	Black bear
Canis lupus Linnaeus	Gray wolf (tracks seen)
Martes americana (Turton)	Marten
Lepus americanus (Erxleben)	Snowshoe hare
Tamiasciurus hudsonicus (Erxleben)	Red squirrel
Castor canadensis Kuhl.	Beaver (house and dam seen)
Peromyscus maniculatus (Wagner)	Deer mouse (trapped)
Alces alces (Linnaeus)	Moose
Rangifer tarandus groenlandicus (Linnaeus)	Barren-ground caribou

Appendix C

CANADIAN WILDLIFE SERVICE
WEIGHT-ESTIMATE FIELD WRITE-UP SHEET

Surveyor.. Sheet No...

Date.. Transect No...

Veg. Type.. Aerial Photo No..

Area..

Species	PLOT RECORD										Total field Wt. grms.	Total lbs./acre	Compilation			
	1 FW	2 FW	3 FW	4 FW	5 FW	6 FW	7 FW	8 FW	9 FW	10 FW			%Dry Wt.	Dry Wt.	PUF	lbs. UF
Grasses:																
Forbs:																
Shrubs:																
Lichens:																
Plot Totals																

COMMENTS

1. Range Conditions: ....

....

2. Current Utilization: ....

....

3. Vigor of Major Forage Species: ....

....

4. Biotic Influence: ....

....

5. Timber: Age..

   Method of determination...

   Density ....

   Composition..

6. Topography: ....

....

7. Site Productivity: ....

....

8. Soil: ....

....

....

9. Slope: ....

....

10. Remarks: ....

....

....

....

....

FORAGE PRODUCTIVITY IN WHITE BIRCH AND BLACK SPRUCE FORESTS IN VARIOUS AGE CLASSES

TABLE 22

Air-dry forage in recently burned forests 1 to 10 years of age

	Locations							Average productivity per class in lbs.
	Higginson Lake	Grove Lake	Oblate Lake	McKeever Lake	Little Faraud Lake	Marchant Lake	Dodge Lake	
	Grams per 80 plots X 10							
Grass & grass-like plants								
Agrostis scabra	650	—	—	—	—	2262	—	
Calamagrostis canadensis	1350	1800	48	5646	229	450	7228	
Poa glauca	750	—	—	—	—	—	—	
Poa interior	—	—	—	—	—	—	26	
Carex aenea	—	36	176	547	2600	325	2366	
Carex brunnescens	—	—	350	—	—	—	—	
Carex canescens	—	—	—	438	—	—	—	
Carex deflexa	—	1196	1845	193	246	—	832	
Carex foenea	850	—	—	—	—	—	—	
Carex spp.	350	—	—	—	70	—	—	
Equisetum sylvaticum	—	—	187	1718	—	—	751	
	3950	3032	2606	8542	3145	3037	11203	63
Herbs								
Epilobium angustifolium	14950	7400	5894	7395	13350	10943	6640	
Corydalis sempervirens	150	—	20	420	740	80	300	
Epilobium glandulosum	—	—	—	—	30	—	—	
Petasites palmatus	—	—	—	T*	—	—	—	
	15100	7400	5914	7815	14120	11023	6940	122
Shrubs								
High value								
Vaccinium vitis-idaea var. *minus*	4232	3066	819	836	336	442	676	
	4232	3066	819	836	336	442	676	18
Moderate value								
Salix spp.	200	—	350	5150	2925	1400	45	
	200	—	350	5150	2925	1400	45	18
Low value								
Alnus crispa	—	336	3045	2373	—	—	2543	
Andromeda polifolia	—	88	50	—	—	23	—	
Arctostaphylos uva-ursi	—	48	28	—	—	630	—	
Ledum groenlandicum	5432	1956	374	4642	462	598	1560	
Ribes glandulosum	—	—	—	60	45	—	765	
Rubus chamaemorus	—	46	—	253	—	76	68	
Rubus idaeus var. *aculeatissimus*	247	—	—	1104	836	23	768	
Vaccinium myrtilloides	—	—	3894	—	48	—	—	
Vaccinium uliginosum	—	299	644	—	48	—	—	
	5679	2773	8035	8432	1439	1350	5704	60
Total shrub weight	(10111)	(5839)	(9204)	(14418)	(4700)	(3192)	(6425)	(96)
Lichens								
High value								
Cladonia alpestris *Cladonia amaurocraea* *Cladonia mitis* *Cladonia uncialis*	74	364	30	—	—	210	T	
Cladonia rangiferina	—	17	—	—	—	—	—	
	74	381	30	—	—	210	T	1
Moderate value								
Cetraria nivalis	—	75	T	—	—	—	—	
Peltigera canina	—	140	30	—	—	720	T	
Stereocaulon spp.	—	62	99	—	—	60	T	
	—	277	129	—	—	780	T	2
Low value								
Cetraria crispa *Cladonia alpicola* *Cladonia botrytes* *Cladonia cariosa* *Cladonia coccifera* *Cladonia cornuta* *Cladonia cristatella* *Cladonia deformis* *Cladonia pyxidata* *Icmadophila ericetorum*	355	130	T	—	—	390	T	
	355	130	T	—	—	390	T	2
Total lichen weight	(429)	(788)	(159)	0	0	(1380)	T	(5)
Others								
Lycopodium annotinum	100	500	—	—	—	—	—	
Marchantia polymorpha	—	—	—	80	660	600	225	4
	100	500	—	80	660	600	225	
Total weight	29690	17559	17883	30855	22625	19232	24793	
Average pounds of forage per acre	371	219	223	385	282	240	310	290

