Fire in the Subarctic Wintering Ground of the Beverley Caribou Herd

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ABSTRACT: The study documents the timing, prevalence and importance of fires in a 105,000-sq-km area of the Northwest Territories, Canada, bounded by long 104° and 112°, lat 60° to tree line. Lightning caused most of the fires and accounted for almost all of the area burned in a 7-year period. In this part of the subarctic, the fires appear to follow a seasonal pulse that progresses in June and July from the SW toward tree line in the NE, retreating in August. The normality of fire in this part of the northern boreal zone is beyond dispute. There is no conclusive proof that fire regime has changed substantially in recent times from what it was previously. The implication is that endemic animals, such as caribou, are adjusted to recurring fires.

INTRODUCTION

Few who have studied the boreal forest doubt that fire is one of its natural processes. Overwhelming evidence of fire incidence due to lightning storms has been marshalled in recent years. Also, many students of the north have commented on the direct and indirect effects of fire in destroying and renewing vegetation cover and habitats (e.g., see the three symposia proceedings edited by Slaughter et al., 1972, by the U.S. Forest Service, 1972, and by Wright and Heinselman, 1973).

In this study we document the timing, prevalence and importance of lightning fires in a large block of the subarctic forest (approximately 40,700 sq miles¹) extending from Ft. Smith at 112° long eastward to 104° long, and from 60° lat NE to tree line (Fig. 1). Known as the "Caribou Range" because it serves as a wintering ground for the Beverley Herd of barren ground caribou (Rangifer tarandus groenlandicus), the area has been patrolled by fire-suppression crews of the Department of Indian and Northern Affairs since 1966. The surveillance and control program was initiated at a time when it was suspected that fire posed a serious threat to the vegetation of the wintering range and therefore to the Beverley Herd itself.

The data used in this paper were compiled from the original fire report forms and maps prepared by the Northwest Lands and Forest

¹ Because areal descriptions in forestry literature and in fire reports are given in square miles and in acres, these units are used throughout this report. Conversions to metric units are 1 square mile = 2.59 square kilometers and 1 acre = 0.405 hectares.
Service, Department of Indian and Northern Affairs. From discussions with staff at Ft. Smith, N.W.T., it seems likely that most of the area significantly significant fires for the 7-year period were reported. Many spot fires by lightning strikes undoubtedly escaped detection, but in any case the available dates of fires, plus notes and maps on locations and size, provide a sufficient sample for the analyses undertaken.

Acknowledgments.—For much assistance in gathering information, we express our appreciation to the staff of the Canadian Wildlife Service in Edmonton and Ottawa. Also, we thank J. Gilmour and E. Powder of the Department of Indian and Northern Affairs at Ft. Smith. We would like to acknowledge the helpful discussions and criticisms of R. Bone, J. L. Bergsteinsson, A. D. Kiil, J. A. Larsen, B. R. Neal, D. Spittlehouse and G. W. Scotter. This work was supported by a grant from the Canadian Wildlife Service. The opinions expressed here are ours and are not necessarily those of the Canadian Wildlife Service.

GEOGRAPHIC DESCRIPTION

The Caribou Range is located on the Precambrian Shield which here consists mainly of an Archaean crystalline basement with Pro-

Fig. 1.—Map of fire distribution in the study area for the period 1966-72. Dots represent the location of fires occurring during this period. The lines indicate the eastern or northeastern limits to which fires occurred in the specific months.
terozoic intrusives (Douglas, 1970). Common rock types are massive granites, gneissic granites and granodiorites that outcrop extensively or are overlain by a glacial drift veneer of varying thickness. Three major terrain types are recognizable on the available small-scale aerial photographs:

(1) A strongly drumlinized, deep drift E of ca. 108° long, with open lichen-spruce woodland on the uplands and with muskeg- and shrub-covered peatlands on the lowlands. Northwestward the vegetation shows a gradual transition from forest to tundra, the division between the Northwestern Transition (Section B.27) and the Forest-Tundra (Section B.32) occurring along a NW-SE axis that runs from about 63° lat, 109° long to 60° 45' lat, 104° long and roughly parallels tree line farther to the NE (Rowe, 1972).

(2) An ablation drift, mostly bedrock-controlled, W of about 108° long characterized by a denser forest cover of spruce and pine, with less lichen-woodland and open peatland than appears eastward.

