The role of wildland fire in caribou ecology

An Annotated Bibliography

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Webpage: http://www.absc.usgs.gov/research/caribou/fire_impacts.htm

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1. Adams, Layne G. 1983. Buckland Valley Master Habitat Management Plan. AK-020-WHA T/3 Buckland Valley. Bureau of Land Management, Fairbanks, Alaska. 17 . pp.

Note: No abstract; portions pertaining to fire are presented here. The Buckland Valley is an important wintering area for the Western Arctic Caribou Herd.

Abstract: Objective 2: Improve, maintain or enhance habitat diversity by managing naturally ignited wildfire.

a. Complete vegetation mapping of the Buckland Valley Wildlife Habitat Area (WHA), that was initiated during Fiscal Year (FY) 82, by end of FY84.

Rationale: At this time, the land cover on that portion of the WHA west of the Tagagawik River has been mapped from 1:60,000 scale color IR photos and ground truthed. Photo coverage of the remaining one-third of the area has been purchased by the Bureau of Land Management (BLM). It will be necessary to complete this mapping effort to provide a fuels map for the fire management planning effort.

b. Develop a fire management plan for the WHA by end of FY85.

Rationale: A fire management plan, similar in intent to the Alaska Interagency Fire Management Plan for the Tanana/Minchumina Planning Area, will be developed by BLM, with input from ADF&G and adjacent land owners, for the WHA. This plan will allow BLM to select areas where natural fires will be allowed to burn when conditions are favorable. This action will reestablish a more normal fire regime, maintain habitat diversity, and reduce suppression costs.

This fire management plan will either be developed as a supplement to this habitat management plan or as a portion of the Interagency Fire Management Plan that includes the WHA, depending on timing of the interagency plan. The interagency plan completion for the Seward Peninsula is not scheduled at this time but will be no earlier than FY85. Work accomplished on the WHA fire management plan will allow for reduced suppression efforts on public lands in the WHA prior to completion of the interagency plan and facilitate BLM input into the Seward Peninsula plan.

c. Continue to monitor transects established for the Ulukluk Creek fire recovery study.

Rationale: During summer 1981, transects were established on a small burn on Ulukluk Creek to monitor recovery of vegetation on the area. These transects were re-observed 11 days after the fire and in 1982. Continued monitoring of this area would add insight into post-fire succession on lichen dominated tussock tundra, an important area for study according to Klein (1982) who stated that "long-term monitoring of the responses of varying types of range vegetation to fires of differing intensities clearly should be a high priority of government agencies responsible for management of caribou range lands."

Literature Cited:
Klein, D.R. 1982. Fire, lichens, and caribou. J. Range Manage. 35(3):390-395.

Keywords: Alaska/ Buckland Valley/ fire/ habitat management/ lichens.

2. Ahti, T. and Hepburn, R. L. 1967. Preliminary studies on woodland caribou range, especially on lichen stands, in Ontario. Technical Series. Research Report (Wildlife) No. 74. Department of Lands and Forests, Ontario. 134 pp.

Note: Abstract and sections related to fire reproduced below.

Major report sections are as follows: Introduction; Methods of Study; Food Habits of Woodland Caribou in Ontario ; Important Terrestrial and Arboreal Macrolichens of Northern Ontario, Their Distribution and Ecology; Ecology and Composition of Ground Lichen Stands; Ecology and Composition of Arboreal Lichen Stands; Vegetation of Peatlands; Divisions of Woodland Caribou Range of Ontario and Assessments of Their Carrying Capacities; Range Management for Woodland Caribou; Acknowledgments; References; Sample Plots; Tables; Figures; Keys to the Macrolichens of Northern Ontario.

Abstract: In 1958 an extensive survey of northern Ontario was made with the purpose of describing and classifying the vegetation, and particularly the lichen resources, of this area as a habitat for woodland caribou (*Rangifer tarandus caribou*). Survey methods consisted of random and systematic observations along 4,800 miles of aerial transects, and intensive examination of 74 ground plots and 72 examples of arboreal lichen stands.

Distribution and ecology of 38 of the most abundant macrolichens are discussed. The ecology and composition of typical lichen stands throughout the study area are outlined in relation to substrata, to their use as food for caribou, and to the distribution of vascular plants.

On the basis of broad land types and availability of lichens, seven major divisions of the caribou range are proposed, and estimates are given for carrying capacity in each. It appears that present food supplies could support about six times as many caribou as now occupy the range, particularly north of 53° N lat.

Controlled burning is suggested as the best method of range management.

Keys to 138 macrolichens of northern Ontario are included in this report.

Stands on Swampy Burns (p. 34): In general, fire increases ground lichen stands especially in peatlands. A lichen bog will be much more lichenous after fire. If the bog is dry enough to burn, it is generally also dry enough for lichen growth. In Ontario, only *Sphagnum fuscum* bogs are dry enough to burn to any large extent although in the Sioux Lookout and Geraldton Forest Districts a considerable amount of lichen is found on burned-over margins of fairly wet swamps.

Stands of ground lichen are also seen in burned-over, formerly heavily-wooded swamp forests. Both of these lichenous peatland types represent transitory vegetation, which will change into moss communities along with the invasion of black spruce.

Lichen peatlands seem to provide the best winter range for caribou. Besides lichen, the same or neighbouring sites usually produce many sedges, herbs and shrubs which are highly palatable in summer, late fall and in early spring. Even in the middle of winter several vascular plants are available. The lichenous peatlands in the Kapuskasing, Geraldton and Sioux Lookout Forest Districts and in the southern Patricias, however, are not important lichen range since their lichen occurs in very patchy, scanty stands.

Range Management for Woodland Caribou (p. 58): Our rudimentary knowledge of food habits and range requirements among the Ontario woodland caribou now indicates that lichen resources are more than sufficient for the present population. More detailed information, however, may show that caribou need additional or larger units of range in order to use it to their best advantage.

Ground Lichen Range: Cringan (1948) made the following suggestions for the experimental extension of *Cladonia* range: (1) controlled burning of the forest, (2) logging and controlled burning of the slash, (3) logging, topping and scattering of the slash, (4) increasing the area of existing *Cladonia* patches through logging, destruction of cone-bearing tops, removal of slash and manual stripping of moss in bands around existing patches.

The first is no doubt the most effective and the only practical method. In the Northern Boreal

Lichen Belt lichen supplies could easily be increased by burning *Sphagnum fuscum* peatlands - treeless bogs or wooded muskegs. The result of heavy fire is an almost solid reindeer lichen stand in some 40 to 50 years, and because black spruce and mosses regenerate more slowly than lichen on those sites, good lichen growth persists for at least 100 years.

In more southern latitudes the black spruce muskegs produce considerable lichen after burning. In these regions controlled ground fire in over-mature jack pine woodlands and mossy rock outcrops would produce the best lichen stands. On these sites the humus layer is thinnest, but relatively long-lived lichen stands could be established even on thick humus. In sandy black spruce stands the best lichen results from burning off the humus layer. When this happens lichens grow fairly well but the forest regenerates slowly. The rotation period of the burning treatment would be much shorter here than in the Northern Boreal Lichen Belt. The natural succession of jack pine woodland into dense black spruce-feather moss forest could be prevented by removal of black spruce seedlings and by thinning the jack pine stands to keep the woodland continuously open so that feather-mosses are inhibited.

Light ground fire in pine-lichen woodlands would not interfere with the normal development of the pine, nor reduce the value of the current timber resource to any significant degree. Selective thinning would likely benefit the pine stands themselves while favouring lichen.

On rocky outcrops patchy burning of the mossy vegetation on thicker soil would be best. It is not advantageous to strip the bedrock entirely bare. A shallow layer of loose soil is necessary for reindeer lichens to prosper on rocks.

In spruce-lichen woodlands thinning and burning are also the best management methods, but unless the spruce stand is very thin, ground fires will spread into and damage the trees. Burning gives good results in tundra heaths, also.

Perhaps the best results are achieved if new burns are situated adjacent to continuously occupied range, since caribou are inclined to follow traditional routes. It might be advisable to burn only a third of a lichen stand in need of improvement, and another third only after the regeneration of the first piece, and so on.

In habitats other than forests with thin humus, or peatlands with dry surfaces, very little can profitably be done to increase ground lichen supplies.

Tree Lichen Supplies: The best yields of arboreal lichens are found in old and moist coniferous forests. The following measures are recommended for maintenance of tree lichen supplies: (1) protection against forest fire, (2) protection of lichenous forests against logging and fire on shores, swamp margins, swamps and close to the northern timber line, and particularly forests known to act as winter range for caribou, e.g., the islands of Lake Nipigon, (3) thinning of dense spruce and fire forests in critical areas, (4) felling of lichen-covered trees, especially those killed by budworm, when snow conditions are unfavorable. This method, formerly widely used in reindeer husbandry, would be only locally useful in caribou management.

The management of ground lichen stands is definitely more important than management of tree lichens in the potentially productive caribou districts of northern Ontario.

Future management of caribou range might well be concentrated north of the northern C.N.R. line, since human disturbances will almost certainly result in further deterioration of the range to the south.

Literature Cited:

Cringan, A.T. 1948. Report upon forest conditions of Burnt Island in connection with woodland caribou range requirements. Ont. Dept. Lands and Forests unpubl. rpt. 6 pp.

Keywords: arboreal lichens/ boreal forest/ Canada/ caribou/ feather mosses/ forest fires/ forest management/ lichens/ logging/ prescribed fires/ *Rangifer*/ winter range.

3. Andreev, V. N. 1954. Growth of forage lichens and methods to improve it. Geobotanica. 9:11-74.

Note: English translation. Paper does not mention fire, but describes the growth stages and maturation period of lichens. Therefore, despite the absence of reference to fire, the conclusions have been reproduced below due to their relevance to basic lichen ecology and post-fire regeneration. The conclusion section was copied from a xeroxed portion of a report by Andreev, and the title and source were not available. The xeroxed copy appears to be the original translation, with some words crossed out. Although it is cited above as the 1954 Geobotanica paper, it is possible that these conclusions are from a different report or an earlier version of the Geobotanica report. The 1954 paper is the only one I have found cited in the literature. Due to the poor quality of the xerox, some words or portions of words were illegible. Illegible portions of words are designated by a ?; when a word was likely correct but there remains some possibility of error, the word is followed by (?).

Abstract: Conclusions: (1) The growth of fruticose lichens takes place at various rates for different species and in different living conditions. The amount of growth is also subject to considerable fluctuations during the process of ?togenesis and depends on the period of development in which the plant is at the time and on the dimensions and age of the living part of podetium.

(2) In the fruticose *Cladoniae* the stalk of the podetium branches once a year, at the tip. A single ring is formed each year on the stalk of the podetium, representing the distance between two main lateral branches. In their first year the rings consist of small projections about 0.5 mm in length. (Translator's note: the preceding sentence, apparently obscure at first reading, means that when the stalk forks at the tip one prong (0.5 mm in length) is the future continuation of the main stalk and the other is a future lateral branch. Strictly speaking, a "ring" should not be described as such until its second year, when it would be bounded by one lateral branch above and another beneath.) In succeeding years the rings increase their length considerably. The period of growth of each ring is on an average about ten years, varying from 6-7 years up to 20-25 years. In the first half of that period the amount of annual growth of the ring gradually increases, and in the second half it falls sharply. During the growth period the length of each ring increases to from 10 to 15 times the original dimensions. The cessation of growth of the ring is due to the death of the algal cells; at the same time the fungal component begins to ?.

(3) The growth of the podetium as a whole is the sum of the amounts of growth of individual rings. There are three periods in the life of the podetium: (a) the period of formation of the podetium or the growth-accumulation period, (b) the podetium-renewal period, and (c) the period of dying-off of the podetium.

During the first period the length of the podetium increases annually as a result of the formation of new rings and the extension of old ones. The amount of growth increases each year as the number of growing rings increases.

During the second period the total length of the podetium continues to increase, but the length of the living part remains more or less constant because one ring at the base of the podetium dies off each year. The podetium continues to grow during that period, but no further accumulation of growth takes place, as the number of rings in the living part of the podetium remains constant. At the beginning of the second period the total amount of living mass continues to increase for some time on account of the growth of lateral branches. During that period the living part of the podetium attains its greatest length and contains its greatest number of rings. The number of rings in the living part of the podetium corresponds to the duration of their life in years.

In the third period there occurs a decrease in length and a gradual dying-off of the living part of the podetium in consequence of a falling-off in the vigour of the plant, expressed in cessation of the branching process and shorter duration of life for individual rings.

In specific living conditions each species of fruticose lichens is characterized by a more or less definite number of years for the duration of the first period of its life. The second period of its life may last for decades, even as much as a century. In view of the possibility of changes (?) in external conditions over such a long time, it is difficult to assign a definite length to that period.

(4) Changes in nutrition have a very pronounced influence on the rate(?) of growth and the duration of life of individual rings. The length of the living part of the podetium and the number of rings in it increase with improvement of living conditions and decrease if they deteriorate. The ? growth depends to a considerable degree on the length of the living part of the podetium, which determines the area of the assimilating surface and (?) the amount of metabolism. The power of self-regulation of length possessed (?) by the living part of the podetium is of great importance in the adaptation of fruticose lichens to harsh living conditions and, combined with the high resistance of lichens to frost and drought, makes possible their wide distribution in the Far North and on high mountains.

(5) Regeneration of the podetium of *Cladonia*, like that of the corticose(?) thallus of other lichens, after a greater or lesser part of it has been removed by grazing reindeer, proceeds similarly to the growth of the podetium in the first period of its life. On the "stump" left after grazing a new podetium, as it were, begins to form, whose rate of growth depends on the size of the "stump." If some young lateral branches are left, one of them takes over the functions of the main stem of the podetium. In that ?ant the rate of re-growth depends on the length and age of the lateral branches. Usually if only the top of the podetium (from one-quarter to one-third of its height) is removed, regeneration is completed in from two to five years; if the greater part (from two-thirds to three-quarters) is removed, regeneration takes place over a period equal in length to the first period of life of the podetium (varying from 6-7 up to 20-25 years); if the whole or almost the whole of the living part of the podetium is removed, the remaining moribund base either perishes completely or begins slowly to re-grow, the period of regeneration in that case being lengthened by from three to five years.

(6) For production purposes it is important to ascertain the duration of the growth-accumulation period in different species of lichens in different conditions and the amount of living material created by a fully "mature" lichen, i.e. one that has completed its growth-accumulation period. The former can be easily ascertained for fruticose lichens by counting the number of rings in the living part of a podetium in the second period of life. The amount of living material can be found by the usual method ?ting samples of fully "mature" lichens, or from special tables ?led from data obtained from such samples.

The average rate of annual linear growth during the first period of life, like the rate of growth in the second period, and also the duration of the first period of life of a podetium and the height of a mature podetium can be ascertained by morphological analysis of specimens of podetia, made in the laboratory. The rate of current growth during a year or any ? period can be found only by special field investigations, using the counting(?) method.

(7) On the basis of morphological analysis of 37,500 specimens of *Cladonia* podetia, and of studies made by the marking method on more than ? specimens of various species of fruticose lichens in different districts of the Far North, a number of principles have been established.

First: the rate of growth, the height of the living part of the podetium, and the duration of the growth-accumulation period show considerable variations in the several lichen species. According to the degree of "earliness of maturity" we may differentiate three groups of lichens: "late-maturing," with the first period of life lasting from twelve to fourteen years (*C. alpestris*); "medium-maturing," with that period lasting from nine to eleven years (*C. sylvatica*); and "early-

maturing," with that period lasting from eight to nine years (*C. rangiferina*). These groups are also distinguished from each other by their rate of growth, which is greater with earlier maturity. According to that feature, in the first group (with the slowest rate of growth) we must include *Cetraria islandica*; in the second, *Cladonia gracilis* and *Stereocaulon;* and in the third *Cetraria cucullata* and *Cetraria nivalis*. The greatest amount of living material is accumulated by the species that are slow-growing but are very late-maturing, and the least amount by the quickly-growing early-maturing *Cladoniae.* The rate of growth and the earliness of maturity are important features economically and are also important in determining the role of the several species in the composition of plant communities.

Secondly: the rate of growth in all species depends on climatic factors. From the northern sub-zones of the forest zone the rate of growth falls off towards the north, and it reacts very sensitively to the variations in climate in the several sub-zones. The character of the weather during the summer months is reflected in the amount of growth. Lichens in the same zones but in locations with a moister and more prolonged summer show higher growth-rate.

Thirdly: the rate of growth of lichens depends to a great degree on the nature of the plant community. In the more favourable microclimate created by tree and bush communities the rate of growth is sharply raised. In lichen carpets composed of a single species the rate of growth appears to be higher than in mixed carpets.

The above-noted features regarding rate of growth and duration of growth-accumulation period in fruticose lichens are of substantial importance in the task of devising measures for their regulation.

(8) The rate of growth of forage lichens can be considerably altered by human action. Ill-timed and irregular use of pastures seriously slows down growth and reduces the total supply of lichens. By organizing systematic reindeer-pasturing one may greatly increase the rate of growth and the amount of living material in the lichens. To that end it is necessary, in the first place, to use the lichens immediately at the end of the growth-accumulation period, at the very beginning of the podetium-renewal period, because use of "immature" lichens decreases the rate of restoration of the forage supply (since the highest rate of growth occurs in the later years of "maturing") but use of "over-mature" lichens leads to loss of part of the forage supply through dying-off of the base of the podetium; secondly, lichens should be mostly top-cropped, i.e. grazing should be restricted to the upper part of the podetium, measuring about one-third of the height of the living part, as when that is done the rate of re-growth of the lichen is 1.5 times as high as when from two-thirds to three-quarters of its height is removed and twice as high as when from 80 to 95% of its living part is removed.

(9) A most important practical measure for regulating the growth of forage lichens is pasture-rotation, that is, using pastures successively in an order based on the periods taken to restore the forage supply after grazing. The period of pasture-rotation (the duration of a single rotation) depends on the time taken in restoration and on the area of the pastures in use. The time taken to restore the forage supply depends in turn on the duration of the growth-accumulation period and on the height at which the lichens are cropped, and the area of the pastures in use depends on their degree of accessibility (which varies with the depth and density of the snow cover) and on the methods used for pasturing reindeer. The following pasture-rotations are recommended: two-year rotation, when lichens are top-cropped; three-year rotation, when from two-thirds to three-quarters of the height of the lichens is removed, and the proportion of the lichen-covered area used is from 15 to 20% with "late-maturing" lichens and from 25 to 30% with "early-maturing" and "medium-maturing" lichens; four-year rotation, with the same height of cropping and with use of from 25 to 30% of the lichen-covered area when the lichens are "late-maturing" and from 40 to 50% when they are "early-maturing" or "medium-maturing". In most cases a two-year rotation is permissible in the first half of the winter and a three-year or four year rotation in the second half. The establishment of a pasture-rotation system must in each individual case be preceded by study of the condition of the range, and also of natural and economic conditions affecting the pasture-rotation.

(10) Besides pasture-rotation, an important measure for regulating the growth of fruticose lichens is the organization of a proper alternation of pastures during the season, and of correct methods of herding reindeer on the pastures. The most complete utilization of lichen supplies is achieved by proper selection of late-autumn, winter, and early-spring pastures, and organization of proper successive use of them during the season. The roster of pasture use should provide for the first visits to be made to the pastures that soonest become inaccessible on account of deep snow cover, while keeping for later use the pastures that remain accessible longest and have the richest supplies of forage. A rational size of herd for the tundra and the forest-tundra, as shown by the experience of the leading organizations, is from 1,200 to 1,500 head. When pastures are difficult of access and the forage area is broken up into a number of small sections it will be necessary to divide the herd temporarily into two parts. When the herd is of rational size it is possible, by maintaining a planned concentration of grazing reindeer in the pastures and by driving the animals from used pastures to new ones at the proper time, to ensure that the lichens are top-cropped during a considerable part of the snowy period of the year, and to avert excessive grazing of lichens in dug-out spots.

As a consequence of the measures listed above the rate of lichen growth may be in some cases almost doubled, which makes possible a corresponding increase in the number of reindeer on the pastures.

The theory of the growth of fruticose lichens propounded in the present work requires further elaboration in the future. The tasks immediately ahead consist in thorough study of the biology of the growth of fruticose lichens, and -- on the foundation of that study -- the devising of special measures to stimulate the growth of lichens, accelerating it to a much greater degree than is possible at present by means of rationalization of the periods and methods of use of lichen ranges.

Keywords: grazing/ lichens/ lichen growth/ rangeland/ reindeer.

4. Anonymous 1981. Methods used to determine the ecological effects of fire on plant succession and related resources on Bear Creek burn. Bureau of Land Management 86 pp.

Note: No abstract. Report documents methods used to study the effects of the 1977 Bear Creek fire between the South Fork and the Windy Fork of the Kuskokwim River, Alaska. Wildlife found in the burned area include moose, bison, caribou (primarily in winter), bears, wolves, furbearers, small mammals, and a variety of bird species. The report describes methods to sample vegetation and wildlife resources. Large mammal studies included winter aerial surveys to estimate animal numbers and distribution, forage utilization, browse condition, and winter food habits (microhistological analysis of fecal pellets). The report also includes numerous maps and sample data sheets.

Abstract: Not available.

Keywords: Alaska/ boreal forest/ caribou/ fecal pellets/ fire/ forest fires/ forage/ interior Alaska/ *Rangifer*/ wildlife.

5. --- 1978. Workshop report; Section 6: The ecology of fire on caribou rangelands. Page 35 *in* Klein, David R. and White, Robert G., eds. Parameters of caribou population ecology in Alaska. Fairbanks, Alaska, 17 Nov 1977-19 Nov 1977. Biological Papers of the University of Alaska. Special Report No. 3. University of Alaska-Fairbanks. Fairbanks, Alaska, 49 pp.

Note: A model of caribou population ecology was developed during the symposium and was then used as a basis for discussion. The following section was excerpted from the discussion of plant-animal relations.