*T = Trace

TABLE 23

Air-dry forage in forests 11 to 30 years of age

	Location and age of forests						Average Productivity per class in lbs.
	Higginson Lake 16 yrs.	Faraud Lake 19 yrs.	Marchant Lake 27 yrs.	Dodge Lake 13 yrs.	Father Lake 20 yrs.	Chipman Lake 15 yrs.	
	Grams per 80 plots X 10						
Grass & grass-like plants							
Calamagrostis canadensis	—	—	—	300	660	1148	
Gramineae—unidentified	525	161	50	—	—	—	
Carex aenea	—	—	—	275	—	140	
Carex deflexa	—	—	—	25	660	—	
Carex spp.	53	—	225	—	60	—	
	578	161	275	600	1380	1288	9
Herbs							
Epilobium angustifolium	136	165	18	320	420	1197	
Cornus canadensis	—	—	—	—	92	—	
Geocaulon lividum	14	—	—	50	23	—	
	150	165	18	370	535	1197	5
Shrubs							
High value							
Vaccinium vitis-idaea var. *minus*	10973	16000	26312	29588	11206	18299	
	10973	16000	26312	29588	11206	18299	234
Moderate value							
Empetrum nigrum	—	—	—	90	—	—	
Prunus pensylvanica	—	—	—	—	68	801	
Salix spp.	275	625	563	—	1368	1059	
	275	625	563	90	1436	1860	10
Low value							
Alnus crispa	6762	—	2183	—	2589	—	
Arctostaphylos uva-ursi	912	275	—	428	585	3300	
Ledum groenlandicum	13901	5786	12844	11492	8379	3354	
Linnaea borealis	—	—	—	—	—	72	
Ribes glandulosum	—	—	—	—	203	—	
Rubus idaeus var. *aculeatissimus*	—	25	—	23	46	566	
Vaccinium myrtilloides	—	—	—	430	790	—	
Vaccinium uliginosum	621	—	—	90	630	26	
	22196	6086	15027	12463	13222	7318	159
Total shrub weight	(33444)	(22711)	(41902)	(42141)	(25864)	(27477)	(403)
Lichens							
High value							
Cladonia alpestris *Cladonia amaurocraea* *Cladonia mitis* *Cladonia uncialis*	354	838	2100	701	880	529	
Cladonia rangiferina	T	—	30	88	—	—	
	354	838	2130	789	880	529	12
Moderate value							
Cetraria nivalis	19	80	210	170	80	—	
Peltigera aphthosa	120	80	750	T	—	T	
Peltigera canina	920	320	930	1322	760	220	
Stereocaulon spp.	105	240	840	597	120	—	
	1164	720	2730	2089	960	220	16
Low value							
Cetraria crispa *Cladonia alpicola* *Cladonia bacillaris* *Cladonia botrytes* *Cladonia cariosa* *Cladonia cenotea* *Cladonia coccifera* *Cladonia cornuta* *Cladonia cristatella* *Cladonia deformis* *Cladonia gracilis* *Cladonia pyxidata* *Cladonia turgida*	1354	4480	3810	4040	3880	4900	
	1354	4480	3810	4040	3880	4900	47
Total lichen weight	(2872)	(6038)	(8670)	(6918)	(5720)	(5649)	(75)
Total weight	37044	29075	50865	50029	33499	35611	
Average pounds of forage per acre	463	363	635	625	418	445	492