(3) Extensive trains of ice-contact stratified drift running from E-W through both the former terrain types, though most strongly expressed in the eastern (drumlinized) area, where vegetation is characteristically an open lichen and shrub woodland interrupted by patches of bare blown sand.

Detailed descriptions of some of the vegetation types adjacent to the Caribou Range or within it can be found in Raup (1946), Argus (1964, 1966), Maini (1966) and Larsen (1971).

The region has a continental climate, with short, cool summers, long, cold winters and with 10-12 inches (25-30 cm) of precipitation. About half the precipitation is rain and half is snow, the latter usually appearing early in October and disappearing late in April or May.

Causes of Fires and Area Burned

A total of 273 fires were reported over the 7-year period. Most fires were in 1970 and 1971 with 68 and 73 fires, respectively, whereas 1967 and 1968 had the fewest fires with nine and one, respectively (Table 1). Lightning caused 85% of all fires, whereas man caused 15%. The seasonal pattern of lightning fires is very marked, with most occurring in June and July, fewer in August and only occasional ones in early September (Fig. 2). In contrast, the incidence of man-caused fires is more or less constant from the time the ground becomes free of snow in the spring to the return of snow in autumn. A slight rise in man-caused fires during July and August may be attributed to decreasing insect pests and a resulting increase in numbers of fishermen and picnickers travelling out around the settlement of Snowdrift.

A total of about 1.6 million acres burned in the period 1966-72, which, on an annual basis, is about 0.9% of the total area (26,048,000 acres). However, acreages burned, as well as numbers of fires, vary tremendously from year to year (Table 1). The variance for these data is much larger than the average annual burn, and therefore the latter
is not a good estimate of the expected annual burn. Over the same 7-year period, lightning accounted for 99.9% of the area burned, the remainder being due to man and unknown causes. In no year did man-caused fires account for more than 1% of the total area burned, except in 1968 when there was only one fire reported; it was man-caused and it burned one acre. That year there was above normal rainfall in the Caribou Range throughout the summer as indicated by the climatic records at Ft. Smith and Ft. Reliance for June, July and August. The data show the very great importance of lightning-caused fires compared to those started by man, and they agree with the conclusions of others who have studied similar areas.

Scotter (1967) analyzed the 1961-64 fire reports for protected areas in the Northwest Territories, Alberta (including Wood Buffalo National Park), Saskatchewan and Manitoba. At that time the protected areas were largely centered on settlements, except in northern Alberta. He found an annual burn rate of 0.7% (i.e., 2.7% for 4 years), and he reported that 72% of all fires were caused by lightning. This is comparable to our figures of 0.9% burned annually and 85% attributed to lightning, the higher percent of lightning-caused fires probably being due to the few settlements and sparse population of the Caribou Range. Scotter did not report the percent of total area burned by lightning fires though undoubtedly it was large.

Hardy and Franks (1963) showed that, popular forestry opinion to the contrary, lightning was a substantial factor in the forest fires of Alaska. They found that the 25% of fires started by lightning accounted for 75% of the area burned. Barney (1969) also demonstrated in Alaska that in 7 years out of 10, lightning fires were bigger than man-caused fires, i.e., they burned larger areas. He reported that of the small fires (10-100 acres in size), 62% were caused by lightning and 23% by man, and most in the latter category were less

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than one-quarter acre. In a later report, Barney (1971) showed that lightning accounted for the largest percent of yearly burned acreage whereas man-caused fires were less important in the total and were individually small (80% were less than 10 acres). In the Yukon, Requa (1964) stated that lightning accounts for a large percent of the yearly fires, e.g., 76% of those occurring in June and July. Kiil (1971) analyzed fire reports for protected areas mostly around settlements in the Yukon and found that 35% of the fires were lightning-caused. Over a 5-year period for which data were available, 59 lightning-caused fires accounted for over 50% of the total acreage burned (A. D. Kiil, pers. comm.). We conclude that our results are not atypical for the northern boreal forest.

**Fire Patterns in Space and Time**

In order to analyze the geographic and seasonal distribution of fires, the area including the Caribou Range, between 60° and 64° lat

![Seasonal distribution of fires](image)

*Fig. 2.—Seasonal distribution of fires in the study area for the period 1966-72. The points represent averages for each month*

- Lightning-caused fires
- Man-caused fires
and between 104° and 112° long, was divided into 16 rectangular blocks, each approximately 4900 sq miles in size (Fig. 3). The numbers, sizes and months of occurrence of fires from 1966-72 were tabulated for each of the 16 blocks. Fires that crossed block boundaries were assigned to the block in which their largest area occurred.