Abstract: Extensive fires on tundra rangelands in northwestern Alaska during the drought conditions of 1977 point out the need for both short and long term research into the effects of fire on these lands as caribou (or reindeer) range. It is also important to determine the cycles of vegetational change following fire in the various upland communities and under the variable site conditions and fire intensities that prevailed. Change on the new burn areas should be monitored, and more intensive and immediate comparisons should be made with plant recovery patterns on older burns with a known or determinable fire history. The ecology of fire in spruce-lichen wintering areas should also receive increased research emphasis.

Keywords: Alaska/ caribou/ fire/ post-fire succession/ Rangifer.

6. Arseneault, Dominique and Payette, Serge. 1992. A postfire shift from lichen-spruce to lichen-tundra vegetation at tree line. Ecology . 73(3):1067-1081.

Abstract: The environmental changes associated with a fire-induced shift from old-growth lichen-spruce krummholz to lichen-tundra vegetation have been evaluated at a tree line site in northern Quebec. Tree ring and growth form patterns of black spruce (*Picea mariana*) remains lying on the ground in a lichen-tundra community were used to reconstruct within a 4600-m^2 quadrat, the structure of a conifer stand at the time of the burn (~AD 1750). The pre-fire spruces were the last members of a long regenerative sequence leading to maintenance of a lichen-spruce stand formed after a burn ~ 1700 yr BP. At this time postfire recruitment was most likely facilitated by favorable climatic conditions. Before the 1750 fire event the krummholz was predominantly maintained by layering, due to severe climatic conditions at least since the beginning of the Little Ice Age (~AD 1580). The site was deforested by the 1750 fire, because of the limited regenerative potential of stunted spruce. Postfire spruce exclusion has been responsible for major environmental changes associated with a thinner snow cover. Along the border of the deforested site snow cover depth was controlled by living spruces, whereas postfire shrubs (mostly dwarf birch, *Betula glandulosa*) of the lichen-tundra stand were unable to trap drifting snow. A significant decrease in thickness of the snow cover following deforestation was deduced from a comparative analysis of stem morphology of pre-fire spruces and present snow conditions. Inception of gelifluction lobes and mudboils was also caused by a change in the soil thermal regime associated with a reduced snow cover. Our results confirm the hypotheses that several lichen stands of the forest-tundra are postfire communities succeeding from degraded conifer stands during cold periods of the late Holocene.

Keywords: Canada/ climatic change/ deforestation/ dendro-ecology/ fire/ forest-tundra/ lichen-spruce/ lichen-tundra/ Picea.

7. Auclair, A. N. D. 1983. Role of fire in lichen-dominated tundra and forest-tundra. pp. Pages 235-256 *in* Wein, Ross W. and MacLean, David A. eds. Role of fire in northern circumpolar ecosystems. John Wiley and Sons; New York.

Note: Chapter sections are: 13.1 Introduction; 13.1.1 Predisposition to fire; 13.1.2 Fire occurrence; 13.1.3 Vegetation distribution; 13.2 Vegetation flammability and behaviour of fire; 13.2.1 Extrinsic factors; 13.2.1.1 Meteorology; 13.2.1.2 Uniformity; 13.2.2 Intrinsic factors; 13.2.2.1 Tissue content; 13.2.2.2 Surface-volume ratio; 13.2.2.3 Vertical plane; 13.2.2.4 Fuel mass; 13.3 Fire-induced changes; 13.3.1 Combustion and mineralization of organic material; 13.3.1.1 Quantity of organic matter; 13.3.1.2 Plant and soil nutrients; 13.3.1.3 Allelopath and burnt-litter compounds; 13.3.2 Changes in surface and soil microclimate; 13.3.2.1 Temperature and radiation flux; 13.3.2.2 Soil moisture; 13.3.3 Alteration of soil stability and hydrology; 13.3.3.1 Thermokarst subsidence; 13.3.3.2 Hydrology and erosion; 13.3.3.3 Element losses; 13.4 Post-fire regeneration; 13.4.1 Plant succession; 13.4.2 Changes in soil decomposers; 13.4.3 Changes in insect, bird, and mammal species; 13.5 Future research needs; 13.6 References.

Includes extensive reference list.

Abstract: Unique aspects of fire in lichen tundra and forest-tundra were enumerated. The very high inherent fire susceptibility is related to the presence of lichens and shrubs. Lichens are predisposed to burning by virtue of continuous distribution on the soil surface, high surface-volume ratio, and rapid desiccation related to the absence of roots, vascular tissue, and tissue that resists moisture loss. In most fires, two-thirds of the organic matter in live biomass is not combusted and there is only minor loss of nutrients during burning. Decomposition rates are low and nitrogen limited.

Post-fire regeneration of vascular species is rapid. Shrubs sprout the same year of the fire and tree establishment peaks within 2-3 years. Lichen growth is slow by comparison and the lichen may require 50-80 years to develop a continuous cover.

Keywords: fire/ forest fires/ forest-tundra/ lichens/ post-fire succession/ soils/ tundra.

8. Avramchik, M. N. 1939. The after-grass of some forage plants on tundra pastures. Trans. Inst. Pol. Agr. 4:89-131.

Note: Citation and summary, based on an English summary of the paper, from Courtright, A.T. 1959. Range management and the genus *Rangifer*: A review of selected literature. M.Sc. This, Univ. of Alaska, Fairbanks, AK. 172 pp.

Abstract: ["After-grass" is a term meaning, roughly, "secondary growth after removal by grazing, cutting, burning, etc., of the natural new growth." It does not apply only to grass, but to browse and other types of plants as well.] The following is an abstract of the English summary.

There were three objectives in this study:
1. To establish the ability of tundra forage plants to "grow the after-grass."
2. To determine the quantity of after-grass and the time at which it grows.
3. To determine the chemical composition of the after-grass and its palatability to reindeer.

Two different experiments were made; one to determine the growth after cutting in early summer (beginning of July) and the other to determine growth after cutting in the beginning of August. A third experiment to determine growth after removal by fire was made with *Eriophorum vaginatum*; on one plot the cover was burned in early spring (April 11) and on the other on June 6. Twenty-three chemical analyses of grass, foliage, and after-grass were made. Summarized, the results of the experiments were as follows:

... 5. "After-grass is no different" when *Eriophorum vaginatum* is burned in early spring than when it is burned in the middle of summer.

6. Chemical analyses of after-grass indicate that its nutritive value is very high -- higher than that of primary growth of plants collected in late summer and fall. It also contains less fiber than the latter. Palatability, at least in the case of shrubs, is increased.

Keywords: *Eriophorum*/ fire/ forage/ nutrient content/ reindeer.

9. Banfield, A. W. F. 1951. The barren-ground caribou. Dept. of Resources and Development, Northern Administration and Lands Branch, Ottawa. 56 pp.

Note: General report about caribou. Brief section about fire effects reproduced below. Major report sections are: Introduction; Migration; Changes in Range and Status; Physical Description;

Vegetation Studies; Individual Behaviour; Group Behaviour; Vital Statistics; Growth; Pathology; Accidents; Ecological Relations; Wolf Predation; Human Utilization; Human Population in Caribou Range; Native Game Returns; Conclusion.

Abstract: Human Influence on Migration (p. 11):
... The most important influence exerted by man upon the movements of caribou, however, is the destruction of forage through fires. The lichens, upon which the caribou rely for winter forage, are slow-growing plants. It has been ascertained from investigations in Alaska that it may take a burnt-over lichen area as long as 25 years to regenerate. If the humus is destroyed the loss is, for all practical purposes, permanent.

During the present investigation information which would indicate an actual desertion of a burned area by the caribou was sought, and was obtained from the aerial flights. It was observed that caribou and their tracks were absent from recently-burned areas, while their tracks were abundant in adjacent "green" areas. During migration periods it was observed that the routes traveled by the animals lay in "green" corridors between burned areas. Large burned areas were practically devoid of winter caribou tracks.

The tundra and the northern fringe of the woods are largely unaffected by fires, but there have been many destructive fires in the heart of the wooded winter range of the caribou. ...

Keywords: Canada/ caribou/ disturbance/ fire/ lichens/ migration/ winter range/ Rangifer.

10. -- 1954. Preliminary investigation of the barren ground caribou. In two parts. Part I. Former and present distribution, migrations, and status. Wildlife Management Bulletin. Series 1. Number 10A. Minister of Northern Affairs and National Resources, Ottawa.

Note: No abstract. Describes migration patterns and distribution of individual herds. Major report sections are: Introduction; Present Investigation; Itinerary; General Description of the Physical Environment; Historical Records; Present Distribution; Population Data and Estimates; Migration Routes; Spring Migration; Midsummer Migration; Autumn Migration; Human Influences upon Migration; Changes in Range, Status, and Migrations; Summary.

Section related to fire reproduced below.

Abstract: Human Influences upon Migration
Forest Fires
The most important influence exerted by man upon the movements of caribou is through the destruction of forage by forest fires. Lichens, upon which the caribou rely for winter forage, are exceedingly slow-growing plants. It has been ascertained from investigations in Alaska by Palmer (1926) that it may take a burnt-over lichen area as long as 25 years to regenerate. If the humus is destroyed the loss is, for all practical purposes, permanent. Lichens must be considered as a long-term crop, comparable to trees. Thus, fires under sub-Arctic conditions may be even more damaging than at lower latitudes. Harper (1932) and Clarke (1940) have previously pointed out how forest fires may reduce greatly the number of caribou that can be supported on the taiga winter ranges.

During the present investigation factual information which would indicate an actual desertion of a burned area by the caribou was sought. Such evidence was obtained in abundance from the aerial reconnaissance flights.

It was observed that caribou and their tracks were almost always absent from the recently burned areas, even at times when tracks were abundant in adjacent "green" areas. Occasionally the winter distribution of caribou was observed to be delineated by the boundaries of "green" taiga. In Figure 17 the observations made on flights in northern Saskatchewan during January, 1949, are shown.

From the figure one can note the presence of caribou bands in the unburned areas and their absence from the burned areas. Similar observations were made on several flights in Manitoba, Saskatchewan, and the Mackenzie District, Northwest Territories.

It was observed that the routes traveled by the migrating animals lay in "green" corridors between burned areas. Such was the case at Ghost Lake, Mackenzie District, on April 24, 1949, where the route lay eastward along a narrow "green" corridor between two extensive burns at Matberry Lake and south of Ghost Lake. Large burned areas were practically devoid of winter caribou tracks in the snow. Small burns were occasionally crossed by single trails but there was no evidence of feeding.

The tundra and the northern fringe of the taiga are largely unaffected by fires, but there have been many large destructive fires in the heart of the taiga winter caribou range. In the Mackenzie District, there were large burned areas in the Mattberry-Indian Lake region. A large area east and northeast from Yellowknife was useless as caribou range because of the destruction of the vegetation by numerous recent fires. There were also large burns in the lower Talston River region. The winter range south of Fort Reliance was still largely intact.

There have been damaging fires about Tazin Lake and Camsell Portage, Saskatchewan. Large areas of former caribou winter range in northern Saskatchewan, south of Wollaston Lake and west of Reindeer Lake, have been destroyed. Throughout this area no caribou were observed during reconnaissance flights in January and February, 1949. Large burns north of Fond-du-lac and Stoney Rapids have probably deflected migration routes away from these crossing points. It is estimated that 30 per cent of the winter range in Saskatchewan has been devastated and will not be productive for many years.

Similarly in northern Manitoba there have been large burns recently in the caribou winter range. Large areas north and west of Southern Indian Lake, as well as areas in the Angling River drainage south of the Nelson River, have been destroyed. It seems probable that recent destruction of winter forage in the Southern Indian Lake region may have been a contributing cause of the recent southward movement of caribou herds into central Manitoba in winter.

It is difficult to assess the full effect of recent burns upon the population of the species. Hitherto it has meant a shift of the caribou herds to other areas, which have usually been available. It is probable that were the larger part of the winter range destroyed by fire, the population of caribou would be reduced by starvation.

Literature Cited:

Clarke, C.H.D. 1940. A biological investigation of the Thelon Game Sanctuary. Nat. Mus. Can., Bull. No. 96, Biol. Ser. No. 25. 135 pp.

Harper, F. 1932. Mammals of the Athabaska and Great Slave Lakes region. J. Mamm. 13:19-36.

Palmer, L.J. 1926. Progress of reindeer grazing investigations in Alaska. U.S. Dept. Agr., Bull. 1423. 36 pp.

Keywords: Canada/ caribou/ caribou distribution/ fire/ forest fires/ lichens/ winter range/ Rangifer.

11. Bergerud, Arthur T. 1971. Abundance of forage on the winter range of Newfoundland caribou. The Canadian Field-Naturalist. 85:39-52.

Abstract: The abundance of forage for caribou (*Rangifer tarandus*), mainly evergreen shrubs and terrestrial lichens, was measured at 22 locations in Newfoundland. Study areas were selected to represent plant successional stages following fires on former forest sites and in lichen woodlands

and also on subalpine winter range used by caribou. The supplies of forage were substantial and there appeared to be no absolute shortage of food for caribou. It was concluded that forest fires in the past have increased the extent of winter range by altering closed-canopy forests to lichen woodlands or shrub-barrens, and prostrate subalpine spruce-fire thickets to lichen-shrub barrens.

Keywords: Canada/ caribou/ fire/ lichens/ post-fire succession/ Rangifer.

12. ---. 1974. Decline of caribou in North America following settlement. Journal of Wildlife Management. 38(4):757-770.

Abstract: The numbers of caribou (*Rangifer tarandus*) in North America generally declined in the 1800s and early 1900s. Four hypotheses are discussed relative to this decline: (I) numbers decreased because of a shortage of lichen supplies caused by the destruction of lichen pastures by fire and logging; (II) population declined because of increased hunting mortality, augmented by increased natural predation of some herds by wolves (*Canis lupus*); (III) a combination of hypotheses I and II above; and (IV) caribou declined in Alaska because of increased movement of marginal habitats with high numbers. This review supports hypothesis II--that numbers declined because of increased hunting mortality and natural predation of some herds, and argues that the range-destruction hypothesis has not been shown to be either a necessary or sufficient cause to explain the decline.

Keywords: caribou/ fire/ hunting/ lichens/ logging/ population decline/ predation/ *Rangifer*.

13. Beverly and Kaminuriak Caribou Management Board. 1986. Executive summary of the long-term management plan for the Beverly and Kaminuriak caribou herds.

Note: Citation from ASTIS bibliographic database; abstract attributed to the author.

Abstract: The Beverly and Kaminuriak Caribou Management Board was created to implement the Beverly-Kaminuriak Caribou Management Agreement, signed in 1982 by the Governments of Canada, Manitoba, Saskatchewan, and the Northwest Territories and witnessed by participating native groups. The Board is a forum for caribou users, managers, and biologists to discuss caribou issues and to recommend management actions and the allocation of resources. After several years of research, discussion, and negotiation, the Board developed a draft management plan that is being submitted for government and public review before it can be considered operational. This Executive Summary is intended for the use of Ministers, senior public servants and wildlife organizations. A popular version, issued concurrently, forms part of a special edition of the Board's newsletter aimed at traditional users and is translated into native languages. The full-length, detailed version will, when approved, constitute a guide for program managers and specialists during the term of the management agreement. Caribou have been important to the traditional users for centuries, and will continue to be so in the future. They provide for the subsistence requirements of an expanding northern population, and satisfy cultural and aesthetic needs of both northern and southern Canadians. The Caribou Management Board was formed at a time when an apparent decline in the Kaminuriak herd population threatened the herd's existence, and when managers and users were frustrated by a lack of understanding that prevented them from reaching mutually acceptable management solutions. Circumstances have since changed. The Kaminuriak herd population has rebounded dramatically and both herds are healthy, although there are user communities that still do not have ready access to them, which is a cause of hardship for many native people. In addition, there are high expectations on the Board as a working model for governments and users to work in harmony on a worthy resource. ... The board relies heavily on the traditional knowledge of user constituents, most of whom have spent a lifetime observing the caribou in all places and all seasons. It also recognizes that the managers and biologists who serve either as members or advisers have impressive scientific credentials and experience. ... It is this combination of scientific and traditional skills and knowledge, and the mutual respect that has

grown between Board members and their advisers, that make the Board unique, strong and worthy of full attention from the public and the Ministers in authority. ...

Keywords: Beverly Herd/ Canada/ caribou/ fire/ hunting/ Kaminuriak Herd/ subsistence/ taiga / wildlife management/ Rangifer.

14. Black, R. Alan and Bliss, Lawrence C. 1978. Recovery sequence of *Picea mariana-Vaccinium uliginosum* forests after burning near Inuvik, Northwest Territories, Canada. Canadian Journal of Botany. 56:2020-2030.

Abstract: *Picea mariana-Vaccinium uliginosum* vegetation was sampled in a north-south transect near Inuvik, N.W.T., Canada. Four stages in the postfire recovery sequence were described. Little qualitative change in vascular plants was found in the transect or with time since burning, although quantitative changes were found to exist. Contrary to vascular plant development, an orderly postfire succession of cryptogamic species was found. The postfire recovery sequence by comparison with other open boreal forest studies has a persistent shrub-dominated stage. Burning, with few exceptions, occurred within 100 years of examination along the transect. Objective analyses by Bray-Curtis ordination and reciprocal averaging ordination were used to analyze the vegetation data and proved useful in the data reduction and interpretation of results.

Keywords: boreal forest/ Canada/ fire/ forest fires/ lichen succession/ lichens/ ordination/ *Picea*/ post-fire succession.

15. Bradshaw, Corey J. A. and Hebert, Daryll M. 1996. Woodland caribou population decline in Alberta: fact or fiction? Rangifer. Special Issue No. 9:223-234.

Note: Paper presented at the Sixth North American Caribou Workshop, Prince George, B.C., Canada, 1-4 March 1994. Includes discussion of fire and caribou ecology in the section on habitat loss.

Abstract: We re-assessed the view of a major woodland caribou (*Rangifer tarandus caribou*) population decline in Alberta. Several historical publications and provincial documents refer to this drastic decline as the major premise for the designation of Alberta's woodland caribou an endangered species. In the past, wildlife management and inventory techniques were speculative and limited by a lack of technology, access and funding. The accepted trend of the decline is based on many speculations, opinions and misinterpretation of data and is unsubstantiated. Many aerial surveys failed to reduce variance and did not estimate sightability. Most surveys have underestimated numbers and contributed unreliable data to support a decline. Through forest fire protection and the presence of extensive wetlands, the majority of potential caribou habitat still exists. Recreational and aboriginal subsistence hunting does not appear to have contributed greatly to mortality, although data are insufficient for reliable conclusions. Wolf (*Canis lupus*) population fluctuations are inconclusive and do not provide adequate information on which to base prey population trends. The incidence of documented infection by parasites in Alberta is low and likely unimportant as a cause of the proposed decline.

Keywords: Canada/ caribou/ habitat loss/ hunting/ pathology/ population decline/ predation/ wildlife management/ Rangifer.

16. Bunnell, F.; Dauphine, D. C.; Hilborn, R.; Miller, Donald R.; Miller, F. L.; McEwan, E. H.; Parker, G. R.; Peterman, R.; Scotter, George Wilby, and Walters, C. J. 1975. Preliminary report on computer simulation of barren ground caribou management. Pages 189-193 *in* Luick, Jack R.; Lent, Peter C.; Klein, David R., and White, Robert G., eds. Proceedings of the first international reindeer and caribou symposium. Fairbanks, Alaska, 9 Aug 1972-11 Aug 1972. Biological Papers of the

University of Alaska, Special Report No. 1. University of Alaska-Fairbanks. Fairbanks, Alaska, 551 pp.

Abstract: Abstract: A computer model was developed to look at the dynamics of a caribou population on the winter range. Represented in the model are browse and lichen production, total caribou population, winter harvest, summer harvest and calf survival. The main objective of this simulation model was to evaluate management practices. The model has proven useful as a means of testing the interaction of management interventions such as harvest rates, selective hunting, rate of forest fire burns and calf survival.

Keywords: caribou/ forage/ forest fires/ hunting/ lichens/ management/ model/ population dynamics/ winter range / Rangifer.

17. Carroll, Steven B. 1978. The role of fire in the jack pine-lichen woodlands of the Athabasca Plains region of Canada. Pages 47-49 *in* Dube, D. E., eds. Proceedings - Workshop on fire ecology in resource management. Edmonton, Alberta, 6 Dec 1977-7 Dec 1977. Information Report. NOR-X-210. Canadian Forestry Service.

Note: Report reproduced in its entirety.

Abstract: During the summer of 1977, the jack pine-lichen woodlands of the Athabasca Plains Region of northeastern Alberta and northern Saskatchewan were studied with the following objectives: (1) to determine the structure and species composition of these woodlands, (2) to document the frequency and role of fire in the region, and (3) to document the post-fire recovery of the vegetation. This summary will deal with the latter two objectives.

The widespread occurrence of fire margins, even-aged stands, fire-scarred trees, charred wood and charcoal in the soil attests to the importance of fire in this region. Analysis of fire-scar dates indicates mean fire return intervals (MFRI) of 17.2-29.0 yr at six widely scattered sites. When the MFRI was calculated for individual stands (that is, did not include intervals between fires occurring in different stands), the values ranged from 27.7 to 53.8 at the six sites. This interval averaged 45.0 yr when data from all six sites were combined.

Floristically, these woodlands are very simple. Sampled species totaled only 4 trees, 6 shrubs, 27 herbs, 5 dwarf shrubs, 2 Pteridophytes, 8 Bryophytes, and 31 lichens. Despite this simplicity, species do replace each other over time (since burning).

One of the first species to colonize is jack pine, since a nearby seed source is almost always present in the form of remnant trees or patches of forest. Other colonizers include *Polytrichum piliferum, P. juniperinum, Ceratodon purpureus, Cladonia coccifera, Cladonia gracilis, Vaccinium myrtilloides, V. vitis-idaea, Ledum groenlandicum, Hudsonia tomentosa, Arctostaphylos uva-ursi, Carex foenea, Agrostis scabra*, and *Epilobium angustifolium*. The species which colonize a particular site depend on many factors, and vary geographically.