TABLE 24

Air-dry forage in forests 31 to 50 years of age

	Location and age of forests				Average productivity per class in lbs.
	Offset Lake 39 yrs.	Faraud Lake 32 yrs.	Father Lake 31 yrs.	Chipman Lake 50 yrs.	
	Grams per 80 plots X 10				
Grass & grass-like plants					
Calamagrostis canadensis	72	—	60	30	
Gramineae—unidentified	—	125	—	—	
Equisetum sylvaticum	18	—	—	—	
	90	125	60	30	1
Herbs					
Epilobium angustifolium	28	18	—	—	
Geocaulon lividum	1840	420	23	—	
	1868	438	23	—	7
Shrubs					
High value					
Vaccinium vitis-idaea var. *minus*	13258	28872	30602	19633	
	13258	28872	30602	19633	289
Moderate value					
Empetrum nigrum	336	—	135	—	
Salix spp.	450	625	1008	—	
	786	625	1143	—	8
Low value					
Alnus crispa	—	—	1560	1328	
Andromeda polifolia	80	—	—	—	
Arctostaphylos uva-ursi	478	200	1756	—	
Ledum groenlandicum	3254	10186	9620	1508	
Ledum palustre var. *decumbens*	94	—	—	—	
Rubus chamaemorus	—	25	—	—	
Vaccinium myrtilloides	1254	—	—	—	
Vaccinium uliginosum	2530	118	68	—	
	7690	10529	13004	2836	106
Total shrub weight	(21734)	(40026)	(44749)	(22469)	(403)
Lichens					
High value					
Cladonia alpestris, *Cladonia amaurocraea*, *Cladonia mitis*, *Cladonia uncialis*	3127	3600	7505	4798	
Cladonia rangiferina	184	180	21	144	
	3311	3780	7526	4942	61
Moderate value					
Cetraria nivalis	550	495	161	130	
Peltigera aphthosa	—	1745	920	1280	
Peltigera canina	851	3707	2714	1232	
Stereocaulon spp.	3664	4905	4116	1633	
	5065	10852	7911	4275	88
Low value					
Cetraria crispa, *Cladonia alpicola*, *Cladonia bacillaris*, *Cladonia botrytes*, *Cladonia cariosa*, *Cladonia cenotea*, *Cladonia coccifera*, *Cladonia cornuta*, *Cladonia crispata*, *Cladonia cristatella*, *Cladonia deformis*, *Cladonia gracilis*, *Cladonia multiformis*, *Cladonia pyxidata*, *Cladonia turgida*, *Cladonia verticillata*, *Nephroma arcticum*	3096	3285	4692	2964	
	3096	3285	4692	2964	44
Total lichen weight	(11472)	(17917)	(20129)	(12181)	(193)
Total weight	35164	58506	64961	34680	
Average pounds of forage per acre	439	731	812	433	604

TABLE 25

Air-dry forage in forests 51 to 75 years of age

	Location and age of forests			Average productivity per class in lbs.
	Grove Lake 70 yrs.	Oblate Lake 60 yrs.	Oblate Lake 65 yrs.	
	Grams per 80 plots x 10			
Grass & grass-like plants				
Calamagrostis canadensis	75	—	—	
Gramineae — unidentified	—	90	T	
	75	90	T	1
Herbs				
Geocaulon lividum	20	320	1820	
	20	320	1820	9
Shrubs				
High value				
Vaccinium vitis-idaea var. *minus*	22251	13965	17934	
	22251	13965	17934	226
Moderate value				
Empetrum nigrum	—	126	147	
Salix spp.	—	300	225	
	—	426	372	3
Low value				
Alnus crispa	3402	840	—	
Arctostaphylos uva-ursi	—	—	624	
Kalmia polifolia	21	—	—	
Ledum groenlandicum	5965	5258	6952	
Vaccinium myrtilloides	—	1464	696	
Vaccinium uliginosum	—	2569	759	
	9388	10131	9031	119
Total shrub weight	(31639)	(24522)	(27337)	(348)
Lichens				
High value				
Cladonia alpestris *Cladonia amaurocraea* *Cladonia mitis* *Cladonia uncialis*	2766	6930	4635	
Cladonia rangiferina	849	315	450	
	3615	7245	5085	66
Moderate value				
Cetraria nivalis	205	900	810	
Peltigera aphthosa	420	1874	1575	
Peltigera canina	300	10253	3285	
Stereocaulon spp.	293	14850	9225	
	1218	27877	14895	183
Low value				
Cetraria crispa *Cladonia alpicola* *Cladonia cariosa* *Cladonia carneola* *Cladonia cornuta* *Cladonia crispata* *Cladonia cristatella* *Cladonia deformis* *Cladonia gracilis* *Cladonia pyxidata* *Nephroma arcticum*	984	3581	3600	
	984	3581	3600	34
Total lichen weight	(5817)	(38703)	(23580)	(283)
Total weight	37551	63635	52737	
Average pounds of forage per acre	469	795	659	641