Geographically, most fires occurred in the W and SW (blocks 1, 2, 8, 9,) where 168 of the 273 fires (61%) were reported. Similarly, 98% of the total area burned was in the same four blocks. Here also, 90% of the man-caused fires occurred, but they burned only 415 acres or 0.03% of the total. The village of Snowdrift is in block 9 where most of the man-caused fires were reported (26 in 7 years or 74% of the block total from all causes). The total area of these man-caused fires seems to have had little influence on either the geographic or seasonal trends of fires in the 7 years of observation.

There is a seasonal ebb and flow of fires into the area from the SW and back out again. Ignitions move in a wave in spring NE

Fig. 3.—Isolines of fire sizes, in acres, expected to recur on the average of every 5 years. See text for method
towards tree line and retreat from tree line in late summer and autumn. By plotting the occurrence of fires in each of the 16 blocks, it was possible to draw sets of isolines showing fires in May, June, July and August for the 7-year period (Fig. 1).

The May isoline shows fires in the lower Taltson River system as well as northward to Great Slave Lake and northeastward to Artillery Lake. In June, fires occur up to a line more or less parallel to and just S of tree line. In July, fires occur throughout the area, right to or beyond tree line. In August the line of fire occurrence has retreated to the southwestern third of the region. Isolines are not shown for September because fires occur very infrequently then; a few, however, were reported in the Taltson River area just NE of Ft. Smith and in the area near Snowdrift on the E arm of Great Slave Lake.

It is desirable to know how often a fire of a certain size can be expected to occur in any one area and how this expectation changes over the whole region. Average recurrence interval of fires of certain sizes were calculated as follows: All fires in each of the 16 blocks were ordered by size and numbered in sequence, the largest fire being "1." To calculate the recurrence intervals we used the methods described by Dalrymple (1960) for flood-frequency analysis. The formula is 
\[(n + 1)/m,\]
where \(n\) is equal to the number of months of record and \(m\) is the magnitude of the fire on the numerical scale. In order to determine the same time of recurrence, an equation was fitted for each block using a least-squares technique with the recurrence intervals as the independent variable and fire size as the dependent variable. The equations allow the calculation of fire sizes at the desired recurrence intervals for a particular block. These values were then used to construct a trend surface map for equal-sized fires.

The results for recurrence intervals on the average every 5 years are shown in Figure 3, providing an approximation of fire-size probabilities over different periods of time. In general, the maps show a zone of greatest recurrence of large fires in the southwestern quarter in blocks 1, 2, 4, 7, 8, 9 and 10 and a zone of lowest recurrence of small fires in the S-central part from tree line into areas 3, 6 and parts of 2 and 7.

The seasonal and geographic patterns show that the largest number of fires has burned the most acreage over the longer season in the lower Taltson River system and in the area of the E arm of Great Slave. The least acreages burned and shortest fire season are adjacent to tree line (see also Larsen, 1965). Nevertheless, the role of fire in modifying tree line should not be discounted. It is interesting that the open lichen-woodland on drumlinized terrain E of 108° long appears to be less susceptible to burning than the western closed forests on bedrock-controlled drift, at least during the 7 years of records. Investigations on the ground show that the lichen-woodlands have been burned in the past, but apparently fires recur at rather long intervals there.
CLIMATE AND FIRES

The seasonal, geographic and recurrence patterns of fires noted in the last sections can be explained tentatively by the interaction of two air masses, the continental Arctic and the maritime Pacific (cf. Bryson, 1966). Continental Arctic air has its source region in the high Arctic over either ocean or land. It is characteristically cold, dry and stable, i.e., it is cooler (and drier) than the surrounding air and, hence, tends to subside and gain moisture. On the other hand, maritime Pacific air enters the Great Slave Lake region from the S and W, emanating from a source region in the north Pacific. This air is characteristically warmer, moister and more unstable than the continental Arctic air. Several other air masses having source regions to the S can be identified, but in effect they can be considered as maritime Pacific, too. From September to May the Caribou Range area is under the influence of continental Arctic air, with maritime Pacific air entering the region chiefly from June to August. The seasonal progression of lightning fires, shown in Figure 1, follows a pattern similar to the incursion of Pacific air.