After initial establishment of vegetative cover, the species composition continues to change. *Cladonia coccifera* is soon replaced by *Cladina mitis* as the dominant lichen. Other lichens, including *Cladonia uncialis, Cetraria nivalis* and *Cladina stellaris*, increase in importance. *Cladonia gracilis* is less predictable, but is often codominant at this point, as are the two *Vacciniums*. Bryophytes such as *Pleurozium schreberi, Dicranum polysetum* and *Ptilidium cilare* begin to appear. At this point (30-60 years after burning), a stand will likely burn, beginning the cyclical succession once again. If a stand remains free from fire, however, succession is likely to proceed in one of two directions, although variations are possible.

In most instances, the canopy will continue to thin, allowing more solar radiation to reach the ground. This maintains a warm, dry microclimate at ground level which favors the maintenance

of the *Cladina mitis* dominated mat, although species such as *Cladonia uncialis*, *C. gracilis*, *Cladina stellaris* and *Cetraria nivalis* may continue to increase in cover. These park-like woodlands are among the most beautiful of Canada's forests.

Despite continued changes in the relative importance of species, the lichen mat totally recovers (in terms of thickness and total cover) in approximately 45 years. This contrasts sharply with regeneration times farther north in the Canadian Shield.

In more mesic areas, and especially on north-facing slopes, *Picea mariana* may begin to seed in, or may form a subcanopy equal in age to the higher pine canopy. Through regeneration and layering, radiation levels on the ground are reduced. The increased moisture available under such conditions allows the Bryophytes to gain in importance. Given sufficient time, a mixed pine-spruce canopy forms, with a lichen-bryophyte understory. The modified microclimate can be expected to modify the fire regime by increasing fire-free intervals.

Under the mesic successional regime, the thickness of the lichen-bryophyte mat does continue to increase, and the species composition continues to change. The lichen species *Cladina rangiferina*, *C. stellaris*, *C. arbuscula* and *Cetraria nivalis* may eventually attain greater cover than *Cladina mitis*. Only under these conditions do *Cladina stellaris* woodlands form in the region. The *Stereocaulon paschale* woodlands reported from farther north are totally absent from this region.

Keywords: boreal forest/ Canada/ fire/ fire frequency/ forest fires/ jack pine/ lichen succession/ lichens/ microclimate/ post-fire succession.

18. Carroll, Steven B. and Bliss, Lawrence C. 1982. Jack pine-lichen woodland on sandy soils in northern Saskatchewan and northeastern Alberta. Canadian Journal of Botany. 60(11):2270-2282.

Abstract: Open woodland forests dominated by *Pinus banksiana* occur on sandy soils in northeastern Alberta and northwestern Saskatchewan and are generally even-aged and uniform in height. Ordination techniques were used to divide the stands (n=38) into the following communities: *Pinus banksiana/Vaccinium myrtilloides* seral community; *Pinus banksiana/Cladina mitis*, *Pinus banksiana/Vaccinium myrtilloides/Cladina mitis* in uplands; and *Pinus banksiana - Picea mariana/Ledum groenlandicum/Cladina* spp. in lowlands. Fires occur with a mean return interval of 38 years (range at six locations, 28-54 years). *Pinus banksiana* recolonizes rapidly after fire, and average thickness of lichen cover is reached in 45 years. This is a shorter time interval for recovery than is reported for the Northwest Territories. Stands that escape fire 90+ years become more open in upland sites, but in lowlands *Picea mariana* becomes codominant with associated shift in lichen species and an increase in bryophytes.

Keywords: boreal forest/ Canada/ forest fires/ jack pine/ lichens/ ordination/ *Picea*/ post-fire succession.

19. Christiansen, Janet S. 1988. A spruce-lichen woodland in northern Alaska: Post-fire regeneration and community dynamics. University of Washington. Seattle, WA. 95 pp.

Note: Ms. Sc. thesis. No abstract; conclusions section reproduced below.

Study area not used by caribou to any great extent. This thesis documents post-fire ecology of a spruce-lichen woodland in Alaska, where such habitats are uncommon. Conversely, most of the papers related to fire and caribou in Canada concern spruce (and sometimes jack pine)-lichen woodlands.

Abstract: The conclusions of this study are the following:

1.) Wildfires burned the spruce-lichen woodlands at Walker Lake in 1891 and 1913. Trees that survived these fires are scattered among younger trees and are numerous in some areas.

2.) Patterns of tree regeneration after fire were different for black spruce than for white spruce. Age distributions for black spruce stands show strong peaks of establishment within the firest two decades after fire, with establishment dropping off to low levels within 35 years of the fire. Regeneration in the white spruce stands was more continuous, without strong peaks.

3.) Few trees have established in the past 25 years. The lack of current tree regeneration may be due to the poor seedbed provided by the lichen mat.

4.) The soil moisture regime is probably a major factor determining the vegetation composition of the woodlands. Black spruce dominates on finer textured soils, while white spruce occurs mainly on sandier soils. The stands on finer textured soils are also generally denser, with thicker lichen mats and higher shrub cover.

5.) Tree growth is slow on all plots. Because of the slow tree growth and narrow crown form and the eventual termination of seedling establishment, these stands develop slowly. Stand canopies would probably remain open for several centuries, even in the absence of fire, allowing the continued dominance of the understory by lichens.

Keywords: Alaska/ boreal forest/ lichens/ *Picea*/ post-fire succession/ soils.

20. Cichowski, Deborah B. and Banner, Allen 1993. Management strategy and options for the Tweedsmuir-Entiako caribou winter range. Land Management Report. No. 83. ISSN 0702-9861; No. 83. Research Branch, Ministry of Forests, Victoria, British Columbia. 48 pp.

Note: Report mostly concerned with logging on winter range. Fire is mentioned in Section 6.3.2 of the discussion on pg. 32 (see below).

Abstract: Section 6.3.2. Tweedsmuir-Entiako caribou

Some aspects of Tweedsmuir-Entiako woodland caribou ecology still need to be addressed. In late winter, caribou move to ranges near the mouth of the Entiako River. Food habits of caribou at that time of year are not well understood. There is little habitat containing abundant terrestrial lichens. It appears that they may switch from feeding on terrestrial lichens to feeding on arboreal lichens or vegetation in snow-free areas. A better understanding of forage selection during late winter will facilitate defining harvesting guidelines compatible with late winter range.

Terrestrial lichen stands begin declining over the long run (200-300 years) as feather mosses colonize the forest floor, and they must undergo periodic disturbance to regenerate back to productive stands. In the past, wildfires acted as a disturbance factor. Today, however, with widespread fire suppression efforts, occurrence of wildfires has been significantly reduced. Eventually terrestrial lichen sites in high value caribou management zones must be regenerated back to productive levels. Further research into regenerating terrestrial lichen stands while minimizing potential impacts to the caribou population is also required and a Fire Management Plan for the winter range should be developed.

Although arboreal lichens are used less than terrestrial lichens on the low elevation winter range, arboreal lichens are a secondary food source during winter. Where possible, both terrestrial and arboreal lichens should be maintained. The caribou winter habitat map shows terrestrial lichen abundance only. Methodology should be developed to predict arboreal lichen abundance and used in conjunction with the caribou habitat map.

Because the Tweedsmuir-Entiako caribou population is declining, a management strategy for the caribou winter range must address caribou population considerations in the short run, as well as caribou population and habitat considerations in the long run. Further research is required to determine the primary limiting factor causing the population decline. Once the cause of the decline is known, wildlife management techniques may be employed to stop the declining population trend. A better understanding of the population limiting factor will also result in a better understanding of potential indirect effects of timber harvesting on the Tweedsmuir-Entiako caribou winter range. Harvesting guidelines could be further refined to maximize caribou habitat and timber harvesting potential.

Keywords: arboreal lichens/ British Columbia/ caribou/ fire/ fire management/ logging/ population decline/ terrestrial lichens/ Rangifer.

21. Cochrane, Ross G. and Rowe, John Stanley 1969. Fire in the tundra at Rankin Inlet N.W.T. Pages 61-74 *in* Proceedings of the Tall Timbers Fire Ecology Conference. Tallahassee, Florida, 1969. No. 9. 13 pp.

Note: Summary reproduced below.

Abstract: (Summary) Fires do occur in the Canadian tundra and their traces were observed on a variety of topographic sites. They burn readily downwind but are easily halted by physical obstacles in an upwind direction.

Burning is selective, reflecting fuel differences in the vegetation and habitat moistness. *Alectoria* lichen communities burn readily and evenly. *Cetraria* lichen communities burn less easily, while mixed lichen-and-heath communities burn irregularly according to type and quantity of fuel. Apparently Labrador tea and ground birch are particularly flammable and burn fiercely.

Growth and regeneration of lichens and heaths following fire seems to be slow. Arctic holy grass is an important early colonizer of dry, sandy and stony burned areas. Its dominance in a locality, especially if banded alternately with sparsely vegetated moss-peat areas, strongly suggests earlier fire influences.

Keywords: Canada/ fire/ lichens/ tundra/ tundra fires.

22. Cole, Glen F. 1982. Restoring natural conditions in a boreal forest park. Trans. N. Amer. Wildl. Nat. Resour. Conf. 47:411-420.

Abstract: Voyageurs National Park is located in northern Minnesota. Its northern and eastern boundaries parallel a historic fur trade route that influenced the location of the boundary between the United States and Canada. About two-thirds of the park's 344-square-mile (891 km^2) area is land, and the remainder is made up of numerous small and large lakes. The interspersion of forested land, massive rock outcrops and lakes make the park very scenic. It is also somewhat unique because it is the only U. S. park on the mainland in a southern boreal forest region. Isle Royale National Park is also in this region, but its biota is characteristic of island areas. The information in previous sections identifies four major man-caused problems (i.e. changes from natural conditions). These are: 1. Preventing all forest fires prevents the park from having a natural forest vegetation. 2. Two of the park's four native cervid species are absent and a third persists in precariously low numbers. 3. Reduced food for carnivores is causing further declines in the numbers and kinds of native wildlife species in the park. 4. Regulated lake levels are having adverse effects on wild rice, fish, and other wildlife. Some possible solutions to these problems, in the form of hypotheses that can be tested by research, follow. 1. Allowing fires to burn within designated areas where they can be confined (by natural barriers or control) will reestablish mosaics of forest vegetation comparable to those before logging. 2. Introductions will reestablish

viable populations of woodland caribou, moose, and/or elk. 3. Reestablishing caribou, moose, and/or elk populations will increase food for native carnivores. 4. The present adverse effects of regulating lake levels on various aquatic species can be reduced, without serious conflicts with other presently authorized uses of water, by approximating the magnitude and timing of natural fluctuations in most years and reducing the extreme fluctuations from occasional natural floods or droughts. Alternatives to these solutions range from doing nothing to employing actions that solve one problem, but not others. For example, one alternative to reestablishing caribou, moose, or elk populations to provide food for carnivores is to prescribe burn forests to maintain high numbers of white-tailed deer. This would not restore the park's native cervid fauna or maintain a natural forest vegetation. Doing nothing seems certain to result in more native species becoming less abundant or absent. These and other alternatives relating to cervid introductions or fire are covered in greater detail in planning or environmental impact documents. Alternative ways of regulating lake levels are being explored with different users of water and an International Joint Commission, which must authorize any changes. It is intended that any actions to correct problems be monitored and evaluated by research. This approach has been previously used to correct similar problems in other national parks (Hayden 1971, Kilgore 1971, Houston 1971). The introductions of native cervids should be of particular interest because they would allow various hypotheses about the effects of parasites, interspecies competition, and inbreeding to be tested in the field. More important, however, these and other appropriate actions could assure that representative examples of natural southern boreal forest environments and their native wildlife are preserved in Voyageurs National Park.

Keywords: boreal forest/ caribou/ fire mosaic/ forest fires/ Voyageurs National Park/ wildlife introductions/ Rangifer.

23. Collins, William B., McElwain, Darien E., Dale, Bruce W., Joly, Kyle, and Adams, Layne G. **In prep**. Fire, forage lichens, and caribou distribution.

Abstract: This paper is currently (summer 2004) in preparation. Vegetation plots were studied at known caribou locations and random locations in the both the current and historic winter ranges of the Nelchina Caribou Herd. Comparisons between used and random locations will be made, as well as comparisons between the winter ranges.

Keywords: boreal forest/ caribou/ habitat selection/ forest fires/ lichens/ Nelchina/ Rangifer/ succession.

24. Courtright, Alan T. 1959. Range management and the genus Rangifer: A review of selected literature. University of Alaska-Fairbanks. Fairbanks, Alaska. 172 pp.

Note: M. Sc. thesis. Includes bibliographies of papers and reports, some originally in Russian. Some entries extensively annotated. No abstract, but select passages reproduced below.

Abstract: (Preface) ... This paper is divided into three main sections. The first consists of a brief review of the research that has been conducted on the foods, food habits, and food requirements of the genus *Rangifer*, and the relationships of these studies to general range management in the north. It is intended primarily as a guide and framework for the reading of the individual items in Section II. ... In Section II the individual papers which have been abstracted, summarized, reviewed or otherwise treated are listed in alphabetical order (by author). The third section is composed of tables, lists, and other "compiled" and tabulated data selected from the works in Section II; these are grouped according to subject for easy comparison. ...

Effects of Fires, Other Animals (Including Man) Climate, and Other Factors on the Range: Due to the catholic tastes of the genus *Rangifer* in regard to non-lichen forage -- Igoshina (1937) mentions 130 species as being a part of the diet in summer, 30 to 40 in winter -- and to the fact

that the value of lichens has not been properly defined, there appears to be little profit in making definite statements concerning the effects of fires, man, climate, or other factors on the grazing capacity of northern ranges. The following generalities however, have been repeated by one or more authors with varying amounts of substantiation and are worth noting:

1. The fact that lichens are sensitive to smoke and air pollution and for this reason disappear from the vicinity of large cities is mentioned even in encyclopedias. ...

2. Fire is much more destructive to the lichen cover of an area than grazing. Repeated burning, according to Lutz (1956), may result in permanent or nearly permanent replacement of lichens by grasses, sedges, and other plants. The effects of fires have also been mentioned by Palmer (1941), Edwards (1952) and Avramchik (1939). The latter's writings indicate the possibility of a difference in palatability of "after-grass" grown after burning and that resulting from clipping or grazing. The indication is expressed in rather vague terms, however, and may stem from translation difficulties.

In addition to changing the plant composition of an area, fires may break up a range into units of "good" range separated by areas which caribou avoid: Lutz (1956) states that caribou avoid burned areas. Thus a range as a whole could become "undesirable" even though it contains a large proportion of palatable and nutritious plants.

It is always possible that some fire may be beneficial to the range. Certainly there does not appear to be enough evidence to warrant the common assertion that fire is always detrimental to caribou range. Occasional small local fires may assist in returning a few nutrients to the soil or may otherwise benefit production. Most forest fires, however, are neither small nor local, and it is difficult to see where the usual uncontrolled fire can be anything but harmful to the range.

3. Caribou were once much more extensively distributed in North America than they are at present. It appears to be tacitly assumed, though often unwritten, that retreat of the animals to their present range has been caused by disappearance of the lichen cover. A number of reasons have been given for the retreat of lichens northward, and all of them probably contain some degree of truth. Fires, logging, air pollution and other factors could all have had a part in reducing the extent and continuity of lichen cover.

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Edwards, R.Y. 1952. Fire and the decline of a mountain caribou herd. J. Wildl. Manage. 18(4):243-251.

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Palmer, L.J. 1941. 1941. Progress report, caribou versus fire in interior Alaska (A study of burned-over lichen ranges). 37 pp. U.S. Dept. Int., Fish and Wildl. Serv.

Keywords: air pollution/ bibliography/ caribou/ lichens/ rangeland / *Rangifer*.

25. Cumming, H. G. 1992. Woodland caribou: Facts for forest managers. The Forestry Chronicle. 68(4):481-491.

Note: Abstract and section on fire reproduced below.

Abstract: A literature review points to predation as the proximate factor controlling woodland caribou (*Rangifer tarandus caribou*) populations in most cases, but that finding does not obviate the need for caribou to be included in forest management. Managers must consider the indirect effects of forest operations on caribou through their impacts on caribou mortality factors, such as predation. Lichens remain important. Habitat destruction may in some cases be the ultimate cause of population decline. Reactions of caribou to disturbance vary, and remain controversial: more research is needed. Multiple resource managers of boreal commercial forests should identify sensitive components of caribou range- calving grounds, rutting locations, wintering areas, and travel routes among them- and prescribe for these areas in forest management plans. Ways of accommodating caribou in commercial forests are not well established, but some examples suggest how this might be done. Most importantly, areas that have been proven by their continued use to contain all necessary requirements for caribou survival should not be physically altered until their essential qualities and functions are better understood.

Fire

Fires impinge on woodland caribou primarily through their effects on lichen supplies. The immediate consequence of fire is to destroy lichens and because of this, many biologists consider fire to have strictly negative effects on caribou habitat (Edwards 1954, Cringan 1957, Scotter 1972, Seip 1990). Other biologists point to the fact that large stands of ground lichens often originate after fires and conclude that fires are good for caribou range (Euler *et al.* 1976, Miller 1979). Klein (1982) pointed out the importance of differentiating between short-term and long-term effects. A consensus may be emerging that fires reduce the taiga's potential to support caribou for up to 50 years, but over periods of a century or more, they are essential for maintaining ecological diversity and forage production for caribou (Klein 1982). This idea was supported by Schaefer and Pruitt (1991) who found that local caribou numbers in Manitoba decreased to half previous levels (36 to 18) following a fire, but suggested that long term benefits might accrue, depending on local fire history. The boreal ecosystem is a complex system. Even if direct effects of fire become well understood, indirect effects also have to be considered. Fires set back succession, favouring deer and moose. Normally, forest managers would consider this change to be beneficial but the change to early forest successional stages may increase the number of deer or moose and so increase the probability of caribou picking up brain worms, or being eaten by wolves. The consequence of these possibilities are detailed later.

Literature cited:

Edwards, R.Y. 1954. Fire and the decline of a mountain caribou herd. J. Wildl. Manage. 18:512-526.

Cringan, A.T. 1957. History, food habitats, and range requirements of the woodland caribou of continental North America. Trans. North Am. Wildl. Conf. 22:485-501.

Euler, D.L., B. Snyder, and H.R. Timmerman. 1976. Woodland caribou and plant communities on the Slate Islands. Lake Superior Can. Field-Nat. 90:17-21.

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Miller, D.R. 1979. Wildfire effects of barren-ground caribou wintering on the taiga of northcentral Canada: a reassessment. Pages 84-98 *in* Proc. Sec. Intern. Reindeer/caribou Symp. Roros, Norway. Direktorated for vilt og ferkvannsfisk. Trondheim.

Schaefer, J.A. and W.O. Pruitt, Jr. 1991. Fire and woodland caribou in southeastern Manitoba. Wildl. Monogr. 116: 39 pp.

Scotter, G.W. 1972. Fire as an ecological factor in boreal forest ecosystems in Canada. Pages 15-

24 *in* Proc. Conf. Fire in the Environment. Denver, Colo. U.S. Forest Ser. FS-276.

Seip, D.R. 1990. Ecology of woodland caribou in Wells Gray Provincial Park. British Columbia Min. Environ Report. 43 pp.

Keywords: boreal forest/ caribou/ forest fires/ forest management/ predation/ *Rangifer*.

26. Davis, James L.; Shideler, R., and LeResche, R. E. 1978. Fortymile caribou herd studies. Federal Aid in Wildlife Restoration. Projects W-17-6 and W-17-7. Jobs 3.13R, 3.15R, and 3.16R. Final Report - Alaska Federal Aid in Wildlife Restoration. Alaska Department of Fish and Game, Juneau, Alaska.

Note: Final report consists of 3 separate reports: Size, composition, and productivity of the Fortymile Caribou Herd; Movements and distribution of the Fortymile Caribou Herd; and Range Reconnaissance- Fortymile Caribou Herd. Although the final report was printed in June 1998, individual reports covered the time period 1973-1975. Summary of the third report (Range Reconnaissance- Fortymile Caribou Herd) is reproduced below.

Abstract: The generalization that fire has been the cause of widespread North American caribou declines in the late 1800s and early 1900s is not tenable. Evidence from Alaska and Canada suggests that fire has never been the major limiting factor to most caribou populations. The role of fire in caribou declines can only be evaluated on a case-by-case basis. Destruction of lichens has been hypothesized as the primary detrimental effect of fires. However, several studies have shown that caribou and reindeer are not dependent on lichens. Furthermore, there is evidence that lichen forage can in fact increase following fire, and that forage species from seral stages which are dependent on fire are heavily utilized by caribou. Indirect effects of fire on caribou, such as adverse snow accumulation, increase in predator numbers, and exposure to disease transmitted by animals dependent on seral stages, may be as important in explaining population declines as the hypothesized destruction of lichens.

Extermination of caribou from the Kenai Peninsula is the most frequently cited Alaskan situation in which fire has been assumed to be the cause. This speculation is too simplistic - it is probable that other factors such as overhunting and adverse weather were possible primary causes.

Although fires may have reduced the winter carrying capacity of the Fortymile herd's range during this century, the number of animals present at any time has been well below the calculated carrying capacity. The most conservative estimate of carrying capacity was 70,000-90,000 in 1956, when the population was only 50,000 animals. The present carrying capacity is conservatively estimated at 61,000 animals, while the population is 4,000-6,000. Furthermore, at no time since 1956 has the population level even approached the carrying capacity estimates.

Keywords: Alaska/ Canada/ caribou/ fire / Fortymile Herd/ lichens/ winter range/ Rangifer.

27. Davis, James L.; Valkenburg, Patrick, and Boertje, Rodney 1982. Home range use, social structure, and habitat selection of the Western Arctic Caribou Herd. Final Research Report. Contract No.: CX 9100-8-0032 . Alaska Department of Fish and Game, Fairbanks, Alaska. 36 pp.

Note: Prepared for the U.S. National Park Service.

Abstract: During 1978-81, 38 male and 55 female caribou (*Rangifer tarandus*) were successfully radio-collared in the range of the Western Arctic Caribou Herd (WAH) and monitored on a year-round basis for 322 and 736 collar-months, respectively. Males were relocated 83 times and females 279 times. Collared males died or shed collars more frequently than females. As of 31 December 1981, radio collars were functioning on a maximum of 19 males and 53 females.