TABLE 26

Air-dry forage in forests 76 to 120 years of age

	Location and age of forests						Average productivity per class in lbs.
	Grove Lake 115 yrs.	S. McKeever Lake 120 yrs.	N. McKeever Lake 110 yrs.	Faraud Lake 95 yrs.	Father Lake 115 yrs.	Newnham Lake 110 yrs.	
	Grams per 80 plots x 10						
Grass & grass-like plants							
Calamagrostis canadensis	50	—	—	—	120	130	
Gramineae—unidentified	150	514	197	195	—	—	
Carex spp.	—	—	—	—	300	—	
Equisetum sylvaticum	—	36	124	71	231	—	
	200	550	321	266	651	130	4
Herbs							
Geocaulon lividum	—	—	—	—	23	339	
					23	339	1
Shrubs							
High value							
Vaccinium vitis-idaea var. *minus*	25230	19677	29976	31425	32526	32022	
	25230	19677	29976	31425	32526	32022	356
Moderate value							
Empetrum nigrum	115	—	425	—	1060	91	
Salix spp.	—	75	—	T	T	—	
	115	75	425	T	1060	91	4
Low value							
Alnus crispa	1554	2394	1710	1771	8658	42	
Andromeda polifolia	—	—	25	—	46	—	
Ledum groenlandicum	10274	6490	4994	6688	—	6760	
Ledum palustre var. *decumbens*	—	88	198	—	—	—	
Rubus chamaemorus	—	—	425	—	204	T	
Vaccinium myrtilloides	—	—	—	—	—	207	
Vaccinium oxycoccus	—	—	25	—	69	—	
Vaccinium uliginosum	115	—	—	T	68	—	
	11943	8972	7377	8459	9045	7009	110
Total shrub weight	(37288)	(28724)	(37778)	(39884)	(42631)	(39122)	(470)
Lichens							
High value							
Cladonia alpestris, *Cladonia amaurocraea*, *Cladonia mitis*, *Cladonia uncialis*	4074	10880	9632	7566	11247	12136	
Cladonia rangiferina	2915	10080	6944	4515	13668	4531	
	6989	20960	16576	12081	24915	16667	205
Moderate value							
Cetraria nivalis	565	1000	1248	880	925	475	
Peltigera aphthosa	100	7640	2959	3000	4864	260	
Peltigera canina	280	4520	2899	7720	5852	4660	
Stereocaulon spp.	T	1560	1120	5920	836	660	
	945	14720	8226	17520	12477	6055	125
Low value							
Cetraria crispa, *Cladonia alpicola*, *Cladonia botrytes*, *Cladonia cariosa*, *Cladonia carneola*, *Cladonia cenotea*, *Cladonia coccifera*, *Cladonia cornuta*, *Cladonia crispata*, *Cladonia cristatella*, *Cladonia deformis*, *Cladonia gracilis*, *Cladonia multiformis*, *Cladonia pyxidata*, *Cladonia turgida*, *Icmadophila ericetorum*, *Nephroma arcticum*	1041	1680	1632	2640	1900	3325	
	1041	1680	1632	2640	1900	3325	25
Total lichen weight	(8975)	(37360)	(26434)	(32241)	(39292)	(26047)	(355)
Total weight	46463	66634	64533	72391	82597	65638	
Average pounds of forage per acre	581	833	807	905	1032	820	830