Bryson (1966) studied the climate of the ecotone of the boreal forest and tundra in central Canada (see also Larsen, 1965, 1971), and postulated a transition zone in summer between the cool, dry stable Arctic air mass to the NE and the warm, moist, unstable Pacific air mass to the SW. He presented evidence that from winter to summer this zone of climatic transition moves as a pulse from SW to NE, occupying a modal position in the region of tree line by July. Thereafter, the zone retreats southwestward, reaching a modal position near the southern boundary of the boreal forest in January.

Field experience in the Caribou Range indicates that the frontal activity which marks this zone of climatic transition, and the summer convective storms in the area under the influence of the unstable Pacific air, are conducive to lightning and are the cause of lightning fires.

FIRE AND CARIBOU

Theories about the effects of fire on vegetation in the boreal forest have important implications for habitat management. The argument for fire suppression in the Caribou Range has been stated briefly in the following proposition: caribou are climax animals, dependent on the climax boreal forest for survival in the winter season; their preferred winter food consists primarily of fruticose ground lichens and pendulous arboreal lichens that characterize climax coniferous types; fire destroys the lichens which, once burned away, are only renewed by a slow process of succession extending over many decades; fire, therefore, exerts one of the controls over population size of the barren ground caribou.

Because of the apparent connection between caribou, lichens and fire, much attention has been given to the subject. However, very few data on which to build a logical case have been available. Based only
on observation, many authors have subscribed at least in part to the argument set out in the previous paragraph (see Palmer, 1926; Palmer and Rouse, 1945; Harper, 1932, 1955; Clarke, 1940; Leopold and Darling, 1953; Banfield, 1954; Kelsall, 1957, 1968; Banfield and Tener, 1958; Pruitt, 1959). It is no longer heretical to profess suspicion of climax animals dependent on climax vegetation. Recent literature suggests that caribou are fairly versatile animals, moderately cosmopolitan in their eating habits and adaptable to a range of northern habitats.

From studies of the barren ground caribou in Newfoundland, Bergerud (1972) argued that they are generalists in their food habits. He observed that in the winter they eat all species of higher plants, if these can be located, taking lichens and mosses "mostly in reference to abundance." He concluded that although caribou are adapted to use a diet of lichens, lichens are not essential. A recent report on the Porcupine Caribou Herd in the Yukon-Alaska region (Jakimchuk et al., 1974) supports the same hypothesis. The latter authors appear to be committed to the thesis that fire is the foe of the caribou habitat and, therefore, of caribou. Nevertheless, they report (with some puzzlement) that despite the absence of extensive lichen range on the lichen-less Old Crow Flats and on the Arctic coast, caribou do winter successfully there. Others also have commented on the feeding flexibility of the caribou; for example, Tener (1963) pointed out that the Peary caribou on the Arctic Islands subsist mostly on sedges. Kelsall (1968) has stated in studies of forested winter range in northwestern Saskatchewan and Northwest Territories that although lichens were the main food, other plants comprised over 50% of the items eaten. Examination of his data indicates that, as Bergerud (1972) has stated, most plants are taken in relation to their abundance, with lichens being the most abundant ground cover. In short, it is unlikely that caribou are locked into a winter dependence on lichens. Fires recur in boreal vegetation, and it is a reasonable supposition that caribou long ago adapted to that fact of life. Indeed, the question may legitimately be asked if periodic fires do not improve the caribou winter range in both the short and intermediate terms by mineralizing nutrients and renewing the growth of sedges, forbs, shrubs and even lichens.

**Fire Trends**

Shorn of its significance for the supposed lichen-caribou relationship, the question still remains: has there been an increase in fires on the Caribou Range in recent historic times? Unfortunately, the period of fire records for the Northwest Territories (less than 20 years) is not long enough for rigorous analysis of trends and of recurrence patterns. Neither the number of thunderstorm days reported in 15 years (Fig. 4) nor the number of lightning fires as a percentage of total fires for 18 years (Fig. 5) shows any trend during this short period. Of course the accuracy of the data is questionable, for the sound of thunder has
been the sole criterion of lightning storms in meteorological reports, whereas an increase or decrease in fires is obviously controlled by other factors than ignition.

The question of fire frequency over the last few centuries can be approached indirectly by studies of the vegetation. Only two authors, Kelsall (1960) and Scotter (1964), have attempted to provide quantitative data in this way.