By relocating collared caribou for 2 or more years, we found that the only movement patterns of collared individuals included the following: (1) females returned each May to the traditional WAH calving area on the North Slope; (2) both sexes used the foothills near the calving grounds in May and June; and (3) both sexes returned to the arctic coastal plain in summer. Use of a particular winter range during successive winters by an individual was not predictable. In addition, the number of caribou using a particular winter range varied greatly between years, although the most important wintering areas consistently included the Selawik and Buckland River drainages, the arctic coastal plain, and the central Brooks Range.

Findings from this study and concurrent complementary studies have helped identify discrete caribou herds within the greater range of the WAH. The Teshekpuk Herd and Central Arctic Herd clearly exist as discrete entities which reside year-round on the North Slope in the northeast corner of the WAH's range. Seven of 15 females and all males collared in the Price and Oumalik River drainages in April 1981 remained in this vicinity through summer 1981. This may indicate a widely scattered distribution of the Teshekpuk Herd among other possibilities. The Ray Mountains Herd exists in the southeastern portion of the WAH's range, and the Andreafsky Herd is distributed near the southwestern extent of the WAH's range. However, within northwestern Alaska, no discrete herd inhabits NPS lands year-round. This implies that the caribou which seasonally use NPS lands in northwestern Alaska can be maintained only through cooperation between private landowners, the State of Alaska, and various Federal agencies.

Because of the current and historic seasonal distribution patterns of the region's caribou, policies for managing NPS lands in northwestern Alaska will generally have substantial effect on important direct mortality factors to caribou. These policies will affect the caribou population by controlling hunting, both for subsistence and sport, and predation through protective regulations for major predator species. NPS policies will have less impact on welfare factors such as habitat because critical seasonal habitats extend well beyond or occur totally outside of NPS lands.

We investigated the existence of strong social bonds between individuals by radio-collaring 2 to 4 caribou in each of 17 groups (38 individuals). Although 125 resightings were made of these 38 individuals, we did not document any persistent, nonrandom associations between individuals. Our present data and observations support the hypothesis that the basic units of caribou social structure are either "temporary, tenuous associations of individuals " (Lent 1965) or "open, social units" (Bergerud 1974).

The most unexpected aspect of habitat selection by the WAH, and the one possibly having greatest habitat management implications, was that spruce (*Picea* spp.) forest habitat was rarely used even in winter. Instead, open tundra plateaus, tussock communities, and windblown ridgetops were favored. Food habits of caribou wintering on the arctic coastal plain apparently differed substantially from those of caribou wintering in the Selawik Hills and south of the Brooks Range. For instance, caribou feces collected on the arctic coastal plain in late winter contained about 40-50 percent less lichen fragments and 4 times more shrub fragments (primarily *Vaccinium*) than similar samples collected south of the Brooks Range.

Review and assessment of effects of fire on the WAH suggest to us that wildfires had little or no effect on the WAH's decline between 1970 and 1976. The WAH apparently uses tundra wintering habitats more than tree-dominated winter habitats. Consequently, emphasizing research on tundra fire ecology rather than taiga fire ecology should be more relevant to managing the WAH.

Literature Cited:

Bergerud, A.T. 1974. Decline of caribou in North America following settlement. Journal of Wildlife Management. 38(4):757-770.

Lent, P.J. 1965. ???

Keywords: Alaska/ caribou/ caribou distribution/ fire/ habitat use/ Western Arctic Herd / Rangifer.

28. Davis, James L.; Valkenburg, Patrick; Pitcher, Kenneth W., and Larson, Douglas N. 1990. A conceptual basis for caribou management in Alaska. Alaska Department of Fish and Game, Fairbanks, Alaska. 6 pp.

    Note: 1990 Alaska Department of Fish and Game caribou workshop committee report. Brief section on forest fires reproduced below.

    Abstract: *Forest fires:* Northern boreal forests are important caribou winter ranges and wildfire is as important to these forests as rain is to rain forests. Natural wildfire maintains a mosaic of different aged forest and removes thick unproductive, insulating mats of old lichen and moss. However, excessive burning as a result of man-caused fires could result in a long-term reduction of winter range. At present, however, we believe that the primary problem with fire is that too many small natural ignitions have been or are extinguished initially.

    Keywords: Alaska/ boreal forest/ caribou/ forest fires/ Rangifer.

29. Edwards, R. Y. 1954. Fire and the decline of a mountain caribou herd. Journal of Wildlife Management. 18(4):521-526.

    Note: Author's summary reproduced here. Article contains descriptions of pre- and post-fire vegetation that are not discussed in the summary.

    Abstract: *Summary:* A mountain caribou herd in Wells Gray Park, British Columbia, is one of many in the province that has decreased in size since the turn of the century. Fire appears to be the cause of decline of the Wells Gray herd. Since 1926 about 70 per cent of the forests below 4,000 feet have been burned, and caribou, which appear to require mature lowland forests for winter range, are now confined in winter to the unburned forest remnants.

    The fires were followed by a dramatic change in composition and population density of the mammalian community. The caribou decline was accompanied by declines in a few other species, while the overall effect of fires was to create a mammalian abundance previously unknown.

    To maintain and eventually to increase this herd, management will include protection of the animals, protection of existing lowland forests from fire, and a long-term endeavour to increase the area of lowland climax or near-climax forests.

    Keywords: Canada/ caribou/ fire/ population decline/ *Rangifer*.

30. Eriksson, Olof 1975. Sylvicultural practices and reindeer grazing in northern Sweden. Pages 108-121 *in* Luick, Jack R.; Lent, Peter C.; Klein, David R., and White, Robert G., eds. Proceedings of the first international reindeer and caribou symposium. Fairbanks, Alaska, 9 Aug 1972-11 Aug 1972. Biological Papers of the University of Alaska. Special Report Number 1. University of Alaska-Fairbanks. Fairbanks, Alaska, 551 pp.

    Note: Abstract and section on controlled burning reproduced here.

    Abstract: The most obvious immediate effect of large scale logging is the large quantity of slash that produces physical obstruction to winter grazing. Bioclimate, plant cover and availability of forage plants during winter are altered radically after clear cutting large areas. Beneficial effects of logging are an enlarged supply of epiphytic lichens immediately after the felling, and

sometimes an increased growth of higher plants during following years. Reforestation methods also have an impact on the reindeer grazing resource. Controlled burning of clear cut areas, that destroys lichen stands for decades but that for some years may stimulate a rich growth of certain higher plants, is now almost abandoned. Mechanical preparation of the seed bed may destroy forage plants and reindeer herds also are reluctant to move across treated areas. Today, the use of herbicides to control deciduous growth in planted areas is restricted, since aerial application is prohibited. Aerial fertilization is practiced widely in Sweden. Little is known about the effect on plants used by reindeer. However, this method is used only on rich lands to make fast growing trees grow still faster the last few years before harvest. These rich lands are normally not of great importance to the reindeer industry. Although little research concerning interactions between logging and reindeer husbandry has been carried out so far, it seems reasonable to suspect that the reindeer husbandry will suffer if the existing sylvicultural practices are not changed to some extent.

Controlled Burning
Usually one has to promote reforestation actively if one wants to get a new productive forest in a logged over area within reasonable time.

The oldest method is controlled burning, a method that is now more or less abandoned since on one hand it is fairly expensive and on the other hand it gives uncertain results. During 1970 only 736 ha were burned over in Lappmark (Skogsstatistisk arsbok, 1970).

According to Domanverket (1972) burning is a biologically useful method in northern Sweden on moist ground with a thick layer of raw humus; that is, on ground that is not of prime importance as winter pasture.

Uggla (1958) has studied the effect of wildfires in lichen-rich pine (*Pinus silvestris*) forests in Muddus National Park, county of Norrbotten. He has reported a regeneration period of more than 40 years for reindeer lichens (*Cladonia* spp.). Holmback and Malmstrom (1947) have burned some study plots when making experiments in order to improve seed beds in lichen-rich pine forests in North Sweden. After 10-12 years only a few lichen thalli were to be seen. Fairly soon after a burning there is, however, an increased growth of certain higher plants that are eaten by reindeer. Among these are, for example, *Deschampsia flexuosa*. These plants, however, have their annual period of optimum production when there are plenty of other plants available for reindeer to eat and when the larger part of the reindeer population does not use this range.

Literature cited
Domanverket. 1972. Skogsvardshandbok, Stockholm.

Holmback, B. and C. Malmstrom. 1947. Nagra markforbattringsforsok pa nordsvenska tallhedar. Meddelanden fran Statens skogsforskningsinstitut Band, 36 nr. 6., 82 pp.

Uggla, E. 1958. Skogsbrandfalt i Muddus nationalpark. Acta Phytogeographica Suecica nr 41 Uppsala.

Keywords: fire/ forestry/ lichens/ pine forest/ prescribed fires/ reindeer/ Sweden.

31. Esseen, Per-Anders. 1983. Ecology of lichens in boreal coniferous forests with reference to spatial and temporal patterns. University of Umea. c1983. various pagings.

Note: Ph.D. thesis. Citation from BOREAL bibliographic database.

Abstract: Doctoral thesis dealing with the ecology of epiphytic lichens in old *Picea abies* forest of the fire-refugia type and epigeic as well as epixylic lichens in a successional sequence of fire-susceptible *Pinus sylvestris* forests in Medelpad and Vsterbotten in central and northern Sweden.

Keywords: lichens/ Sweden/ taiga.

32. Evans, H. Frank. 1964. An investigation of woodland caribou in northwestern United States. Trans. N. Amer. Wildl. Nat. Resour. Conf. 29:445-453.

Abstract: The future of caribou presents several enigmas. If serious fires are averted, if future intensive forestry practices do not too dramatically alter optimum lichen growing conditions and if illegal hunting does not lead to its extinction in the region, are caribou likely to survive in any numbers? The answer to the question poses another--will the seral forests following logging and fire mature enough to support sufficient lichen pastures to sustain the species before these forests are likewise assigned to logging! Future logging practices will probably demand less timber size. Only time, caribou population behavior and lichen ecology studies may reveal the answers. This creature which is associated with climax or relatively mature forests would appear to be doomed since man does not maintain climaxes but destroys them. However caribou possess one remarkable characteristic that assists them in their seemingly tenuous existence. Their extremely restless, roaming behavior (Murie, 1935) seems to persistently probe enormous geographic areas and this brings the species in contact with such habitat that has matured sufficiently to support them. If such supporting habitat which has been destroyed early in the century is regenerated before the species is reduced too severely in numbers, caribou may find it and yet survive in the forests of northwestern United States. Physical barriers within the study area were considered almost nonexistent since it was established that caribou appear to travel high ridges in the summer season. Therefore these ridges provide excellent avenues of travel by means of which the animals may traverse large segments of unsuitable habitat and find islands of aging forest where winter lichen pastures will feed them until summer makes grasses and forbs again available in the highlands. Fortunately, man is not often found in the summering areas above timber and does rather little hunting in dense forest, so caribou habits may permit some respite from human contact. On the other hand, the restless, extensive wandering increases the likelihood of contact with humans. The roam range concept permits an understanding of several phenomena associated with caribou. First, it permits an explanation of the variation of year to year distribution and seeming fluctuation in populations that might be observed. Second, it adequately explains the reoccurrence of caribou in areas widely separated in time and space from previous reports of the animals as well as accounting for their appearance where they have not been previously reported. Third, it permits an explanation of how the Kaniksu Forest herd may have remained relatively stable when there was no evidence of predation or disease but presumed normal reproductory behavior. If small bands wander from the area it subtracts any increment of increase and accounts for reappearance elsewhere. Fourth, it would tend to prevent a boom and bust of populations which would deplete their range. It was the reoccurrence of caribou in the sixth decade in the three widely separated areas that was the most encouraging aspect of this study and the one which permits some hope for this rare species in northwestern United States. The prediction is made that caribou will continue to wander widely in their small bands of a few to a dozen or more animals and will occasionally be reported. If the west side forests of Glacier National Park reach sufficient maturity and are not reburned, a stable population of caribou may become established there. It is further predicted that man will continue to erode caribou numbers as the wandering animals intersect human activities. This study revealed thirteen illegal caribou kills in a nineteen year period (Evans, 1906) and the probability of discovering illegal kills will be conceded as being very small indeed. Since ever-increasing human populations rely ever more heavily on diminishing old-age timber stands in the economy of the region, it does not appear feasible that any assistance can be given to the management of caribou habitat to assure higher population level. The wandering nature of the animal has been of a high survival value to the species because of slow lichen growth. This characteristic now enhances its chance for survival since forest succession is an even more time-consuming process.

Literature cited:

Murie, O.J. 1935. Alaska-Yukon caribou. U.S. Bur. Biol. Survey, N. Am. Fauna, 54:1-93.

Keywords: caribou/ caribou distribution/ fire/ hunting/ logging/ *Rangifer*/ Rocky Mountains.

33. Ferguson, Robert S. 1983. Fire history of the Beverly caribou winter range, NWT, 1966-1982. File report. No. 34. Northwest Territories Wildlife Service, Yellowknife, NWT. 15 pp.

Abstract: Fire history of the Caribou Range Subdistrict south of the treeline (116,778 square km) was investigated by analyzing the fire statistics compiled by the Forest Service, Northern Affairs Program, Department of Indian Affairs and Northern Development. The Forest Service has been monitoring and mapping fires by aerial reconnaissance in the Caribou Range Subdistrict since 1966. From 1966 to 1982, 533 fires burned approximately 1.9 million hectares or 16.26 percent of the Caribou Range Subdistrict. The annual burn rate ranged from <0.01 to 6.43 percent, and averaged 0.96 percent for the 17 year period. Forty (40) percent of the total burned area was attributed to the 1979 fire season. The majority of fires (72%) and most of the burned area (79%) occurred west of 108 degrees W longitude. This pattern is consistent with earlier studies of fire history and reflects regional differences in lightning incidence and length of fire season. The annual burn rates reported for the Caribou Range Subdistrict should be regarded as preliminary estimates because of the limitations of monitoring and mapping fires by aerial reconnaissance.

Keywords: caribou/ caribou distribution/ forest fires/ fire history/ Beverly Herd/ Rangifer.

34. Filion, L. and Payette, Serge. 1989. Subarctic lichen polygons and soil development along a colonization gradient on eolian sands. Arctic and Alpine Research. 21(2):175-184.

Abstract: The postfire recovery sequence during the last 150-200 yr, lichen-ground colonization pattern, and soil development in a parabolic-dune system along the east coast of Hudson Bay, northern Quebec, were documented using fifteen contiguous vegetation belts. Differential plant colonization takes place during succession because of a sustained exposure gradient associated with site position in the dune environment. Along the colonization gradient, seven developmental stages were identified, showing distinct vegetation and soil types and particular lichen-ground polygonal patterns. Soil development proceeded successively from bare sands, regosol, and shallow eluviated dystric brunisol. Bare sands are first colonized by *Polytrichum piliferum* and subsequently by *Stereocaulon paschale* and *Rhacomitrium canescens*. At stage 2, *Rhacomitrium* forms an extensive cover, while *Stereocaulon* takes over at stage 3 with a significant increase of invading species. The formation of thin desiccation cracks and inception of lichen polygons, resulting in the dominance of *Cladina mitis* at stage 4. The progressive dominance of *Cladina alpestris* and podzolic soil development toward a late lichen-spruce woodland (stages 5 to 7) are characterized by a sharp decline in species diversity and the appearance of mostly ephemeral lichen polygons. It is concluded that the two lichen-polygon types are associated with vegetation and soil development during plant stabilization of eolian sands: the *C. mitis* type and the *C. alpestris* type, respectively, formed during transient successional stages and late lichen-woodland stages.

Keywords: Canada/ dunes/ fire/ lichen regeneration/ lichens/ mosses/ post-fire succession/ soil development/ soils.

35. Fire Subcommittee of the Alaska Land Managers Cooperative Task Force 1979. The Fortymile interim fire management plan.

Note: Fire management plan for the Fortymile River region in eastern Alaska. Section pertaining to caribou reproduced below.

Abstract: *Caribou:* Portions of at least five and perhaps six caribou herds inhabit this area at

various times of the year. The major herd encompassed by this plan is the once-numerous Fortymile herd. While historic reasons for the initial decline of this herd are not well known, loss of winter range due to fire has been largely discounted as a prime causative factor after investigation by the Alaska Department of Fish and Game. The present population of 3,500 - 5,000 caribou is well below the estimated carrying capacity of 50,000. Human harvest averages fewer than 50 animals annually. There is some viewing use of the herd when it crosses the Taylor Highway in October. The main herd winters east of the highway between Eagle and the Ladue River.

Based on recent studies, it appears that caribou may not be adversely affected by fire to the degree once believed. Because under the Interim Fire Management Plan the prescription for late-season fires is conservative, the probability of large conflagrations is greatly reduced. While a large percentage of the winter range of the Fortymile caribou herd lies within this area and received the lowest suppression priority, caribou numbers are presently well below carrying capacity.

Keywords: Alaska/ caribou/ fire/ fire management/ forest fires/ Fortymile Herd/ interior Alaska/ population decline/ wildlife/ winter range/ Rangifer.

36. Foote, M. Joan 1983. Classification, description, and dynamics of plant communities after fire in the taiga of interior Alaska. Research Paper. PNW-307. USDA Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. 108 pp.

Note: Abstract and select sections about lichens reproduced below.

Abstract: One hundred thirty forest stands ranging in age from 1 month postfire to 200 years were sampled and described by successional series (white spruce and black spruce) and by developmental stage (newly burned, moss-herb, tall shrub-sapling, dense tree, hardwood, and spruce). Patterns of change in the two successional series are described. In addition, 12 mature forest communities are described in quantitative and qualitative terms.

White spruce sites: Mosses, when present, grow on the basal trunks and exposed roots of quaking aspen or occasionally in small patches on the forest floor. Lichens, primarily *Cladonia* spp., occur but never in large amounts.

Patterns of change on white spruce sites: Ground lichens are always present in small quantities. *Peltigera* spp. appear to peak in the tall shrub stage, and *Cladonia* spp. peak in the dense tree stage. ... Lastly, the number of species present in a given area increases continuously well into the tall shrub-sapling stage and then remains almost constant. Most species are present throughout succession but in varying amounts. Other species occur in some stages but not all. *Ceratodon purpureus*, *Marchantia polymorpha*, fireweed, willows, hardwoods, and *Cladonia* spp. are examples of the latter group.

Black spruce sites: The vegetation is dominated by trees, but low shrubs, mosses, and sometimes lichens are also prominent. Black spruce, quaking aspen, paper birch, Alaska larch, mountain-cranberry, bog blueberry, the mosses *Pleurozium schreberi* and *Sphagnum* spp., and lichens *Cladina* spp. and *Cladonia* spp. grow prominently on black spruce sites.

Patterns of change on mesic black spruce sites: Ground lichens all follow one pattern. They appear slowly and increase gradually to cover the greatest area during the dense tree stage, after which they slowly decline. *Peltigera* spp. are the first to appear, and they usually occur in the greatest amounts. *Cladina* spp. and *Cladonia* spp. account for most of the remaining lichen cover. On mesic sites in this study, only small quantities of lichens were found in stands representing the spruce stage of development.

Comparisons of patterns of change: Other species in both series develop their greatest numbers

and/or cover in the intermediate stages and decline or disappear thereafter. Bebb, grayleaf, and Scouler willows as well as *Peltigera* spp. are important in the tall shrub stage. *Cladonia* spp. and *Cladina* spp. are important in the dense tree stage. And quaking aspen and paper birch may be important in the dense tree and hardwood stages. The lichen species are more extensive on black spruce sites and the hardwood species on white spruce sites.

Keywords: Alaska/ fire/ fire ecology/ forest fires/ forest types/ interior Alaska/ *Picea*/ plant associations/ post-fire succession/ taiga.

37. Foster, David R. 1984. The dynamics of *Sphagnum* in forest and peatland communities in southeastern Labrador, Canada. Arctic. 37(2):133-140.

Abstract: Long fire rotation, high levels of precipitation, and acidic nature of the bedrock are factors contributing to the dominance of *Sphagnum* in many upland and peatland communities in southeastern Labrador. Vegetation development induced by local or regional environmental change frequently involves replacement of species assemblages of various bryophytes and lichens by species assemblages dominated by *Sphagnum.* In upland forests the successional sequence following fire often culminates in a carpet of *Sphagnum girgensohnii* overgrowing feather mosses. Similarly, following a change in the water table, *Sphagnum lindbergii* encroaches as a broad carpet over *Cladopodiella fluitans* and *Gymnocolea inflata* on recently exposed mud bottoms in bog hollows. On bog hummocks, following fire or changes in the moisture regime, *Sphagnum fuscum* overtops *Cladonia* lichens to form a pronounced recurrence horizon.

Keywords: Canada/ fire/ lichens/ mosses/ post-fire succession/ taiga.

38. Freddy, David J. and Erickson, Albert W. 1975. Status of the Selkirk Mountain caribou. Pages 221-227 *in* Luick, Jack R.; Lent, Peter C.; Klein, David R., and White, Robert G., eds. Proceedings of the first international reindeer and caribou symposium. Faribanks, AK, 9 Aug 1972-11 Aug 1972. Biological Papers of the University of Alaska. Special Report No. 1. University of Alaska-Fairbanks. Fairbanks, AK, 551 pp.

Note: Abstract and brief section about fire reproduced here.

Abstract: The Selkirk Mountain caribou (*Rangifer tarandus montanus*) are the only naturally remaining caribou in the contiguous United States, being found in the Selkirk Mountains of northern Idaho, northeastern Washington and southern British Columbia, Canada. Observations indicate there is a minimum of 35 caribou in the herd. These animals are divided into at least three small groups and occupy a somewhat discontinuous range. The animals wintered in the subalpine fir-Engelmann spruce forest in areas of moderate relief between the elevations of 1,380 m and 2,160 m. Arboreal lichens of the genus *Alectoria* comprised the main winter food. Ecological damage to already limited winter range could seriously jeopardize the size and distribution of this herd. Special land classification, logging restrictions, forest fire control and continued protected status for these animals are essential management considerations.