TABLE 27

Air-dry forage in forests over 120 years of age

	Location and age of forests						Average productivity per class in lbs.
	Higginson Lake 125 yrs.	Offset Lake 150 yrs.	Oblate Lake 130 yrs.	Marchant Lake 155 yrs.	Dodge Lake 170 yrs.	Chipman Lake 135 yrs.	
	Grams per 80 plots x 10						
Grass & grass-like plants							
Calamagrostis canadensis	—	—	36	75	75	600	
Poa glauca	164	—	—	—	—	—	
Gramineae—unidentified	—	—	18	—	—	—	
Carex spp.	—	—	—	25	—	—	
Equisetum sylvaticum	—	—	—	—	20	—	
	164	—	54	100	95	600	2
Herbs							
Epilobium angustifolium	—	—	14	—	—	—	
Cornus canadensis	75	—	—	—	—	—	
Geocaulon lividum	—	1240	300	—	—	—	
	75	1240	314	—	—	—	3
Shrubs							
High value							
Vaccinium vitis-idaea var. *minus*	18570	20140	15897	31746	34476	39672	
	18570	20140	15897	31746	34476	39672	334
Moderate value							
Empetrum nigrum	—	189	1848	—	—	—	
Salix spp.	—	275	600	—	—	—	
	—	464	2448	—	—	—	6
Low value							
Alnus crispa	336	924	1785	1981	4276	315	
Andromeda polifolia	55	—	—	—	—	—	
Ledum groenlandicum	4364	2407	8624	7280	11752	5408	
Rubus chamaemorus	—	—	—	—	40	—	
Vaccinium myrtilloides	—	484	552	—	—	—	
Vaccinium uliginosum	—	2208	2404	—	—	—	
	4755	6023	13365	9261	16068	5723	115
Total shrub weight	(23325)	(26627)	(31710)	(41007)	(50544)	(45395)	(455)
Lichens							
High value							
Cladonia alpestris, *Cladonia amaurocraea*, *Cladonia mitis*, *Cladonia uncialis*	15118	6372	7305	7647	18983	16130	
Cladonia rangiferina	10004	3772	667	7650	18327	14497	
	25122	10144	7972	15297	37310	30627	264
Moderate value							
Cetraria nivalis	972	4250	1000	456	820	1100	
Peltigera aphthosa	520	69	2139	960	533	5134	
Peltigera canina, *Peltigera malacea*, *Peltigera pulverulenta*	1677	4807	3805	2820	492	4131	
Stereocaulon spp.	409	42672	5233	99	697	1292	
	3578	51798	12177	4335	2542	11657	179
Low value							
Cetraria crispa, *Cladonia alpicola*, *Cladonia bacillaris*, *Cladonia botrytes*, *Cladonia cariosa*, *Cladonia cenotea*, *Cladonia coccifera*, *Cladonia cristatella*, *Cladonia deformis*, *Cladonia gracilis*, *Cladonia pyxidata*, *Cladonia turgida*, *Cladonia verticillata*, *Icmadophila ericetorum*	1978	2350	4372	1401	3321	3872	
Nephroma arcticum	—	1426	—	—	41	—	
	1978	3776	4372	1401	3362	3872	39
Total lichen weight	(30678)	(65718)	(24521)	(21033)	(43214)	(46156)	(482)
Others							
Dryopteris fragrans	—	—	—	—	—	20	
	—	—	—	—	—	20	T
Total weight	54242	93585	56599	62140	93853	92171	
Average pounds of air-dry forage per acre	678	1170	707	776	1173	1152	942