Kelsall (1960) studied 9214 sq miles between Great Bear and Great Slave lakes in 1955 and 1956. He attempted to map both burned and unburned forested areas by flying transects, and he found 29% of the area burned and 71% green forest. Unfortunately, the method gives no indication of ages of burns so that many questions are unanswered: such as how much of the area is occupied by old burns that have recovered very slowly and thus appear to be "young," by light.

![Bar chart showing number of thunderstorm days for different weather stations in or near the study area.](image)

Fig. 4.—Number of thunderstorm days for different weather stations in or near the study area. Number of thunderstorm days for each station is read from the top of the appropriate bar. Note the decrease in number of thunderstorm days toward tree line. Data courtesy of the Atmospheric Environment Service, Environment Canada.
surface burns that often go unrecognized because they do so little damage, or by repeated burns in the same area. Furthermore, the causes of fires are unknown for the area and cannot now be determined.

Scotter (1964) approached the problem by using a map of a block of northern Saskatchewan showing forest cover types by stand age, substrata, tree composition, density and height as prepared from aerial photographs by Brown (1961). Using a successional series that linked the various compositional types, and relating age to height, density, substrata and composition, the map data were interpreted in terms of fire extensiveness since 1840. In Scotter's words, "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 1.5 times over the 1885 to 1944 period and 3.1 times over the 1840-1884 period. These increases are coincident with mining activity and white settlement."

We criticize these conclusions only to show that the important question of fire incidence and recurrence is still open and needs further careful study. The two weaknesses of the Brown (1961) map, upon which Scotter based his conclusion, are that the area studied is not homogeneous and that assignment of stand ages was based on the interpretation of small-scale aerial photos. The southern one third of this study is sandy outwash covered with nearly pure stands of jack pine (Pinus banksiana Lamb.), mostly younger than 30 years but with

![Fig. 5.—Number of lightning fires in the Northwest Territories as a percent of the total number of fires. These data are mostly from near settlements, which explains the lower percent lightning fires to other causes than reported for the area studied here. Data from “Forest Fire Losses in Canada” 1952-1969, Can. Dep. For. and Rural Develop., Ottawa](image-url)
large areas younger than 15 years. The remaining two thirds of the area is bedrock and glacial till supporting a predominantly black spruce [Picea mariana (Mill.) BSP] forest usually older than 60 years. The implications for quite different burning regimes are obvious. Stand age was mapped by the visual appearance of the vegetation on small scale (1: 60,000) aerial photos, using limited sample studies on the ground as the reference. A successional (aging) sequence from hardwoods to softwoods, from pine to spruce, and from dense stands to open stands with lichen cover was assumed in estimating ages. Recent field work in the region has convinced us that stand age is not easily identified by vegetation composition and structure and, therefore, the question of a recent increase in fire incidence should remain open.

**Conclusion**

Ideas about the role of fire in the natural landscape are changing rapidly, but recognition of its central importance in the boreal forest is still far from universal. Lack of data on the prevalence, recurrence and ecological effects of fires has, by default, left the door open to the misinterpretation of various processes in northern ecosystems. There seems to be a human tendency to discount fire, to treat it as an extraneous influence, a nuisance that confounds the orderly operation of ecological systems.

Today, there can be no doubt that the fire regime of the uninhabited boreal forest is “normal” and is the result of lightning. Such has undoubtedly always been the case. Archaeological evidence (Noble, 1971, pers. comm.) from about 4900 BP to the AD 1400s documents local fires in the Great Slave Lake region and Great Bear Lake region. These fires were apparently due to causes other than man, probably lightning (Feit, 1969; and W. C. Noble, 1973, pers. comm.).

If it is accepted that fires are a part of boreal forest ecosystems, then it follows that the vegetation has never existed in a “climax” state (sensu Clements) over widespread areas. The mosaic of vegetation of all ages visible today is probably close to the norm. The carrying capacity of the land may well be similar to what it always has been. There is no compelling evidence that fires have increased in recent years or that greater than usual destruction of animal habitat has occurred.

Vegetation patterns in the Caribou Range S and E of Great Slave Lake appear to be a result of the interaction of fire frequency, fuel load (related to age, structure and composition of the vegetation) and landforms. The exact nature of these interactions remains to be elucidated and further work is under way to that end.

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Submitted 16 July 1973

Accepted 19 September 1974