Fire:
Forest fire records dating to the late 1800's indicate much of the study area has been burned, especially at the lower elevations. In 24 instances during 1972, caribou were observed to visit burns that occurred at high altitudes. In 15 of these cases, tracks indicated the animals only traveled through the burned area. In nine cases some feeding occurred; and in one instance, the animals fed in small pockets of trees missed by the fire.

Keywords: arboreal lichens/ caribou/ forest fires/ forestry/ *Rangifer*/ Selkirk Mountains.

39. Gingras, J. J. and Guimont, P. illustrator. 1983. S.O.S. caribous. North. 29(4):24-29.

Note: Citation from ASTIS bibliographic database; abstract attributed to author. English summary, but original article may be in French.

Abstract: ...the writer ... [examines] ... the complex question of the future of northern caribou herds [in Quebec and Labrador]. Whereas the species is virtually extinct in the south, except in places where the animals are protected such as in the Laurentians, in the North, herds are increasing in size. Extensive surveys and studies done over the last ten years by the Quebec Minstry of Recreation, Hunting and Fishing have enabled experts to compile a large amount of data on the numbers, habits, and habitats of the caribou. Statistics of herd sizes in past years show that populations of this animal fluctuate considerably, more than can be explained by over-hunting, land clearance, forest fires and so on. ...Natural mechanisms may eventually help to stabilize the situation but the author suggests various possibilities for controlling or harvesting this resource in a systematic way and thus reap benefits from control of the herds. This would require a considerable amount of negotiation between the various parties involved, whether native groups, environmentalists or governments. Modifications would also have to be made to some existing laws.

Keywords: Canada/ caribou/ population dynamics/ wildlife management/ Rangifer.

40. Gorshkov, V. V. 1995. Changes in the diversity of species of lichens in the post-fire process of revegetation in non-polluted pine forests on the Kola Peninsula. Rossiiskaia Akademiia Nauk. 341(1):118-121.

Note: In Russian. Citation from the Cold Regions - CRREL bibliographic database.

Abstract: Abstract not available.

Keywords: forest fires/ lichens/ pollution/ post-fire succession.

41. Gorshkov, V. V. and Gorshkov, V. G. 1992. Recovery characteristics for forest ecosystems after fires. Rossiiskaia Akademiia Nauk:40 pp.

Note: Citation from Cold Regions - CRREL bibliographic database. Russian summary, English article.

Abstract: Not Available.

Keywords: forest fires/ lichens/ mosses/ post-fire succession.

42. Grissom, Perry, Alexander, Martin E., Cella, Brad, et al. 2000. Effects of climate change on management and policy: mitigation options in the North American boreal forest. Kasischke, Eric S., and Stocks, Brian J. eds. in Fire, climate change, and carbon cycling in the boreal forest. Springer-Verlag, New York. pp. 85-101.

Abstract: Predicted increases in atmospheric carbon dioxide are expected to increase summer temperatures 4-6^{o} C. This summer should increase the fire incidence and also the number and extent of major fires. Fire plays an important role in controlling many ecosystem processes. These changes may effect ungulate living in the boreal forest.

43. Hanson, William A. *chk pp. 1979. Preliminary results of the Bear Creek fire effects studies. Open File Report. USDI Bureau of Land Management, Anchorage, Alaska. 55+ pp.

Abstract: During an extended drought in August and September 1977, Bear Creek Fire burned 140,000 hectares (345,000 acres) of land near Farewell, Alaska. Plant communities prior to the fire included extensive stands of black spruce and white spruce, ericaceous and dwarf birch shrublands, and sedge tussock communities.

On well drained sites, white spruce-hardwood forests burned with high severity and low intensity. All plants were killed and much more mineral soil was exposed. During the first growing season after the fire, pioneer communities on well drained sites consisted of six to eight species, including many white spruce (*Picea glauca*) seedlings, the liverwort *Marchatia polymorpha*, moss (*Polytrichum* spp. and *Ceratadon purpurea*), and fireweed (*Epilobium angustifolium*).

On poorly drained sites, black spruce and shrub-bog communities burned with variable severity and intensity. Very little mineral soil was exposed. Pioneer communities on these sites are largely the result of vegetative reproduction by rootstocks which survived in the thick organic mat. An average of 15 species were present during the first season of growth, including bog blueberry (*Vaccinium uliganosum*), lingonberry (*Vaccinium vitis-idaea*), black spruce (*Picea mariana*), cloudberry (*Rubus chamaemorus*), arctic dwarf birch (*Betula nana*), fireweed, and cottongrass (*Eriophorum* sp.).

Wildlife observations during winter indicate that moose and caribou used an adjacent 5-year-old burn more than adjacent unburned communities, and adjacent unburned communities more than the newly burned areas. Bison are using the 5-year-old burn and newly burned areas extensively.

The fire caused local erosion on glacial moraines. However, almost no erosion has occurred on 80 miles of reclaimed firelines. Two miles of unreclaimed fireline have filled with standing water about 1 meter deep but are not eroding.

Approximately 58 km (36 miles) of the Iditarod Trail, a National Historic Trail, were burned. Several historic roadhouses and three prehistoric sites were damaged by the fire. Several additional cabins and roadhouses escaped burning or were saved by fire crews.

Increased exposure to wind, blockage of the trail by fallen trees, and decreased visibility of the trail due to loss of the forest canopy, have hampered travel by dog sledders during the annual Iditarod Race.

Preliminary observations of the effects of fire and suppression activities on fish, timber, recreation, subsistence users, and socioeconomics of the area are discussed briefly. Studies should be initiated to examine more closely, and from a multifaceted viewpoint, the effects of the fire on local users of the area.

Caribou excerpts: .... Caribou were occasionally seen on the burn in summer. They are reported to be part of the Mulchatna herd, which contains about 5,000 animals. Some of these animals may also be part of the Beaver herd or even the McKinley herd. ...Caribou were using three broad regions of the burn in winter. Most (27 out of 42 animals) were found along the southeastern edge near the moraines. They were feeding in birch and ericaceous shrub-sedge communities. Several smaller groups of caribou were feeding in sedge-grass meadows (old lakebeds) in the northeast portion of the burn. These animals were traveling from meadow to meadow, much like the bison. Along the northwest edge of Bear Creek Burn the only fresh caribou signs were observed on the burn, although older tracks were observed on meadows outside the burn. Along the southeastern edge, most animals were in Farewell Burn or unburned communities along the moraines. ...Although caribou would normally have been a concern, the herds in this area are far below the carrying capacity of their range.

Keywords: Alaska/ boreal forest/ caribou/ fire/ forest fires/ interior Alaska/ post-fire succession/ wildlife/ Rangifer.

44. Hinkes, Michael T. and Campbell, Bruce. 1981. Caribou winter utilization of burned habitats on the Bear Creek Burn study area in interior Alaska.

Note: Presented at the 1981 Alaska Science Conference, but available copy of report was an agency document and not included in an official proceedings; not known if conference proceedings were published. Claims to represent only a brief analysis and summary of caribou habitat studies at Bear Creek. Conclusion section presented here.

Abstract: Conclusions: Although some investigators have shown that caribou can thrive without lichens in their winter diet, and concluded that lichens are not essential to caribou survival, the fact remains that lichens can be a major component in the free-ranging caribou winter diet. The animals at Bear Creek make an effort to search out lichen species even on burned areas where lichens make up less than 3% of the vegetation cover.

Although fire can be detrimental to caribou range and possibly affect caribou abundance, each major herd and physiographic region must be addressed in terms of population numbers and range availability.

The Bear Creek and Farewell fires have probably had minimal impact on the Rainy Pass/Farewell herd. We base this conclusion on four major points. First, the herd is a relatively low density population in relation to its habitat; second, abundance of forage is available in adjacent unburned habitat; third, the burning characteristic on a major portion of the burn left small islands of undisturbed habitat available to caribou, and lastly, that although lichens are slow to regain former abundance, an adequate amount of forage has recovered on some sites within a few years following fire to allow continued use by caribou.

The habitat at Bear Creek is fairly representative of much of the Kuskokwim Basin, particularly along the western slopes of the Alaskan Range. This region is also occupied by the McKinley, Beaver, Sunshine/Cloudy Mountain, Granite Mountain, and Mulchatna herds. These are small populations, and would probably not be adversely affected by fire for the reasons I have summarized. The Kuskokwim Basin is an area where BLM proposes to improve and maintain moose winter range through prescription burning. Moose management objectives should not necessarily conflict with caribou populations in this area.

Keywords: Alaska/ caribou/ fire/ lichens/ *Rangifer*/ winter range.

45. Hinkes, Michael T. and Campbell, Bruce FIND LAST PAGES finish lit. cited 1984. Caribou winter use of unburned and recently burned habitat in interior Alaska BLM Technical Report. 12 pp.

Note: No abstract available; discussion presented here.

Abstract: Discussion: The importance of lichens as a winter food for caribou has been well documented (Banfield 1954; Kelsall 1960, 1968; Scotter 1967; Skoog 1957; Thompson *et al*. 1978; Thompson and McCourt 1981; Davis *et al*. 1982; Adams 1982). *Cladina, Cladonia*, and *Cetraria* lichens were found to be major dietary items (Miller 1976; Adams 1982; Davis *et al*. 1982) and have been considered to be of high value to caribou in the winter (Kelsall 1960, Scotter 1964).

The Farewell caribou herd exhibited a clear preference for lichens during the winters of 1980 and 1981. Lichens were the most utilized forage on all sites at Farewell, yet they were not the most common ground cover, especially on burned sites. This suggests that lichens are important winter

forage for the Farewell herd and are actively sought over other available food items.

The winter preference by caribou at Farewell for lichens of the *Cladina*/*Cladonia* group followed by *Cetraria* is similar to what others have found (Miller 1976; Adams 1982; Davis *et al*. 1982). Kelsall (1960) and Scotter (1964) considered *Cladina mitis*, *C. rangiferina*, *Cladonia amaurocraea*, *C. uncialis*, and *C. alpestris* high value species. Relatively large quantities of *Stereocaulon* were also consumed by caribou at Farewell. Klein (1972) suggested that nitrogen-fixing lichens of the genera *Stereocaulon* and *Peltigera* appear to "balance" the low protein content of *Cladonia* and *Cetraria*.

Shrubs have often been considered of limited importance in the winter diet of caribou (Cringan 1957, Scotter 1964, Skoog 1968, Pegau 1975). Skoog (1968) noted that although shrub species were widespread throughout caribou winter range, their dietary importance is likely minimal, except under special circumstances, due to reduced palatability. In contrast, shrubs are an important part of the winter diet of some caribou herds. Davis *et al*. (1982) reported the greatest utilization of shrubs by caribou, with 42% of the diet of caribou north of the Brooks Range comprised of shrubs. Murie (1935) found that willows were eaten extensively by the McKinley herd and Kelsall (1960) believed Labrador Tea was actively sought. While shrubs made up only 9.5-16% of the diet at Farewell, they were the second most important food item.

The reported importance of sedge, grass, and grass-like species to caribou varied. Extensive use of *Eriophorum* has been reported by several authors (Karev 1961; Skoog 1968; Davis et al. 1982; Adams 1982). Karev (1961) reports that green forage seems to be a necessary item in the winter diets of caribou. This forage is ???? LAST PAGES LOST!!!

Literature cited:
Adams, L.G. 1982.??

Banfield A.W.F. 1954. Preliminary investigation of the barren ground caribou. Canadian Wildl. Serv., Wildl. Mgmt. Bull., Ser. 1, Nos. 10A and 10B: 79 pp. and 112 pp.

Davis et al. 1982.??

Kelsall, J.P. 1960. Cooperative studies of barren-ground caribou, 1957-1958. Can. Wildl. Mgmt. Bull., Ser. 1, No. 15: 145 pp.

Kellsall, J.P. 1968. The barren-ground caribou of the Canadian mainland. Can. Wildl. Serv., Monograph Ser., No. 3. Ottawa.

Miller, D.R. 1976??? thesis or report?

Scotter, G.W. 1967. Effects of fire on barren-ground caribou and their forest habitat in northern Canada. Trans. N. Amer. Wildl. Nat. Resour. Conf. 32:246-259.

Skoog, R.O. 1957. ??

Thompson et al.??

Thompson and McCourt 1981??

Keywords: Alaska/ caribou/ caribou diet/ *Eriophorum*/ fire/ *Rangifer*/ winter range.

46. Hunter, Malcom L. 1993. Natural fire regimes as spatial models for managing boreal forests. Biological Conservation 65:115-120.

Note: Forest management recommendations have implications for caribou management

Abstract: Because organisms have adapted to the natural disturbance regimes of forest ecosystems such as fires and windfalls, conservationists often suggest that timber harvesting systems be designed to imitate natural disturbance regimes. Using the crown fires that shape true boreal forest ecosystems as spatial models for harvesting would require very large clearcuts; in two studies, mean fire size was 12,710 ha (in Labrador) and 7,764 (in Quebec). Most conservationists would be reluctant to advocate such large clearcuts and it is not easy to justify them from the perspectives of various ethical systems. A solution is proposed in which moderate sized clearcuts would be clustered into portions of land areas bounded by water-bodies. These water-bounded areas have an average size of 770 ha in Labrador and 322 ha in Quebec.

Keywords: Canada/ boreal forest/ forest fire/ clearcuts/ environmental ethics

47. Hustich, Ilmari. 1951. The lichen woodlands in Labrador and their importance as winter pastures for domesticated reindeer. Acta Geographica. 12(1):1-48.

Note: Citation and summary from Courtright, A.T. 1959. Range management and the genus *Ranigifer*: A review of selected literature. M.Sc. This, Univ. of Alaska, Fairbanks, AK. 172 pp.

Abstract: No abstract available. Major article sections are: The Labrador Forests; The Lichen Woodlands in Labrador; Lichen Woodlands in Other Parts of the World; On the Ecology of Lichen Woodlands; Regeneration of the Reindeer Lichen [incl. information about burned ranges]; Forest-Economic Importance of Lichen Woodlands; Capacity of the Labrador Lichen Woodland as Winter Pasture for Reindeer; Appendix [nutritional content of some lichens].

Portions of Courtright's summary pertaining to fire:

... *Cladina mitis* is the first lichen to invade a burned forest. It has a broader ecological amplitude than *Cl. alpestris*, while *Cl. rangiferina* has the widest amplitude of these three main species of reindeer lichens. ...

... Recovery of ground lichens after collection is said to take about 80 years, while recovery after grazing takes from 3 to 40 years. The large differences are caused by the varying opinions held as to when a lichen cover can be considered as "recovered." According to some Finnish Lapps a lichen-cover height of 2-5 cm. is enough to allow new grazing on a lichen field. The recovery of a lichen field is slower after a fire; various references give figures ranging from 30 to 50 years. The regrowth of a lichen field is dependent on the capacity of prolonged growth of the lichen podetions [*sic*, consistently]. Generally the lichen-cover is not completely destroyed after a fire: inside the lichen cover several podetions may preserve their growth capacity. The height reached by a reindeer lichen cover is primarily dependent on how little the habitat has been disturbed. The author has noted about 18 cm. as the maximum height. Others have reported 25 cm.; in such places the lichen cover must have been undisturbed by grazing or fires in at least 100 years. ...

Keywords: boreal forest/ Canada/ disturbance/ fire/ grazing/ lichen regeneration/ lichens/ nutrient content/ reindeer.

48. Ignatenko, I. V. and Pavlov, B. A. 1988. Natural regeneration of *Eriophorum* tussock tundra after a fire. Polar Geography and Geology. 12(3):169-180.

Note: Translated from Geografiya i Prirodnye Resursy, 1988, No. 2, pp. 99-108.

Abstract: The paper examines the impact of fire on area of *Eriophorum* tussock tundra in the Chaun lowland, north-western Chukotka. Studies of regeneration of vegetation and soils at the

same site were made at time intervals of 1,3, and 7 years after the fire. Aspects examined included species composition and biomass of the vegetation, temperature, water content, chemistry and nutrient content of the soils, and the depth to the permafrost table. It was concluded that the regenerated vegetation would appear substantially different (in terms of species composition) from the original communities, with an overwhelming predominance of *Eriophorum vaginatum*, very slow regeneration of shrubs and mosses, and a total disappearance of lichens. However, rates of biomass production would have returned to the original level within 20 years after a fire, although it might take 2-3 times longer for the destabilized soil parameters to return to normal.

Keywords: Chukotka/ *Eriophorum*/ fire/ lichens/ post-fire succession/ tundra fires.

49. Igoshina, K. N. 1939. The growth of forage lichens in the Ural north. Trans. Inst. of Pol. Agr., Ser. "The Reindeer Industry". M. Sc. Thesis(4):7-29.

Note: Citation and summary, based on an English summary of the paper, from Courtright, A.T. 1959. Range management and the genus *Ranigifer*: A review of selected literature. M.Sc. This, Univ. of Alaska, Fairbanks, AK. 172 pp. Only those sections pertaining to lichen succession and response to fire are reproduced here.

Abstract: (excerpts): Lichens destroyed by fire did not show any recovery after three to four years.

The author found that *Cladonia gracilis*, *Cl. cornuta*, *Cl. uncialis*, and *Cl. silvatica* predominated in young lichen cover of 15 years, while with increasing age and the accumulation of turf these species are replaced by the "more moisture-loving" plants *Cl. alpestris* and *Cl. rangiferina*.

The paper also includes sections on lichen growth after mechanical damage and renewal of lichen plants after fire.

Keywords: fire/ lichens/ lichen regeneration/ lichen succession.

50. Johnson, Edward A. 1981. Vegetation organization and dynamics of lichen woodland communities in the Northwest Territories, Canada. Ecology. 62(1):200-215.

Abstract: The variances of species abundances from 141 upland stands are partitioned into habitat and fire frequency. Principal components analysis is then performed on each of these partitions. The habitat ordination has a topographic-canopy coverage gradient and a nutrient gradient. The fire frequency ordination has one gradient which orders species according to their temporal response after fire, from shorter lived, faster growing, competitively poor species to longer lived, slower growing, competitively effective species. The fire frequency ordination interacts with the habitat ordination by changing a site's canopy cover for approximately 10 yr after fire. The nutrient gradient is only slightly affected by the fire frequency. The recovery of vegetation after fire is explained by using the information on the adaptation of species as shown in the two ordinations and from existing life-history information. Most species found in older stands are present in the first years after fire. Recovery by vascular plants, mosses and lichens is by vegetative reproduction and invasion by propagules. Buried viable seeds play little role in recovery. Lichen abundance is best explained by different habitat requirements rather than successional sequences or caribou grazing. Feather mosses are most abundant in specific sites which develop closed canopies and have greater soil nutrients. The habitat and fire frequency ordinations represent two environmental complexes for which species are adapted, and consequently these are also the two predominant levels of vegetation dynamics. The fire frequency ordination represents shorter term dynamics which cause changes primarily in abundance but not species composition. The habitat ordination represents longer term dynamics which cause major changes in species composition.

Keywords: Canada/ feather mosses/ fire/ fire frequency/ jack pine/ lichens/ ordination/ *Picea*/ post-fire succession/ subarctic.

51. Johnson, Edward A. and Rowe, John Stanley. 1975. Fire in the subarctic wintering ground of the Beverley caribou herd. American Midland Naturalist. 94(1):1-14.

    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°, 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.

    Keywords: Beverly Herd/ boreal forest/ Canada/ caribou/ fire ecology/ forest fires/ winter range/ Rangifer.

52. Joly, Kyle, Dale, Bruce W., Collins, William B., and Adams, Layne G. 2003. Winter habitat use by female caribou in relation to wildland fires in interior Alaska. Canadian Journal of Zoology 81:1192-1201.

    Note: Entire abstract presented below

    Abstract: The role of wildland fire in the winter habitat use of caribou (Rangifer tarandus) has long been debated. Fire has been viewed as detrimental to caribou because it destroys the slow-growing climax forage lichens that caribou utilize in winter. Other researchers argued that caribou were not reliant on lichens and that fire may be beneficial, even in the short-term. We evaluated the distribution of caribou relative to recent fires (< 50 years old) within the current winter range of the Nelchina Caribou Herd in east-central Alaska. To address issues concerning independence and spatial and temporal scales, we used both conventional very high frequency and Global Positioning System telemetry to estimate caribou use relative to recent, known-aged burns. In addition, we employed two methods to estimate availability of different habitat classes. Caribou used recently burned areas much less than expected regardless of methodologies employed. Moreover, within burns, caribou were more likely to utilize habitat within 500 m of the burn perimeter than core areas. Methods for determining use and availability did not have large influences on our measures of habitat selectivity.

    Keywords: Alaska/ habitat selection/ lichens/Nelchina Herd/ stand age

53. Joly, Kyle, Dale, Bruce W., Collins, William B., and Adams, Layne G. 2002. Evaluating the Impacts of Wildland Fires on Caribou in Interior Alaska. Arctic Research of the United States 16:63-67

    Note: Report presents the project's preliminary findings; caribou avoided areas burned within the last 50 years, forage lichens are largely absent from these stands, wildfires may affect caribou winter range for decades

    Keywords: Alaska/ habitat selection/ lichens/Nelchina Herd/ stand age

54. Kelsall, John P.; Telfer, E. S., and Wright, Thomas D. 1977. The effects of fire on the ecology of the boreal forest, with particular reference to the Canadian north: A review and selected bibliography.

Occasional Paper Number 32. Minister of Supply and Services, Ottawa, Canada. 58 pp.

Note: Overview of fire in the boreal forest; includes chapters on fire effects on wildlife, including caribou, and on vegetation. Also includes a bibliography.

Report sections are: Introduction; Sources of Information (Symposia, Bibliographies, Systematic reviews, Computerized searches); The Boreal Forest (Climate, Topography, Soils, Vegetation); Fire (History of fire, Causes of fire, Areas burned); Effects of Fire on Soil and Hydrology (Soil nutrients, Permafrost, Fire in rocky areas, Effects of fire on hydrology); Effects of Fire on Vegetation (Types of forest burned, Forest succession, The mosaic effect); Effects of Fire on Wildlife (Fish, Birds, Mammals); Summary and Discussion; Topics for Research; Appendix; Selected Bibliography.