Appendix E

FORAGE PRODUCTIVITY IN JACK PINE FORESTS OF VARIOUS AGES

TABLE 28
Air-dry forage in six jack pine forests

	Location and ages					
	Newnham Lake 5 yrs.	Stony Rapids 15 yrs.	Black Lake 16 yrs.	Newnham Lake 35 yrs.	Black Lake 43 yrs.	Grove Lake 65 yrs.
	Grams per 80 plots x 10					
Grass & grass-like plants						
Agrostis scabra	—	225	—	—	—	—
Calamagrostis canadensis	—	T	—	—	—	—
Gramineae—unidentified	—	100	—	—	—	—
Carex aenea	1520	—	—	—	—	—
Carex deflexa	180	—	—	—	—	—
Carex	—	175	—	—	—	—
Carex spp.	—	250	—	—	—	—
Equisetum sylvaticum	—	720	—	—	—	—
	1700	1470	—	—	—	—
Herbs						
Achillea lanulosa	—	180	—	—	—	—
Achillea sibirica	—	45	—	—	—	—
Epilobium angustifolium	2603	3744	19	—	—	—
Cornus canadensis	—	995	55	—	—	—
Fragaria vesca	—	92	—	—	—	—
Geocaulon lividum	—	—	—	—	—	280
Parnassia palustris	—	225	—	—	—	—
Pinguicula villosa	—	T	—	—	—	—
Pyrola spp.	—	23	—	—	—	—
Taraxacum officinale	—	T	—	—	—	—
	2603	5304	74	—	—	280
Shrubs						
High value						
Vaccinium vitis idaea var. *minus*	1898	2800	7685	24766	5481	27557
	1898	2800	7685	24766	5481	27557
Moderate value						
Empetrum nigrum	—	—	—	—	—	336
Salix spp.	—	1659	—	—	—	—
	—	1659	—	—	—	336
Low value						
Alnus crispa	—	63	15933	18819	6216	—
Andromeda polifolia	—	T	—	—	—	—
Arctostaphylos uva-ursi	—	3761	—	—	—	126
Ledum groenlandicum	125	4092	891	2457	2997	1861
Linnaea borealis	69	92	46	—	—	—
Potentilla tridentata	23	—	—	—	—	—
Rosa bourgeauiana	—	136	—	—	—	—
Ribes glandulosum	—	23	—	—	—	—
Rubus acaulis	—	409	—	—	—	—
Rubus chamaemorus	—	T	—	—	—	—
Rubus idaeus var. *aculeatissimus*	—	T	—	—	—	—
Vaccinium myrtilloides	360	2448	6300	2852	5775	—
Vaccinium uliginosum	—	—	—	T	—	—
Viburnum edule	—	113	—	—	—	—
	577	11137	23170	24128	14988	1987
Total shrub weight	(2475)	(15596)	(30855)	(48894)	(20469)	(29880)
Lichens						
High value						
Cladonia alpestris, *Cladonia amaurocraea*, *Cladonia mitis*, *Cladonia uncialis*	—	380	2496	4350	15899	2308
Cladonia rangiferina	—	—	—	72	363	333
	—	380	2496	4422	16262	2641
Moderate value						
Cetraria nivalis	—	—	—	208	638	749
Peltigera aphthosa	—	4680	—	26	—	520
Peltigera canina	195	6200	T	26	—	2000
Stereocaulon spp.	—	200	—	78	70	3264
	195	11080	T	338	708	6533
Low value						
Cetraria crispa, *Cetraria islandica*, *Cladonia alpicola*, *Cladonia botrytes*, *Cladonia coccifera*, *Cladonia crispata*, *Cladonia deformis*, *Cladonia gracilis*, *Cladonia multiformis*, *Cladonia pyxidata*, *Cladonia turgida*	—	4800	4386	9726	5235	1231
	—	4800	4386	9726	5235	1231
Total lichen weight	(195)	(16260)	(6882)	(14486)	(22205)	(10405)
Others						
Marchantia polymorpha	18	—	—	—	—	—
	18					
Total weight	6991	38630	37811	63380	42674	40565
Average weight in lbs. of forage per acre	87	482	473	792	533	507

WILDLIFE MANAGEMENT BULLETINS

SERIES 1 — Mammals

* 1 The mammals of Waterton Lakes National Park. A. W. F. Banfield. April, 1950.

* 2 Natural history and economic importance of the muskrat in the Athabasca - Peace Delta. W. A. Fuller. March, 1951.

* 3 The mammals of Elk Island National Park, Alberta, Canada. J. D. Soper. November, 1951.

* 4 Populations and movements of the Saskatchewan timber wolf (*Canis lupus knightii*) in Prince Albert National Park, Saskatchewan, 1947 to 1951. A. W. F. Banfield. November, 1951.

* 5 The mammals of Prince Albert National Park, Saskatchewan, Canada. J. D. Soper. June, 1952.

* 6 Surveys of Elk and Other Wildlife in Riding Mountain National Park, Manitoba, 1950-51 and 1952. D. G. Colls. December, 1952.

* 7 The mammals of Riding Mountain National Park, Manitoba, Canada. J. D. Soper. December, 1952.

8 The northwestern muskrat of the Mackenzie Delta, Northwest Territories, 1947-48. W. E. Stevens. 1953.

9 A preliminary study of the muskoxen of Fosheim Peninsula, Ellesmere Island, Northwest Territories. J. S. Tener. 1954.

*10A and B Preliminary investigation of the barren-ground caribou. (2 vols.). A. W. F. Banfield. 1954.

11 Wolf control operations, Wood Buffalo National Park. 1951-52. William Fuller. 1955.

12 Continued barren-ground caribou studies. John P. Kelsall. 1957.

13 Range studies in Banff National Park, 1953. Robert Webb. 1957.

14 Preliminary investigation of the Atlantic walrus (*Odobenus rosmarus rosmarus*). Alan G. Loughrey. 1959.

15 Co-operative studies of barren-ground caribou, 1957-58. John P. Kelsall. 1960.

*16 The biology and management of the bison of Wood Buffalo National Park. William A. Fuller. 1961.

*17 The mammals of Manitoba. J. D. Soper. 1961.

18 Effects of forest fires on the winter range of barren-ground caribou in northern Saskatchewan. George W. Scotter. 1964.

SERIES 2 — Birds

* 1 A study of the bird populations in the apple orchards of the Annapolis Valley, Nova Scotia. J. P. Kelsall. April, 1950.

* 2 Waterfowl and related investigations in the Peace-Athabasca Delta region of Alberta. J. D. Soper. May, 1951.

* 3 The birds of Elk Island National Park, Alberta, Canada. J. D. Soper. February, 1952.

4 The birds of Prince Albert National Park, Saskatchewan. J. D. Soper. June, 1952.

5 The economic status of the herring gulls of the Grand Manan Archipelago, New Brunswick. D. H. Pimlott. June, 1952.

6 The birds of Riding Mountain National Park, Manitoba, Canada. J. D. Soper. December, 1953.

* 7 Waterfowl and other ornithological investigations in Yukon Territory, Canada, 1950. J. D. Soper. September, 1954.

8 Birds of Jasper National Park, Alberta, Canada. I. McT. Cowan. June, 1955.

9 The american goldeneye in central New Brunswick. Brian C. Carter. 1958.

SERIES 3 — Fish

* 1 Prince Albert National Park creel census analysis, season 1948. V. E. F. Solman. May, 1950.

* 2 Limnological investigation of Fundy (New Brunswick) National Park, 1948. V. E. F. Solman. June, 1950.

3 Limnological investigations in Cape Breton Highlands National Park, Nova Scotia, 1947. V. E. F. Solman. 1951. Reprinted November, 1954.

4 Investigation of the spawning of northern pike in Prince Albert National Park, 1953. F. H. Schultz. August, 1955.

5 Investigation of lake trout and common whitefish in Waterton Lakes, Waterton National Park. J. P. Cuerrier and F. H. Schultz. January, 1957.

* *Out of print.*

HOW DOES THE CANADIAN WILDLIFE SERVICE FIT INTO THE NATIONAL WILDLIFE PICTURE?

The Canadian Wildlife Service carries out both wildlife research and management. As a division of the National Parks Branch, Department of Northern Affairs and National Resources, it is charged with the task of carrying out federal responsibilities with respect to wildlife, a renewable resource of ever-increasing importance to the national welfare and economy.

Each province has control over the natural resources within its boundaries, including wildlife. However, because Canada signed the Migratory Birds Treaty with the United States in 1916, there is a federal responsibility for the management and protection of migratory birds. The Canadian Wildlife Service administers the Act for the federal government. In practice, Federal and Provincial Governments co-operate in all matters concerning migratory birds. The Canadian Wildlife Service studies migratory birds throughout Canada and conducts scientific research into other wildlife problems in the Northwest Territories, the Yukon Territory and Canada's National Parks; it also co-operates with the administrative agencies concerned when wildlife management programs indicated by research are instituted.

The Wildlife Service staff includes mammalogists, ornithologists, limnologists, pathologists, and a biometrician.