Abstract: This review analyzes literature relevant to effects of fire on the boreal forest, and on its related wildlife resources, with particular reference to the Canadian North. The selected bibliography contains the more recent and historically important references and is not all-inclusive. Because of a paucity of material pertinent to the forests of the Northwest and the Yukon territories, it has been necessary to extrapolate information from other areas. Alaskan publications have been particularly useful.

It was concluded that fire is the most important factor influencing the ecology of the northern boreal forest; that fire and the resulting forest mosaic are natural features of long standing; and that the boreal forest can be characterized as a fire-dependent ecosystem. Trees, other plants, birds, mammals, and other animals of the forest have evolved in response and adaptation to the frequency, extent, and intensity of fire. With some possible exceptions, a mosaic of varied successional stages in the boreal forest provides a richer habitat for a more varied and abundant fauna than does the monotypic spruce forest characteristic of unburned areas. Specific attention is given to fish, birds, and mammals - particularly to important species of game and furbearers - and to such characteristics of the northern forests as the presence of permafrost, the soils, and the characteristics of unique vegetation. The basic characteristics of different types of fires are also described.

Keywords: boreal forest/ Canada/ caribou/ fire mosaic/ forest fires/ soils/ Rangifer.

55. Kershaw, Kenneth Andrew. 1977. Studies on lichen-dominated systems. XX. An examination of some aspects of the northern boreal lichen woodlands in Canada. Canadian Journal of Botany. 55:393-410.

Abstract: The existence of two major types of lichen woodland in Canada, *Cladonia stellaris* woodland and *Stereocaulon paschale* woodland, is discussed in relation to their seral nature and their rarely developed theoretical climax type.

Our own observations, coupled with previous descriptions from a wider area, suggest that *Stereocaulon paschale* woodland replaces *Cladonia stellaris* woodland in a more or less continuous zone from just west of Churchill across to Great Slave Lake, immediately north and south of latitude 60° N. Both woodland types are often typical of sandy soils (pH 6 or less) and almost always represent the final recovery phase after fire. Rarely, the lichen surface is replaced by a continuous moss cover as the spruce canopy closes. The lichen surface is thus dependent on the lack of competition from higher plants, the absence of which is characteristic of the climate of this northern boreal region. *Cladonia stellaris* woodland also occurs on palsas and peat plateaux where, again, lack of higher plant competition and a suitable pH exist.

The recovery sequence after fire is a highly complex process and as yet only the following parameters have been categorized. In the early recovery phases, limited soil moisture and hence a reduced summer latent heat flux enhance the sensible heat flux. The surface conditions are

analogous to those of a hot desert with very high surface temperatures and extremely large diurnal temperature fluctuations. The physiology of these initial moss and lichen colonizers presumably enables them to tolerate these harsh conditions. The establishment of a few spruce seedlings and the subsequent development of open lichen woodland modulates the harsh summer temperature regime and allows the further development of a vegetated surface. After humus accumulation, which acts as an effective mulch, summer soil moisture is elevated, enhancing the latent heat flux and correspondingly reducing the sensible heat flux. This probably allows the full development of mature lichen woodland with its almost monospecific ground cover of either *Cladonia stellaris* or *Stereocaulon paschale*. Limited data suggest that the net photosynthetic responses of these two species is favoured by the relatively warm mesic conditions established by the open spruce canopy. Good accumulation of snow in the winter is probably also important for protection of the lichen surface from low temperatures. The open nature of mature lichen woodland is apparently maintained by an active inhibition of spruce seedling establishment by the lichen mat, although the mechanism is not entirely clear.

Keywords: Canada/ fire/ lichens/ lichen woodland/ post-fire succession.

56. Kershaw, Kenneth Andrew and Rouse, W. R. 1976. The impact of fire on forest and tundra ecosystems. Final report. ALUR 75-76-63. Minister of Indian and Northern Affairs, Ottawa. 54 pp.

Note: Major report sections are: Overall group objectives; Plant ecology; Microclimate; General conclusions and recommendations.

Conclusions and Recommendations section reproduced below.

Abstract: (General Conclusions and Recommendations)
The additional field work in the 1975 season firmly established the continued vegetation sequence tentatively outlined in the previous report of this program (Kershaw *et al.* 1975). Following the two phases of succession dominated initially, by the moss *Polytrichum piliferum* and then by the lichen *Cladonia stellaris*, the 75 year old burns are dominated by the lichen *Stereocaulon paschale*, constituting a phase which lasts up to 150 years when the lichen cover is replaced by a carpet of mosses and herbaceous plants typical of the final recovery phase. This *Stereocaulon* phase has quite typically an almost pure mat of *Stereocaulon paschale*; such *Stereocaulon* woodland does not appear to have been previously reported. It is very fire susceptible, burning at frequent intervals and probably only rarely does it mature to the final closed canopy spruce woodland. Thus the widespread occurrence of *Sterocaulon* woodland in this region, S.E. of Great Slave Lake, owes its existence to fire. In the absence of forest fires, it would develop into spruce-moss woodland.

Concurrently with the development of the *Stereocaulon* woodland there is a continued increase in tree density, tree size and peat depth. This leads to the final spruce-moss woodland which characteristically is a closed canopy woodland with large overmature (35 m) trees, an abundance of fallen timber following death of the older trees, and a thick layer of peat.

It is significant that caribou grazing is restricted to the *Stereocaulon* phase, with fire essential to the maintenance of such prime grazing habitat in this area. The wide variance between our results and previous studies of post fire recovery sequences in other parts of Canada, demonstrates the considerable element of geographical uniqueness inherent in all post-fire recoveries and it is clear that generalizations from the N.W.T. situation are not valid.

Burning of the lichen woodland leads to long term microclimatic changes which are of considerable magnitude for periods in excess of a half century in this environment. Net radiation is reduced by 20 percent immediately after burning and this decrease remains at least 10 percent after 50 years. The magnitude of evaporation is reduced by 30 percent, one year after burning, and by about 20 percent after 50 years of the post-fire recovery sequence. The increase in soil

temperatures, both surface and subsurface, is in the order of 70 percent immediately following the fire and temperatures are still about 30 percent higher a half century later. Thus burning is accompanied by a hotter soil and a hotter, drier atmosphere for a period exceeding 50 years and if large areas are burned this will exert a strong desiccating influence on nonburned areas downwind which will amongst other things greatly increase evaporation from ponds and small lakes and could lead to a drying up of the shallower ones.

The following recommendations are proposed:
1) The only obvious natural resource of the area appears to be caribou which are dependent on the excellent winter grazing of this area. Accordingly it is recommended that the forage utilization, the growth of *Stereocaulon* mat and the environmental control of this growth should be examined in relation to the management of this area.

2) The degree of uniqueness of fire recovery sequences necessitates similar survey studies to be made in other areas to enable an overall sensible fire policy to be established. Thus, if similar findings were available for Spruce-*Cladonia* woodland, a level of generality would be established, essential to the development of an overall policy.

3) If controlled burning is planned, fires of limited areal extent are preferable and burning in the early summer is recommended.

4) It is questionable if large-scale wildfires should be left uncontrolled to burn themselves out since they affect not only the immediate environment but will lead to an increased desiccation of areas downwind.

Literature Cited:
Kershaw, K.A., W.R. Rouse, and B.T. Bunting. (1975). The impact of fire on forest and tundra ecosystems. INA Pub. No. QS-8038-000-EE-A1.

Keywords: Canada/ caribou/ fire ecology/ fire management/ forest fires/ lichen woodland/ lichens/ microclimate/ ordination/ post-fire succession/ *Stereocaulon*/ snow/ Rangifer.

57. Klein, David R. 1982. Fire, lichens, and caribou. Journal of Range Management. 35(3):390-395.

Abstract: Continental populations of caribou (*Rangifer tarandus*) usually winter in the northern taiga. Fire is a natural feature of the ecology of the taiga but its effect on winter range of caribou has been the subject of conflicting reports in the literature. Lichens, which are an important component of the diet of caribou in winter, are associated with late successional stages in the post fire sequence; therefore their loss when old growth forests burn has been considered detrimental to caribou. On the other hand, several authors have suggested that lichens are not essential for caribou in winter and therefore their loss through forest fires does not seriously affect caribou. Recent nutritional investigations with reindeer and caribou have demonstrated the importance of lichens in their winter diet. Botanical studies have shown that fires are essential for the long-term productivity of the boreal forest and they account for much of the habitat diversity that characterizes caribou winter range. Extremely old forest stands show reduced lichen productivity. I conclude that, when viewed on a short-term basis of 50 years or less, fire may destroy lichens and other forage, thus reducing the taiga's potential to support caribou. Over long-time periods, often of a century or more, fire appears essential for maintaining ecological diversity and forage production for caribou.

Keywords: caribou/ fire/ lichens/ taiga/ Rangifer.

58. --- 1976? Verbal comments. Page 3 in Fairbanks Environmental Center, eds. A conference on survival of Alaska's caribou herds. University of Alaska-Fairbanks, 4 Dec 1976. Fairbanks

Environmental Center; Alaska Humanities Forum. Fairbanks, Alaska, 64 pp.

Note: The purpose of the conference was to provide the public with an opportunity to discuss and assess factors critical to the survival and propagation of Alaska's caribou herds. Emphasis was placed on the importance of "wildlands habitat" and whether such lands could or should be protected. Members of a select panel presented their views during the morning section. The panel, and the interests each member represented, consisted of: Dr. Robert Weeden (moderator); Dr. David Klein (scientist); Willie Goodwin (Native); Jim Kowalsky (environmentalist); Tom Scarborough (sportsman); Max Brewer (industry); and Bob Hinman (agency-Alaska Dept. of Fish and Game).

Some of Dr. Klein's comments were about fire effects on caribou; these are reproduced below.

Abstract: ... I mentioned lichens and the importance of their relationship to old age forest stands, therefore forest fire can be an important factor in the range relationship of caribou. But again there has been controversy as to the significance of fire in influencing caribou range. Generally, however, when fires move through a forest area they destroy lichen. They may not completely destroy them. The lichens may grow more rapidly after the fire has occurred if they are not completely destroyed. So a light fire moving rapidly through a forest area could stimulate lichen growth to a greater level than had previously occurred but generally forest fires are destructive to lichen range and set back the growth of lichen. For thirty five to a hundred years following a fire there may be insufficient lichens for the animals to use.

In Canada there have been studies of the relationship of both caribou and moose to forest stands of varying age. It was found that forest stands in excess of 100 to 120 years of age were those used mostly by wintering caribou and that there was very little use made of younger age stands. On the other hand forest as young as 11 to 30 years were the ones that were preferred and used most frequently by moose. In our work, through the wildlife research unit, in mapping the vegetation types of the western Arctic caribou herd we have been surprised to find through examination of satellite imagery that fires have been more common and have covered more extensive areas than we had anticipated in some of the wintering areas of the western Arctic caribou herd in the Kobuk for exmple. We don't know as yet what the significance of this is because we haven't been able to examine all of the areas on the ground.

Keywords: Alaska/ caribou/ fire/ forest fires/ lichens/ moose/ winter range/ Rangifer.

59. Larin, I. V. 1937. Forage plants of the meadow and pasture lands of the U.S.S.R. U.S.S.R. Commissariat of Agric., All-Union Inst. of Forage Plants. House of the Lenin Acad. of Agric. Sci., Leningrad, U.S.S.R. 994 pp.

Note: Citation and summary from Courtright, A.T. 1959. Range management and the genus *Ranigifer*: A review of selected literature. M.Sc. This, Univ. of Alaska, Fairbanks, AK. 172 pp. Larin is only one editor of the report; names of co-authors were not provided. English summary on pages 861-875 of original document.

Courtright's section pertaining to lichen and fire reproduced here.

Abstract: Lichens, which can become extremely parched during dry weather, easily catch fire, and in forest regions considerable areas are burned out. Recovery after burning proceeds very slowly, the rate depending on several factors; the intensity of the fire, the size of ashes (large ashes serve as rudimentary places of habitation), and the degree of change in cover. According to F.V. Vashkevich recovery takes place more rapidly in rainy years than in dry ones. In one case where studies were made of lichen succession in recovery after fire, it was found that the tubular and goblet-shaped *Cladoniae*, such as *Cladonia gracilis*, *Cl. deformis*, and *Cl. cornuta* were the first colonists. Then gradually the stalked lichens such as *Cl. amaurocraea*, *Cl. silvatica*, and *Cl.*

uncialis began to appear, and usually dominated the area for 10 to 15 years, after which *Cladonia alpestris* began to crowd out other lichen species; *Cl. rangiferina* later joined the latter species, and the two together formed the climax lichen cover. In old pine tree forests *alpestris* alone covered most of the soil surface, hardly any small bushes or *Cl. rangiferina* being found. Although the causes of replacement of one group of lichens by another have not been studied, it is probable that the rate of growth, together with the changes brought about by the lichens themselves and the progression of the succession of other plants are the main factors.

Keywords: fire/ lichens/ lichen regeneration/ post-fire succession.

60. Lent, Peter C. and Klein, David R. 1988. Tundra vegetation as a rangeland resource. pp. 307-337 *in* Tueller, P. T. Vegetation science applications for rangeland analysis and management. Kluwer Academic Publishers; Dordrecht, Boston, London.

Note: Abstract and Section 13.4.2 "Fire in Tundra Rangelands" reproduced here.

Abstract: Tundra rangelands comprise about 10% of the earth's land surface. They provide forage all or part of the year for millions of wild and domestic reindeer and for musk oxen as well as summer range for other domestic ungulates. Arctic tundra habitats are of international significance because of their importance to waterfowl and other migratory bird species.

Tundra plant growth is generally nutrient limited, especially N limited. Wildlife and domestic species exploit tundra to take advantage of short periods of vigorous growth and very high quality forage. Nutrient dynamics within individual plants are rapid and complex and herbivores must respond accordingly for optimal forage intakes. Snowcover is an especially important ecological factor in tundra rangelands, affecting soil-moisture, plant survival, plant community composition, phenology of growth, and access to winter forage by large herbivores moving above and through the snowcover and by small herbivores moving below the snow surface.

Heavy grazing has frequently reduced or eliminated deciduous shrubs and preferred lichen species. Graminoids may be either increasers or decreasers depending upon the specific circumstances. Repeated grazing on summer ranges by species such as reindeer and geese may lead to formation of highly productive lawn-like graminoid communities. Numerous secondary metabolites have now been identified in tundra plants, especially evergreen shrubs. Their effectiveness as defenses against mammalian herbivory and their ecological roles, as in influencing microtine population cycles, are still poorly understood.

Tundra vegetation is sensitive to disturbance and stress, especially where permafrost is present but also in alpine environments where effects of recreational use are of concern. Remote sensing techniques for classifying and monitoring tundra rangelands are relatively well developed. Rehabilitation techniques are also being developed and some are now available to the vegetation manager.

Section 13.4.2 Fire in tundra rangelands: Fires in tundra rangelands occur occasionally in low arctic or sub-arctic environments but not in the High Arctic with discontinuous vegetation and extremely low fuel levels (Wein 1976). A shrub tundra area of over 2,124 km^2 with interspersed small islands of black spruce (*Picea mariana*) east of the Mackenzie River Delta (Canada) burned in 1954. Following the fire this winter range for reindeer showed thawing occurred to 41 cm and karst hummocks resulted. Nine years later there was still no significant lichen forage. *Ledum palustre*, dwarf birch and willows to 3 m in height had returned and *Calamagrostis* spp. was among the significant invaders (Cody 1964).

On the Seward Peninsula of Alaska the effects of a 1977 fire were found to be most marked on well drained slopes with birch and ericaceous shrubs. In poorly drained sedge-shrub communities post-fire thaw depths were only 10-15 cm. *Sphagnum* mats retarded the fire but were killed by it

(Racine 1981). *Eriophorum* tussocks recover rapidly from fires in general. Tussocks were resprouting one month after fire had destroyed 80-90% of the shrub and graminoid biomass (Hall et al. 1978). Domestic reindeer grazed in the burned areas the following spring, selecting new growth of *Eriophorum* spp., *Rubus chamaemorus* and *Salix* spp. (Klein, unpublished).

Literature cited:
Cody, W.J. 1964. Reindeer range survey, 1957-1963. Can. Depart. of Agr., Plant Research Inst., Central Experimental Farm, Ottawa.

Hall, D.K., J. Brown, and L. Johnson. 1978. The 1977 tundra fire in the Kokolik River area of Alaska. Arctic 31: 54-58.

Racine, C.H. 1981. Tundra fire effects on soils and three plant communities along a hill-slope gradient in the Seward Peninsula, Alaska. Arctic 34:71-84.

Wein, R.W. 1976. Frequency and characteristics of Arctic tundra fires. Arctic 29: 213-222.

Keywords: herbivores/ forage/ rangeland/ reindeer/ tundra/ winter range.

61. Leopold, Aldo Starker and Darling, Frank Fraser. 1953. Effects of land use on moose and caribou in Alaska. Trans. N. Amer. Wildl. Nat. Resour. Conf. 18:553-562.

Abstract: The processes of occupation and development of Alaska can be guided and locally even curbed but they cannot be reversed. A continuing change in climax vegetation is to be expected, and the results, as they affect moose and caribou, presumably will follow trends of the past. There is good reason to think that moose will continue to increase and spread as new winter ranges are created by removal of the spruce forest. As far as we can see at the moment, there is perhaps no better use for much of the poorer forest land than to be moose range, so managed as to sustain a maximum number without endangering the range. There is also reason to think that the controlled use of fire to improve critical areas of winter range in central and southern Alaska would be advantageous and, at least in some localities, quite practicable. But such deliberate burning would demand exact knowledge of when, where, and how to burn to achieve the desired reproduction of moose browse without destroying the soil complex. Moose range can be destroyed by a burn as readily as it can be created and preparedness for fire control is expensive. Such intensive management is most practicable and desirable in accessible hunting grounds, near population centers, where demand for hunting and for meat is greatest. There is little object in creating large moose populations unless the harvest is to be taken. In general, present moose hunting regulations in southern Alaska, where the animals are most numerous, seem to us overconservative, particularly when coupled with rigorous predator control. It is our feeling that much larger harvests could be removed from the Kenai and Susitna, for example. At the same time, efforts to rebuild breeding stocks may be necessary for some time to come in parts of the Yukon basin and other lightly stocked ranges. The prospects for caribou are not nearly so good. Caribou, depending upon a climax vegetation, will probably continue to diminish in numbers as their range shrinks with further human encroachment and disturbance. Some great areas of tundra on the slopes of the Brooks Range and Arctic plain probably can be preserved more or less intact far into the future if proper steps are taken to insure protection from overgrazing, and on the south side of the Brooks Range, from fire; fortunately, the Arctic tundra does not burn. But it is unlikely that the great caribou herds of central and southern Alaska can be restored. Rather, efforts at restoration should be gauged by the realization that money and effort so invested can bring but limited returns on ranges no longer suitable for large herds, and even the most conscientious endeavor, along lines of protective legislation and predator control, cannot alter this ecologic fact. Much light could be shed on solution of this problem if in the near future, a full socio-ecological study of the caribou could be made in an undisturbed environment, such as the eastern Brooks Range. Meantime, it is of extreme importance that the remaining lichen ranges be protected from fire. A plan of land-use zoning might well be adopted jointly by the several agencies concerned

with forest and game management which would provide for experimental burning of designated moose ranges, at the same time furnishing active protection from burning of the remaining caribou ranges and of the better silvicultural sites. The controlled use or exclusion of fire should be part of an integrated plan of game management. It is almost inevitable that after occupation of a country by technological, pastoral or agricultural man, we find ourselves struggling to preserve the animals of ecological climax status, such as bison, muskox and caribou. The opportunity to manage and produce game lies largely in populations of those animals which reach maximum abundance at stages of sub-climax or secondary succession, such as deer, elk and moose.

Keywords: Alaska/ caribou/ fire/ fire management/ lichens/ moose/ wildlife management/ Rangifer.

62. -- 1953. Effects of land use on ranges and populations of moose and caribou in Alaska. Conservation Foundation, New York. 6 pp.

Note: No abstract. Sections of the report related to fire and caribou have been reproduced below.

Abstract: Moose and caribou are the most important ungulate mammals throughout most of Alaska by the criteria of biomass, area occupied and use for meat. Our objective has been to view the long-term prospects of moose and caribou in terms of past, present and probable future trends in land use in the Territory.

Ecologic affinities of moose and caribou

Let us consider the ecologic affinities of two species. The moose occupies a habitat of wet forest edge, or tundra with expanses of willows in the draws. It achieves highest density in forest areas that have been opened by fire or any other form of timber removal, permitting regeneration of willow, birch or aspen. Moose may occupy in summer a variety of habitats, including even heavy unbroken forest or high mountain valleys, but the quality of the winter range, which in the final analysis determines population density, is a direct function of the amount of young willow, birch or aspen protruding above the surface of the snow. These critical browse plants are characteristic of secondary stages of vegetational succession, and the moose itself may thus be considered an animal of a sub-climax biota.

Conversely, the caribou seems to require a winter range well supplied with various fruticose lichens, particularly of the genera *Cladonia* and *Cetraria*, which are part of the climax flora of forest border (taiga) and to a lesser extent of tundra. Like the moose, caribou wander into many types of country in spring, summer, and autumn, from coastal low tundra to high glacial valleys, but all winter ranges examined by us contained in the ground cover a fair amount of climax lichen growth which supplies an appreciable, and seemingly an indispensable, part of the winter caribou diet. The caribou, then, may be looked upon as a member of a climax biota.

The considerable overlap in gross areas of moose and caribou range does not disguise the fact of ecologic segregation of the two species along lines of successional stages of vegetation. It follows that changes in climax ground cover may affect the moose and caribou quite differently.

The impact of white settlement on range conditions

The arrival of the white man, with his vices and devices of land exploitation, introduced a set of ecologic influences distinct from those endemic in the hunting-food gathering cultures of Eskimo and Indians. Fire is much the most important of these influences.