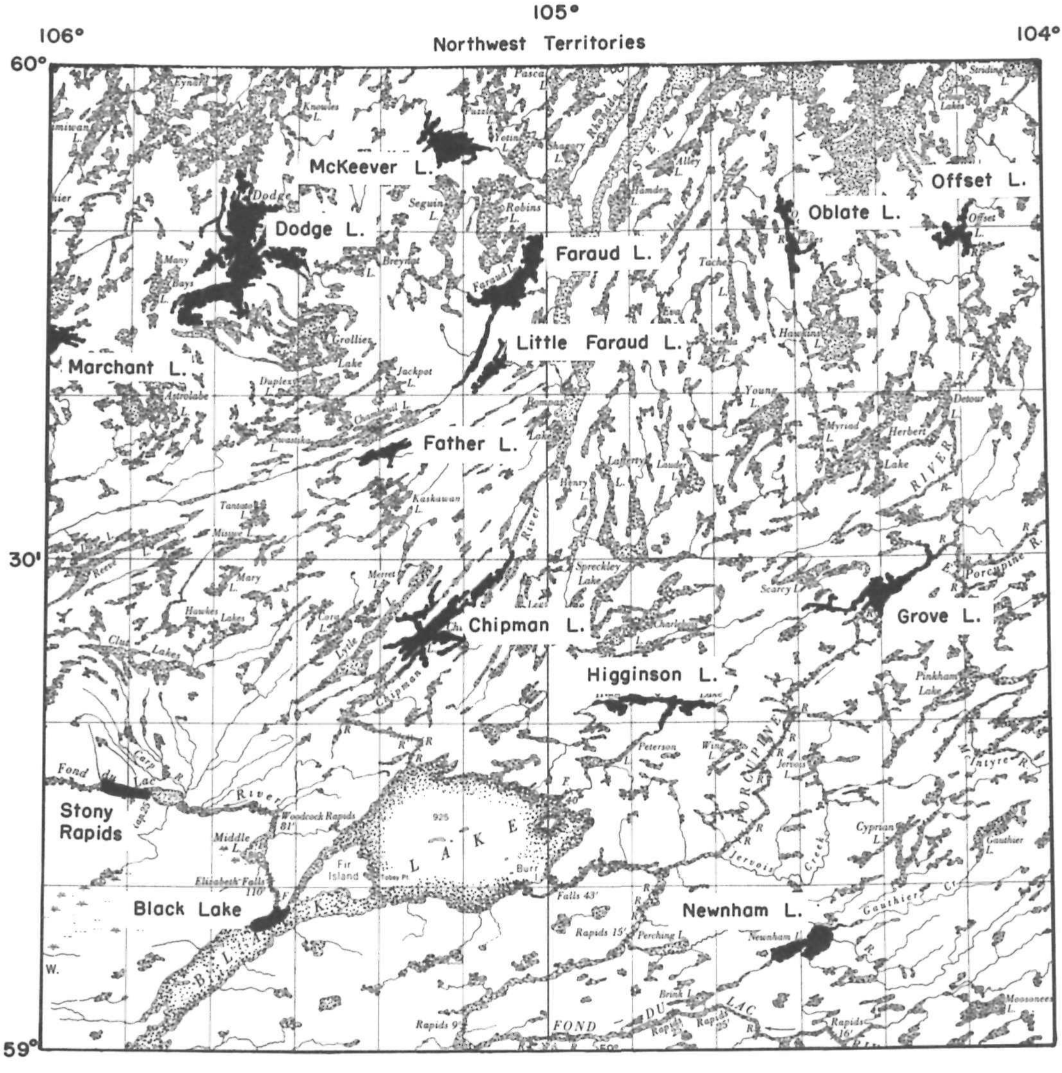
LE RÔLE DU SERVICE CANADIEN DE LA FAUNE SUR LE PLAN NATIONAL

Le Service canadien de la faune s'occupe tout autant de recherche sur la faune que de gestion. Étant rattaché à la Direction des parcs nationaux du ministère du Nord canadien et des Ressources nationales, il représente le gouvernement fédéral dans tout ce qui a trait à la faune, ressource renouvelable d'une importance sans cesse croissante pour la prospérité et l'économie du pays.

Chaque province régit les ressources naturelles qui se trouvent dans son territoire, y compris la faune. Néanmoins, en raison du Traité concernant les oiseaux migrateurs que le Canada a conclu avec les États-Unis en 1916, la gestion et la protection des oiseaux migrateurs est du ressort fédéral. Et c'est le Service canadien de la faune qui s'occupe, au nom du gouvernement fédéral, de faire observer la Loi sur la Convention concernant les oiseaux migrateurs. En pratique, les gouvernements fédéral et provinciaux collaborent en cette matière. Le Service canadien de la faune poursuit l'étude des oiseaux migrateurs dans le pays tout entier et effectue des recherches scientifiques ayant trait à d'autres questions de faune dans les Territoires du Nord-Ouest, au Yukon et dans les parcs nationaux; il collabore aussi avec les organismes administratifs intéressés à l'exécution de travaux de gestion dont des recherches ont établi l'opportunité.

Le Service canadien de la faune a à son service des mammalogistes, des ornithologistes, des limnologistes, des pathologistes et un biométriste.

MAP OF THE STUDY AREAS.



Study sites were located near the lakes indicated in solid black.

NATIONAL PARKS BRANCH ● DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES.

CANADIAN
WILDLIFE
SERVICE