An astonishingly large proportion of the lowlands of central and southern Alaska has burned in the last half century. Miners, trappers and hunters--men who deeply penetrate a country--and more recently the defense forces, have started far more fires than would naturally have occurred. In saying this we take it as axiomatic that the passage of fire through this kind of country is natural, though perhaps at intervals of a century or more. Unfortunately, no fire statistics are available

which would permit us to compare the areas of recent fires with those occurring previous to white infiltration. It is obvious to the traveler that perhaps half or locally much more than half of the taiga has been burned in the immediate past. H.J. Lutz, who has exhaustively studied the history of fires in interior Alaska, estimates that 80 per cent of the white spruce has burned in the past half century.

The quickened rhythm of fires has in general favored the extension of willow-birch-aspen, and concomitantly reduced the original stands of lichen which burn easily and take so long to regenerate. Such a condition has encouraged the spread and local increase of moose, at the same time eliminating or greatly reducing the winter range usable by caribou. For example, caribou have been extirpated from the Kenai Peninsula and in fact from all the lowlands adjoining Cook Inlet; moose in the same region have achieved higher density than anywhere in Alaska. Virtually all of their range has been burned and reburned. Caribou are relatively scarce in the upper Copper and Susitna basins; moose are increasing. Over half this area is burned. Caribou have been materially reduced in the great Yukon drainage; moose, though by no means numerous, are wide spread and holding their own or locally increasing. Such parts of the Yukon as we visited were largely burned. Accelerated burning, in other words, has influenced moose favorably and caribou unfavorably over that large part of Alaska south of the Arctic Circle. Caribou in the north, where fire is not a factor, are quite a different problem and will be discussed separately later in this paper. ...

Management prospects

... Caribou, depending upon climax vegetation, will probably continue to diminish in numbers as their range shrinks with further human encroachment and disturbance. Some great areas of tundra on the slopes of the Brooks Range and Arctic plain probably can be preserved more or less intact far into the future if proper steps are taken to insure protection from overgrazing, and, on the south side of the Brooks Range, from fire; fortunately, the Arctic tundra does not burn. But it is unlikely that the great caribou herds of central and southern Alaska can be restored. Rather, efforts at restoration should be gauged by the realization that money and effort so invested can bring but limited returns on ranges no longer suitable for large herds, and even the most conscientious endeavor, along lines of protective legislation and predator control, cannot alter this ecologic fact. Much light could be shed on solution of this problem if in the near future, a full socio-ecological study of the caribou could be made in an undisturbed environment, such as the eastern Brooks Range. Meantime, it is of extreme importance that the remaining lichen ranges be protected from fire. A plan of land-use zoning might well be adopted jointly by the several agencies concerned with forest and game management which would provide for experimental burning of designated moose ranges, at the same time furnishing active protection from burning of the remaining caribou ranges and of the better silvicultural sites. The controlled use or exclusion of fire, should be part of an integrated plan of game management. ...
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Keywords: Alaska/ caribou/ climatic change/ disturbance/ fire/ fire management/ forest management/ lichens/ management/ moose/ population decline/ post-fire succession/ predation/ prescribed fires/ taiga/ winter range/ Rangifer.

63. Lutz, H. J. 1956. Ecological effects of forest fires in the interior of Alaska. Technical Bulletin . No. 2233. USDA Forest Service 121 pp.

Note: Major report sections are: Introduction; Interior of Alaska; History of Forest Fires in Interior Alaska; Effect of Fire on Trees (includes information on understory plants and succession); Effect of Fire on Soils; Effect of Fire on Hydrologic Relations; Effect of Fire on Animal Populations; Effect of Fire on Economic Development; Summary and Conclusions; Literature Cited; Appendix; Soil Analyses.

No abstract. Sections on lichens and caribou reproduced below.

Abstract: Lichens: Lichens form a large group of plants, a number of which are highly important as food for caribou (*Rangifer arcticus*) and reindeer (*Rangifer tarandus*). Lichens are usually destroyed whenever a surface fire sweeps over an area. The general situation has been stated by Lynge (1921), a close student of the group, as follows:

"If a lichen vegetation has been disturbed or driven away from its natural habitat it will in many cases require a long time before it again can cover it. This is best seen after forest fires. I have seen gaps made by old forest fire, 50 years or more old, where the range of the fire could be traced on the lichen vegetation, *Cladonia alpestris* was more scarce and less developed there than outside the range of the fire. Even quite small fire gaps require an extremely long time before they will be covered with the same lichens again. I have seen experimental fields, 1 square meter large in fine *Cladonia* fields where no trace of *Cladonia alpestris* was visible 5 to 6 years after the fire, and Lapponian tent fire-places so old that even their surrounding stones were sunk into the earth where the place was recognizable on the vegetation. The original lichen cover was gone, sometimes replaced by mosses or by other lichens, as *Peltigera spuria* and *P. aphthosa*, even if the nearest station for these plants was far distant."

Kujala (1926) expressed the view that fire has a more destructive effect on lichens and mosses than on the vascular plants.

Reproduction in lichens may be either sexual or asexual. However, production of soredia and fragmentation appear to be the most common means of reproduction. According to Perez-Llano (1944) a considerable number of foliose lichens, as well as a few crustose and fruticose species, seldom produce apothecia and spores. Those species which appear earliest on burned areas are generally of low stature and probably regenerate from subterranean parts and bits of unburned thallus. The taller fruticose lichens in the reindeer lichen group are likely to be exterminated by fire, and their return is generally slow.

Hustich (1951) stated that in the lichen woodlands of northeastern Canada complete recovery of the lichen cover after a fire requires at least 40 years. He cited estimates from investigators in other countries as follows: Itkonen, 40 to 50 years; Manning 30 years; Sarvas, 30 to 40 years. Aaltonen (1919) stated that in Finland lichens were still not abundant 20-30 years after a forest fire. Tengwall (1928) measured the rate of growth of the reindeer lichens and reported that the rate of development of small plants is about the same as that of large plants. Only when the lichens approach their maximum size does growth slow up. He noted that certain individual large lichens did not grow at all during the years that he carried on his observations; they had reached their maximum size of about 1.8 to 2.6 inches (45 to 65 mm).

The ecology of lichens, particularly as it relates to the effects of fire, is not well understood. Considerable information has been obtained by investigators in northern Europe, however, and an attempt has been made to summarize this for certain species [summary paraphrased below; citations omitted].

Alectoria jubata and other arboreal "beard" lichens: Readily flammable when dry, probably contribute to spread of fire.
Cetraria islandica: destroyed by fires, found almost exclusively in unburned areas. Grows more rapidly than *Cladonia alpestris.*
Cetraria nivalis: Usually associated with *C. cucullata*; grows more rapidly than *Cladonia alpestris.*
Cladonia alpestris: Reindeer lichen of Scandinavian countries. Grows very slowly. Estimates for post-fire recovery range from 10-40 years, but tend to agree that at least 30 years are needed for it to attain full growth.
Cladonia bellidiflora: Greatest abundance 20-30 years post-fire. Can regenerate from underground parts and unburned bits of thallus.

Cladonia cariosa: Similar to *C. bellidiflora*.
Cladonia coccifera: Generally one of the first lichens to appear after fire. Greatest abundance 20-30 years post-fire, and regeneration similar to *C. bellidiflora*.
Cladonia cornuta: More likely to be exterminated by fire than previous 3 species due to taller stature. Disagreement as to niche: one source said it was one of the first species to appear after fire; another considered it a forest species.
Cladonia crispata: Chiefly a forest lichen.
Cladonia deformis: One of first lichens on burned areas. Regeneration similar to *C. bellidiflora*.
Cladonia degenerans: Similar growth characteristics as *C. bellidiflora*.
Cladonia furcata var. *racemosa*: Taller than many other *Cladonias*; more likely to be destroyed by fire.
Cladonia gracilis: Reports disagree: one report says this is one of the first lichens appearing after fire; another considers it a forest lichen.
Cladonia rangiferina: One of the reindeer lichens. Readily destroyed by fire. Estimates of time required for full growth range from 15-40 years. High light requirements.
Cladonia sylvatica: One of the reindeer lichens. Estimates of time required for full growth range from 20-40 years. Regenerates more quickly than *C. alpestris*.
Cladonia mitis: Reindeer lichen. Reportedly one of the first reindeer lichens to invade burned lichen forest. Broader ecological amplitude than other reindeer lichens.
Cladonia uncialis: Reindeer lichen. Full growth achieved 30-40 years post-fire, numerous small plants 10 years post-fire.
Cladonia verticillata: Greatest abundance 20-30 years post-fire.
Icmadophila ericetorum: Found on organic substrate bared by fire.
Nephroma arcticum: Forest species.
Peltigera aphthosa: Endures more shade than many other lichens. In burned areas, found in areas missed by fire or only lightly burned.
Stereocaulon paschale: Maximum size reached 15 years post-fire. Fast growing. Principal axis partly embedded in soil and may be protected from fire, allowing quick regeneration.

Caribou [portion about history of caribou on Kenai Peninsula omitted]**:** The problem of fires and caribou is in a category wholly different from that of fires and moose. Unlike the moose, which prefers pioneer plant communities or at least vegetation representing early stages of successional development, the barren ground caribou normally lives in environments characterized by climax plant communities, tundra, and forest-tundra transition. ...

.... It seems reasonably certain that the increased tempo of burning by forest fires in Alaska since 1890 unfavorably affected caribou populations. Extensive forest fires, particularly in the lichen-rich forest-tundra transitions or woodland areas, have without doubt destroyed large portions of the caribou range. Unlike moose browse, which in favorable circumstances may develop in a few years following fires, caribou range requires very many years for recovery after it has been damaged by fire or by overgrazing.

Fruticose lichens of the *Cladonia* group, *Cetraria* spp., and *Stereocaulon* spp., together with certain beard lichens such as species of *Usnea* and *Alectoria* growing on trees, form the principal winter food of caribou and reindeer (Dugmore and Radclyffe 1913, Aaltonen 1919, Lynge 1921, Seton 1929, Perez-Llano 1934, Hustich 1951). These lichens are all readily killed by forest fires and their recovery is extremely slow as already noted in the section Herbaceous Plants. Aaltonen (1919) reported that even 20 to 30 years following fires the reindeer lichens in Finland (chiefly *Cladonia alpestris*, *C. rangiferina*, *C. sylvatica*, and *C. uncialis*) occurred only sparsely and attained heights of only a few centimeters.

Lynge (1921) noted that *Cladonia alpestris* and *C. sylvatica* grow very slowly in Norway; he estimated that they would require a minimum of 25 to 30 years for full development, even under favorable conditions. Lynge observed burned areas where, after 50 years or more, *Cladonia alpestris* was scarcer and less well developed than in adjacent unburned areas. In 1926 Palmer stated,

"It may take a burned-over lichen area as much as 25 years to come back; or where so badly burned that the cover of humus is destroyed, the changed site conditions may result in a recovered stand of inferior species, or virtually in a permanent removal of the lichens, so far as practical grazing use is concerned. In view of the importance of the lichen areas for winter grazing, it is vital to all reindeer men to guard against fires; and because of the damage to game and fur animals and to tree growth, it is the concern of everyone that fires be prevented and fire protection sought."

In 1945 Palmer and Rouse expressed the view that "A depleted lichen range under complete protection requires from 20 to 40 years for restoration to the original density and height growth." These authors studied the recovery of tundra range after various treatments intended ot simulate grazing by reindeer. In an unpublished report on burned woodland or timbered range, Palmer stated, "A full recovery in lichen composition comprising chiefly short growth forms takes place in about 50 years, following destruction by fire. For full return to the original cover of tall growth lichens it is indicated that considerably more than 100 years will be required." Manning (1946) believed that complete recovery would require 30 years in the country on the east side of Hudson Bay. Hustich (1951) quoted the following estimates of the length of time required for recovery of reindeer lichens following fires: Itkonen, 40 to 50 years; Sarvas 30 to 40 years. Hustich estimated at least 40 years for recovery in northeastern Canada.

Variations in estimates of the length of time required for redevelopment of the lichen vegetation after fires are influenced by differences of opinion of what constitutes recovery, by differences in the intensity and extent of fires, and by differences in site and microclimate. A conservative estimate of the usual length of time would appear to be 40 to 50 years, but in some instances it may be much more. A half century, more or less, is a very long time for caribou range to be out of production. Burned areas are avoided by caribou and, as Schierbeck (1931) has pointed out in Nova Scotia, the return of lichens to such regions does not necessarily mean the return of caribou. Even though the caribou are great travelers it seems reasonable to suppose that they are adversely affected when their range is broken up into small, often isolated, fragments by recurring fires. It also appears probable that under these conditions excessive local overgrazing is more common than on more extensive, continuous range.

The effects of severe fires on fur bearers may be summarized as generally unfavorable. The effects of most fires on moose are generally favorable, but caribou are adversely affected by all fires. Judgment of whether forest fires are good or bad must usually be based on a consideration of the sum total of values involved. These values are timber, wildlife, soil, water, and aesthetic or recreational values. In management, priority may be given to one or a combination of these values, but only after due consideration of the others. The principle of multiple use should be applied to the extent that it is consistent with efficient resource management. Uncontrolled wildfires have no place in either forest or wildlife management. The ultimate place of prescribed burning in Alaska cannot now be stated. Neither the forester nor the wildlife specialist in Alaska today has the requisite knowledge to enable him to use prescribed burning on anything more than a purely experimental basis. There is a great opportunity and need for research on this problem.

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Keywords: Alaska/ caribou/ fire/ fire ecology/ forest fires/ forest types/ interior Alaska/ lichen regeneration/ lichens/ reindeer/ taiga/ wildlife/ Rangifer.

64. -- 1953. The effects of forest fires on the vegetation of interior Alaska. Station Paper No. 1. U.S. Forest Service, Alaska Forest Research Center, Juneau, Alaska. 36 pp.

Note: Report sections: Introduction; Geography of the Alaska Interior; Climatic Conditions of Interior Alaska; The Forests of Interior Alaska; History of Forest Fires in Interior Alaska; Effects of Fires on Forest Trees (White spruce; black spruce; paper birch; quaking aspen; and tacamahac poplar); Forest Succession Following Fires (Recently burned areas, currently regenerating; paper birch type; quaking aspen type; white spruce-quaking aspen type; tacamahac poplar type; white spruce type; and black spruce type); Effects of Forest Fires on Soils; Effects of Forest Fires on Hydrologic Relations; Effects of Forest Fires on Animal Populations; and Effects of Forest Fires on the Future Economic Development of Alaska.

Foreword by R.F. Taylor (Forester in Charge) and section on effects of fire on wildlife reproduced below.

Abstract: (Foreword). The future economic development of Alaska's vast Interior is endangered by uncontrolled fires ranging over vast areas every summer. Potential growth of wood products on what may in future be termed commercial forest land of the Interior is no small item.

On an estimated 40 million acres that are considered to be commercial forest land there are some 350 billion board feet, or perhaps 700 million cords of wood. Possibly some burned-over land not

now considered commercial would be productive if protected and allowed to restock naturally. Just one severe fire, or even repeated light fires, means waiting about 160 years for another crop of timber. When Alaskans finally discover that this timber, properly manufactured, could be one of the most valuable resources in Alaska, forest fires will be viewed with more than mild concern.

Before a resource can be developed it has to be protected. Good headway is being made by the Bureau of Land Management's Forestry Division, but more active support by the people of the Interior is needed and this can come only with a realization of the values being damaged or destroyed.

This paper is a summary of a report by Professor H.J. Lutz of the Yale Forest School who conducted the study under the direction of the Alaska Forest Research Center and with the cooperation of the Forestry Division of the Bureau of Land Management.

Two things stand out in the Lutz report: (1) the Interior forests are not all stunted, slow-growing arctic stands. Large areas of forest in the Interior have as high a volume as stands in northern Maine and southern Ontario where great industries depend on them; (2) fires do a lot more damage than just destroying the timber. They damage the beauty of the landscape for tourists, they create a smoke nuisance that makes flying dangerous and they destroy wildlife habitats of many valuable fur bearers. They are apt to reduce the water supply for mining and when repeated on the same areas, turn a forest into permanent grass and brush.

Effects of Forest Fires on Animal Populations: The wildlife of Interior Alaska is one of the important renewable resources of the region. From it both the white population and the Natives derive very considerable economic benefits. It is a resource that has great attraction for hunters and for the even larger number of tourists who merely wish to see and photograph wildlife in its natural environment.

Exceptions may occur but in general the effect of uncontrolled forest fires on the habitats of fur-bearing animals is unfavorable. The effect on the moose population is still a matter of some conjecture.

In certain areas following fires there quite evidently has been an increase of the moose population. It is only natural that this be interpreted in terms of cause and effect. Despite these examples, it may be doubted that the relationship is always a simple case of "more browse more moose." There are extensive areas in the Interior that have been burned repeatedly and which support much browse but few moose. Moreover records indicate that moose in Alaska have been moving westward and northward for over 75 years and that this movement has taken the animals into areas where burning has not occurred.

Good moose browse does not always follow forest fires. Spruce reproduction may appear in quantity and the more desired willows may not develop in numbers sufficient to withstand heavy use. It should also be recognized that establishment of browse species following severe fires is not immediate; years may pass before the burned areas again support an appreciable amount of food for moose. It may also be doubted that moose can reproduce rapidly enough to utilize fully the browse in extensive burns before it grows up out of their reach.

Accidental, uncontrolled forest fires can no more be justified in wildlife management than in forest management. If, in the future, it is ascertained that the objectives of management (either for wildlife or for timber) can most economically and effectively be attained through burning, then the use of controlled fire will be in order. The place, the time, and the intensity of the burn are all important considerations; surely these are more susceptible of management under controlled burning than when fires are accidental and hence uncontrolled.

The effects of fires on caribou are generally agreed to be harmful or even disastrous. This animal normally lives in environments characterized by climax communities, tundra and forest tundra.

Fruticose lichens of the *Cladonia* group ("reindeer lichens"), together with certain "beard lichens" (*Usnea* and *Alectoria*) growing on trees, form the principal winter food of the caribou. These lichens are highly inflammable when dry and are thus readily susceptible to destruction by fire. Recovery is excessively slow. The length of time required for full recovery varies with the extent and intensity of the fires and site and microclimatic conditions, but an average of 40 to 50 years appears to be a conservative estimate. A half century, more or less, is a very long time for caribou range to be out of production.

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Keywords: Alaska/ boreal forest/ caribou/ forest fires/ forest management/ forest types/ furbearers/ interior Alaska/ moose/ post-fire succession/ wildlife management/ Rangifer.

65. Maikawa, E. and Kershaw, Kenneth Andrew. 1976. Studies on lichen-dominated systems. XIX. The postfire recovery sequence of black spruce-lichen woodland in the Abitau Lake region, N.W.T. Canadian Journal of Botany. 54(23):2679-2687.

Abstract: The postfire recovery sequence in spruce woodland growing on drumlins in the Abitau-Dunvegan Lakes area of the Northwest Territories is described. Four phases are recognized: year 1 to year 20, the *Polytrichum* phase dominated by *P. piliferum*, with *Lecidea granulosa* and *L. uliginosa* as associated species; year 21 to about year 60, the *Cladonia* phase dominated by *Cladonia stellaris* and *C. uncialis*; year 61 to about year 130, the spruce-*Stereocaulon* phase with *Stereocaulon paschale* forming an almost pure lichen ground cover; after year 130 the canopy closes and the lichen cover disappears and is replaced by a moss cover forming the final phase, spruce-moss woodland. These phases are confirmed by component analysis.

The existence of spruce-*Stereocaulon* woodland in the area is thus dependent on cyclic burning. In the absence of fire the spruce canopy would close and the lichen cover would largely disappear. This event is rare in the area with a reburn cycle of about 100 years. Fire is thus an important vector in the maintenance of this extensive barren-ground caribou winter range.

Keywords: Canada/ caribou/ forest fires/ lichen succession/ lichens/ Rangifer.

66. Marshall, H. 1970. Problems of a contemporary arctic village. Arctic. 23(4):286-287.

Note: Short communication; no abstract. Records the effects of a summer 1968 drought on the Old Crow area near the headwaters of the Porcupine River in Yukon Territory. Section pertaining to fire and caribou reproduced below.

Abstract: ... The summer wore on without rain, and because of the dryness forest fires consumed thousands of acres of woodland. A part of this was spruce forest which covered the caribou migration route, and when the fire passed through, the lichen which forms the base of the caribou diet was destroyed. As a consequence the deer took an alternate migration route, bypassing Old Crow, and the people lost their primary source of winter meat. The lichens, *Cladonia* and *Cetraria*, upon which the caribou depend are very slow growing. They often require more than 50 years to recover from a burn, so the possibility of the caribou passing near Old Crow again in the near future appears remote. ...

Keywords: Canada/ caribou/ forest fires/ hunting/ lichens/ migration/ subsistence/ Rangifer.

67. Miller, Donald R. 1976. Biology of the Kaminuriak population of barren-ground caribou. Part 3: Taiga winter range relationships and diet. Canadian Wildlife Service Report Series. No. 36. Information Canada, Ottawa. 42 pp.

Note: Abstract and summary reproduced below.

Report sections are: A. Introduction; B. Study Area; C. Study Periods; D. Seasonal Availability of Vegetation; 1. Methods (1.1 Aerial photography, 1.2 Study plots, 1.3 Lichen growth on caribou pellets, 1.4 Standing crop and nutritional analyses); 2. Results (2.1 Aerial photography and occurrence of fires, 2.2 Vegetation on study plots, 2.3 Lichen growth on caribou pellets, 2.4 Standing crop and nutritional analyses); E. Forage Utilization; 1. Methods (1.1 Winter forage utilization, 1.2 Feeding crater observations and enclosures, 1.3 Rumen contents); 2. Results (2.1 Winter forage utilization, 2.2 Feeding crater observations and enclosures, 2.3 Rumen contents, 2.3.1 Locational changes, 2.3.2 Seasonal changes, 2.3.3 Forage selection on taiga); F. Physical Environment; 1. Methods (1.1 Climatic measurements, 1.2 Soil analyses); 2. Results (2.1 Climatic measurements, 2.2 Soil analyses); G. Discussion; 1. Snow; 2. Food habits; 3. Lichen growth; 4. Forest fires; 5. Condition of range; 6. Capacity of taiga range; H. Summary; I. Literature cited; J. Appendices.

Abstract: The winter range of barren-ground caribou in northwestern Manitoba was studied to learn what potential forage was available, and how weather, in particular snow conditions, affected the foraging of caribou. The potential forage was determined from standing crop and percentage cover of green plants and lichens in study plots. Feeding caribou were observed, and plants were collected from feeding craters and enclosures. Further evidence and confirmation of observed feeding habits were obtained by an analysis of rumen contents. The results of climatic measurements, especially of snow depth and crust hardness, explained the sudden changes observed in caribou diet. The diet changed from predominantly terrestrial lichens and grasslike plants in early winter to arboreal lichens and woody browse in late winter when the snow crust prevented caribou from digging craters. As the snow thawed the caribou fed heavily on exposed plants and lichens especially along the spring migration routes. Otherwise there was no evidence that the caribou were exerting pressure on their winter range forage. Aerial photographs, evidence of rates of lichen recovery, and knowledge of feeding habits allowed some general conclusions to be drawn about the capability of the winter range to support caribou. In particular forest fires are beneficial in that they increase the heterogeneity of the plant cover and favor the growth of some lichens which occur in early successional stages. There is a plentiful supply of forage in the area despite caribou use and fires. Snow cover rather than scarcity of forage limits the capacity of taiga to support caribou.

Summary: The taiga winter range of the Kaminuriak Population is in northern Manitoba, northeast Saskatchewan, southeast Mackenzie District and southwest Keewatin District. I studied portions of northwestern Manitoba and northeastern Saskatchewan during this investigation.

The winter range in northwestern Manitoba is roughly 20 per cent water, 40 per cent lowland and 40 per cent upland. Lowland areas include 80 per cent muskeg and 20 per cent meadow whereas the upland is 80 per cent spruce and 20 per cent jack pine. The upland areas are primarily semi-open to open lichen woodland. Between 1955 and 1967, according to aerial photograph interpretations of the same 9,200-km^2 land area, 192 km^2 or 2.1 per cent of the area burned in 47 different forest fires.

Terrestrial lichens covered 50 to 90 per cent of the ground at 6 caribou enclosures and 23 of 25 study plots located in spruce, spruce and jack pine, and jack pine cover types. *Cladina* lichens, primarily *C. mitis* and *C. alpestris*, were the most abundant in the plots and exclosures. *Cladonia* spp. mainly *C. gracilis*, were common but only occasionally abundant. *Cetraria* lichens were common but not abundant, whereas *Stereocaulon* and *Peltigera* lichens were neither common nor abundant.

The standing crop of terrestrial lichens in the study plots and enclosures ranged from 2,000 to 7,000 kg dry weight per ha at all but two plots. The protein content in lichen samples ranged from 3.20 per cent in *Cladonia* spp. to 16.26 per cent in primarily *Stereocaulon paschale* samples.

Stereocaulon samples also contained a higher amount of energy than *Cladonia*, *Cladina*, or *Cetraria* samples.

Lichen regeneration of primary thalli on artificially denuded 1-m^2 plots occurred on all plots after three growing seasons and covered from 10 to 75 per cent of the plot. Secondary thalli or podetia appeared on 66 per cent of the plots after three growing seasons. Primary thalli and in one instance a podetium were observed on caribou pellets after three summer growing seasons. Removal of the stems and leaves of *Ledum grouenlandicum* stimulated lichen growth whereas removal of only the leaves did not show a change in lichen growth.

Caribou rumen analyses showed that terrestrial lichens, primarily *Cladina* spp. and to a lesser extent *Cladonia* spp. made up the bulk of the winter diet on the taiga. *Stereocaulon* was also an important food, especially during April according to a comparison of its abundance in rumens and its occurrence in the taiga. Twigs and leaves of woody plants as well as grasslike plants were also important winter forages, and mushrooms were eaten when encountered. Seasonal availability appeared to dictate forage use by caribou after early winter.

The availability of forage depends on the depth, density, and crust hardness of snow as well as the proximity of travel routes, and treeless loafing and escape areas. Forage availability does not limit use in early winter, but as soon as snow depths reach about 50 cm various sites become unavailable. *Equisetum fluviatile* and *Carex aquatilis*, preferred forage during the early winter, become less available in mid winter along the drifted shores of lakes and streams. Caribou remain close to loafing and escape areas and therefore make little use of large areas of continuous tree cover. In late winter with the lengthening of day-light hours a crust forms on the snow and caribou change to a diet of arboreal lichens and woody browse. As soon as the crust softens caribou return to a diet of terrestrial forage using south exposures of stream-, lake-, and esker banks as well as old craters on exposed upland sites. In addition, the boles of conifer trees become exposed and are heavily used. Crater enclosures constructed during the early, mid and late winter and spring periods showed that the late winter and spring periods were the only time that the caribou damaged their forage stands. In late winter, arboreal lichen and woody browse crops were depleted locally and in spring the terrestrial forage crop was depleted on exposed sites along the migration routes.

The heterogeneity of plant cover in the taiga of northwestern Manitoba and northeastern Saskatchewan makes it well suited to sustain caribou use during the winter season because it offers caribou a wide range of depth, density, and hardness of snow. Forest fires help to maintain the heterogeneity.

Keywords: Canada/ caribou/ caribou diet/ caribou forage/ forest fires/ Kaminuriak Herd/ lichens/ post-fire succession/ snow/ taiga/ winter range/ Rangifer.

68. ---. 1976. Wildfire and caribou on the taiga ecosystem of northcentral Canada. University of Idaho. Idaho. 131 pp.

Abstract: Caribou numbers declined in northcentral Canada during the mid-twentieth century and effects of wildfire on the taiga winter range were considered as a potential factor causing the decline. No supporting evidence was found for this hypothesis either during a study of the taiga winter range of the Kaminuriak barren-ground caribou population in northwestern Manitoba and northeastern Saskatchewan, or of the Beverly population in northcentral Saskatchewan and southern Mackenzie District, Northwest Territories. Comparison of caribou use on the two taiga ranges showed similar preferences for feeding sites and forage despite differences in wildfire rates. Landforms were generally used according to occurrence and forage use was closely associated with availability. *Cladina* species of lichens predominated in the diet of caribou on both taiga ranges and were the most abundant forage available. *Stereocaulon*, *Peltigera*, and to a lesser extent *Cetraria* species, were selected lichen forage. *Cladonia* species were common constituents

in caribou rumens and common in terricolous lichen communities.

Caribou showed no preference for feeding in stands greater than 90 years old versus stands 40 to 90 years old. Standing crops of terricolous lichens in moderate-aged stands were not significantly different from older-aged stands. Large lichen standing crops were dominated by seral *Stereocaulon* species and were generally in stands less than 110 years old. Caribou seemingly did not select climax lichen species *Cladina alpestris* and *C. rangiferina* over seral lichen species.

Wildfires burned three times more taiga range annually in northcentral Saskatchewan than in northwestern Manitoba. One large fire on the Athabasca Plain accounted for most of the differential burn rate between the two taiga ranges. Reburn of seral stands, especially in the Athabasca Plain area, further inflated the annual burn rate. Forest stands in northcentral Saskatchewan over 70 years old burn annually at a rate approaching a 200-year rotation.

Wintering caribou use a range differently after it has burned. Caribou use recent burns as travel routes during migration and local movements when snow conditions are favorable. Unburned islands within the burn are used as feeding sites. Forest stands adjacent to recent burns become more accessible for feeding. Deflection of major caribou movements by large recent burns appears unlikely.

Without wildfire the taiga ecosystem would be less suitable for supporting wintering barren-ground caribou in northcentral Canada. Periodic wildfire helps maintain vegetative heterogeneity and lichen productivity. Caribou distribution, movements, and forage use in the taiga depend on existing snow characteristics which are influenced by wildfire history and its perpetual effect on the vegetative complex.

Keywords: Canada/ caribou/ forest fires/ lichens/ taiga/ Rangifer.

69. --- 1980. Wildfire effects on barren-ground caribou wintering on the taiga of northcentral Canada: A reassessment. 84-98 Proc. 2nd Int. Reindeer/Caribou Symposium. Roros, Norway, 1979.

Note: Proceedings edited by Reimers, E., Gaare, E., and Skjenneberg, S.

Abstract: Range relationships of barren-ground caribou wintering on the taiga of northcentral Canada were studied 1966 to 1974. Wildfire aspects were emphasized after 1970. Colored aerial photographs were used to quantify differences in landforms and wildfire history. Field studies were conducted in northcentral Saskatchewan ranges of the Beverly Population and northwestern Manitoba ranges of the Kaminuriak Population. Wildfires annually burned 0.7% of the land surface in Saskatchewan and 0.2% in Manitoba. Caribou wintering on both taiga ranges showed no preferences for feeding in stands older than 90 years postfire compared with stands 40 to 90 years old nor for climax lichen species over subclimax species. In both winter ranges standing crops of terricolous lichens in stands over 40 years postfire did not correlate with age either at sites caribou selected for feeding, sites selected for vegetative studies, or sites fenced against caribou use. Burned areas served a different role to wintering caribou than unburned areas. Periodic wildfires help maintain vegetative heterogeneity and terricolous lichen productivity which affects caribou distribution, movements and forage availability.

Keywords: Canada/ caribou/ fire/ lichens/ taiga/ winter range/ Rangifer.

70. Miller, Melanie and See, Marianne. 1981. I. Effect of fire on black spruce/lichen caribou range; II. Justification of research (statement of need). Proposal draft. 15 pp

Note: Bureau of Land Management proposal draft; introduction reproduced here.

Abstract: Introduction: The Bureau of Land Management (BLM) has officially recognized the need for research to obtain fir effects information in Alaska. The following is an excerpt from a memorandum from the Alaska State Director to the BLM Director, December 10, 1974:

Our analysis of fire research in Alaska finds that research data must be closely elated to management decision points including: overall fire policy; resource value class determination; MFP recommendations; and fire situation management decisions. The Washington Creek (Fire Ecology) Study Area will provide a beginning and central focus point for some fire effects and management research. Due to the natural limitations of the area, however, a number of key data requirements cannot be gathered there... including caribou fire relationships. There should be "an immediate concerted effort on a broader scale to gather key information that cannot be gathered at Washington Creek."

The letter also refers to an attachment, a paper titled "Fire Ecology Research Needs: Literature Review and Summary of Previous Works," (no author), which specifies fire research needs on caribou winter range. This paper states:

Alaskan caribou herds are largely dependent on lichens for winter forage. At present we know very little concerning how lichens fit into the fire succession sequence. The basic question to be answered here is, following a major disturbance, such as fire, how long does it take for good lichen range to be established?

Keywords: caribou/ fire/ lichens/ post-fire succession/ Rangifer.

71. Morneau, C. 1988. Retablissement de la vegetation apres-feu dans la partie nord de la foret boreale. Universite Laval. Quebec.

Note: In French. Abstract from ASTIS bibliographic database, but attributed to author.

Abstract: La chronosequence vegetale apres-feu menant a la pessiere a lichens dans la region de la Grande Riviere de la Baleine, situee dans la partie nord de la foret boreale au Quebec, a ete reconstituee par l'etude de neuf sites bien draines. La plupart des especes de la chronosequence recolonisent les sites brules au cours des 15 annees suivant l'incendie, alors que d'importants changements de vegetation se produisent jusque vers 100 ans apres-feu, soit jusqu'au developpement d'une pessiere ouvertse a *Cladina stellaris*. Il n'y a pas de remplacement d'especes chez les plantes vasculaires dominantes au cours de la succession. Par contre, une sequence bien definie d'especes caracterise le developpement des strates lichenique et muscinale en fonction de 5 stades successionnels. Immediatement apres-feu, le sol est surtout colonise par les especes vasculaires. Seulement quelques especes pionnieres, *Polytrichum juniperinum*, *P. piliferum* et *Ceratodon purpureus*, occupent les substrats mineraux 4 and apres-feu. Le stade *Trapeliopsis granulosa - Polytrichum* spp. appasrait 15 ans apres-few. Il est remplace par le stade *Cladonia* spp. 25 ans apres-feu.

Keywords: boreal forest/ Canada/ fire ecology/ lichens/ post-fire succession.

72. Morneau, C. and Payette, Serge. 1989. Postfire lichen-spruce woodland recovery at the limit of the boreal forest in northern Quebec. Canadian Journal of Botany. 67(9):2770-2782.

Abstract: A 250-year postfire plant chronosequence in well-drained sites at the northern limit of the Boreal Forest in the Grande riviere de la Baleine area, northern Quebec, was reconstructed from nine sites associated with the development of the lichen-spruce woodland. Most species recorded along the chronosequence reinvaded burned sites within 15 years after fire, whereas important vegetational changes occurred during the first 100 years of postfire recovery, corresponding to full development of the *Cladina stellaris*-spruce woodland. No vascular plant

species replacement was observed during succession, whereas by contrast a well-defined lichen-bryophyte sequence occurred along five successional stages. Species diversity (Shannon index) was low 4 years after fire, but it has reached a maximum about 25 years after fire and then dropped and stabilized at a low value in old-growth woodlands dominated by black spruce (*Picea mariana* (Mill.) BSP) and *C. stellaris*. The active period of black spruce sexual regeneration spans about 20-25 years, with maximum regeneration occurring between 5 and 14 years after fire. After this period, seed regeneration is mostly sporadic and sustained layering becomes fairly common at all sites. From 100 to 250 years after fire, no significant changes were observed in vegetation structure, floristic composition, species diversity, and spruce regeneration, suggesting that lichen woodlands are selfperpetuating in absence of fire. In limiting spruce regeneration at the ground surface, the lichen cover seems to be the most important factor controlling the open structure of the lichen-spruce woodland.

Keywords: boreal forest/ Canada/ fire history/ lichens/ *Picea*/ post-fire succession.

73. --- 1988. Retablissement de la vegetation apres-feu dans la partie nord de la foret boreale, Nouveau-Quebec. Congres de l'Association Canadienne-Francaise pour l'advancement des sciences. Universite de Moncton, Moncton, N.-B., 1988.

Note: In French. Abstract from ASTIS database bibliography, but attributed to the author.

Abstract: Un projet de cartographie et de datation des feux recents au Nouveau-Quebec demontre l'importance des feux sur la vegetation de la region de la Grande riviere de la Baleine (55 N). Cette region, situee dans la partie nord de la foret boreale, est caracterisee, dans les sites bien draines, par la presence de pessieres a lichens. Le but de la presente etude est d'etablir la chronosequence vegetale apres-feu dans les sites bien draines de cette region et de determiner la relation entre le feu et la presence de pessieres a lichens. 9 sites caracterises par une vegetation apres-feu d'age variable (de 4 a ca. 250 ans) sont etudies. On observe une succession d'especes seulement au niveau des lichens et des mousses. Les memes especes arbustives sont presentes avant et apres un few. L'epinette noire se regenere maintient par la suite de facon vegetative (marcottes) et sporadiquement par graines. Un maximum de diversite specifique est atteint environ 25 ans apres un feu. Apres cs. 250 ans aucune tendance indique que la pessiere a lichens ne peut se maintenir en l'absence de feu.

Keywords: boreal forest/ Canada/ fire ecology/ fire history/ lichens/ mosses/ post-fire succession.

74. Palmer, Lawrence J. 1926 Nov 6.
Author Affiliation: Reindeer Experiment Station, Fairbanks, AK.
Letter To: Chief of Bureau, Biological Survey, Washington, D.C.

Source: L.J. Palmer Collection, Acc. No. 904.

Note: Letter reproduced in its entirety. Poor quality of copy may have resulted in some spelling errors.

Text: Dear Sir:

We have gathered some additional notes on the reproduction of lichens on old burns which tie in with our previous observations. They are as follows:

At Cantwell on an area burned over in 1924, two years ago, showed this spring no growth of lichens as yet started over the main area. In depressions, however, where the burning had been less severe, occasional lichen growth was starting from remnants of plants not fully killed. The main ground surface of the area being level, however, had been so badly burned as to dry out the

soil and in places entirely removed the humus. Here the chief vegetation coming in in abundance was *Arctagrostis*, *Calamagrostis*, and Fireweed (*Epilobium angustifolium*). This area will be watched for further developments.

From prospectors we were informed that on a burned over area on Valdez Creek the lichens were abundantly coming back after a period of forty years. In depressions, especially, a normal lichen cover was observed to have returned.

On a burned over area 13.5 miles from Fairbanks on the Richardson Highway we found the return of a good stand of lichens. On this same area we found a new stand of small spruce trees evidently coming after the fire which indicated an age of about 35 to 40 years (counting rings). We therefore concluded that the recovery of the lichen cover to normal in this case took a period of about forty years.

On the Station pasture area at the College, there is a section covering a broad depression or shallow draw, including about 5 acres, which was burned over in 1918, or 8 years ago. This area now comprises a browse, lichen type of plant cover. The original climax type is *Picea - Larix* with a browse, lichen undercover. The present content is an 8/10 cover of 60% shrubs, 5% mosses, and 35% lichens. The lichen reproduction is abundant over the area and probably of normal stand in numbers of plants, but they are largely inferior forage species and of small height growth. Scatteringly over the area the more important forage lichens are coming in and in height these have in places attained 3 inches. The inferior forage lichens comprising the bulk of the cover are,- species of *Peltigera*, *Cladonia gracilis dilatata*, C*ladonia bellidiflora hookeri*, *Cladonia cyanipes*, *Cladonia deformis*, *Cladonia coccifera*, and *Cladonia gracilis chordalis*. The *Peltigera* by far are the most abundant. Apparently the fire in this area resulted in a replacement, perhaps temporarily, of the vegetation from a higher to a lower order of lichens. The more important forage lichens coming in are,- *Cladonia sylvatica sylvestris*, *Cladonia rangiferina*, *Cladonia amaurocraea*, *Cladonia crispata*, *Stereocaulon coralloides*, and *Cetraria islandica*. A surface fire, in this case, and favorable site in depression or draw undoubtedly accounts for the more rapid lichen recovery. Quadrats are being established on the area for continued observations.

Further observations on extensive burned over areas along the Richardson Highway show as in the above an apparent displacement of vegetation as a result of the fire from a higher to a lower lichen cover. A marked difference in rate of lichen recovery is also shown according to site. In depressions where better moisture conditions prevail the recovery is most rapid. Where the ground is badly burned so as to result in drying out of the soil the recovery is exceedingly slow. Where lightly burned so as not to destroy the humus cover and thereby enabling the surface to maintain moisture, the chances of recovery are greatly enhanced.

An area on the Fox Road burned over in 1916, or 10 years ago, was examined. This area lies on a steep north slope of former spruce, lichen, and moss cover. An adjoining unburned patch of ground indicated a former 25% cover of lichens. The burn was apparently severe, entirely removing the spruce stand and in places exposing the soil. The area is now being taken by a heavy reproduction of birch and aspen and species of browse (*Ledum* mostly), *Calamagrostis*, *Equisetum*, and *Epilobium* (fireweed). The new lichen growth is very scattering and the largest grouth only 1.5 inches high. The species of lichens include,- *Cladonia sylvatica sylvestris*, *Cladonia cyanipes*, *Cladonia bellidiflora*, *Cladonia gracilis dilatata*, and *Stereocaulon coralloides*. The original stand as shown by the adjoining unburned area included such valuable forage lichens as,- *Cladonia sylvatica sylvestris*, *Cladonia rangiferina*, *Cladonia crispata*, *Cladonia degenerans*, *Cladonia amaurocraea oxyceras*, *Cladonia amaurocraea celotea*, *Cetraria cucullata*, *Cetraria islandica*, and *Cladonia gracilis*. In this case the lichen reproduction is exceedingly slow due to a drying out of the soil.

In the Fairbanks section, the chief climax type of the vegetative cover falls under the classification (Boreal Forest) Spruce-Larch forest: *Picea-Larix* Association. The sub-climax type is Birch-Aspen (*Betula-Populus* Associes). The undercover of the Spruce-Larch forest is often largely

mosses and lichens with a scattering of shrubs. The under-cover of the Birch-Aspen type is for the most part, grasses. The important tundra types on the coast and in the uplands of the interior are,- *Eriophorum-Cladonia* Association, *Carex-Cladonia* Assoc., *Eriophorum-Betula* Assoc., *Eriopohorum-Ledum* Assoc., and *Cladonia-Betula* Assoc. Along drainages of the coast belt the type is often *Alnus*, *Salix-Calamagrostis*. On sand spits and along the beaches the characteristic association is *Elymus-Lathyrus*.

Very truly yours,

In charge Reindeer Experiment Station.

Keywords: Alaska/ fire/ lichens/ plant associations/ post-fire succession.

75. -- 1944. Alaska reindeer 1944 (a field report). 60 pp.

Note: Citation and summary from:
Courtright, A.T. 1959. Range management and the genus *Rangifer*: A review of selected literature. M.Sc. This, Univ. of Alaska, Fairbanks, AK. 172 pp.

Palmer's paper was an unpublished, typed (carbon) manuscript headed U.S. Dept. Int., Office of Indian Affairs. No abstract available for report; portions of Courtright's summary reproduced below.

Abstract: ... Where fire occurs the destruction of lichens is usually total, especially on the drier sites. Three stages of succession take place in recovery. The primary stage comprises chiefly the crustose lichens. The foliose and short-growth lichens come in during the secondary stage, and the climax stage brings a return of the tall-growth forms. The number of stages depends on the degree of injury. Recovery is more rapid after grazing, and the first stage is usually not evident, since the food base is not destroyed. [See Palmer 1945, this bibliography, for a list of lichen species characteristic of each successional stage. A similar list was included in the current citation.] Depending on the type and degree of injury, the recovery may be to a changed composition -- recovery to the original composition of lichens usually takes 40 to 65 years. Recovery of tall lichens is faster on wet sites than on dry due to decreased damage of the base. Short lichens require an opening up of the ground cover to permit ready invasion. Full recovery of a stand of mostly short lichens requires 25 to 50 years; a tall-growth recovery may take 100 years or more. For practical purposes of grazing management, combined recovery of both forms to a full stand is reached in about 50 years. Replacement of some of the tall forms by short growth lichens is offset by the greater protein and vitamin value of the short forms. In stages of succession and rate of recovery, the reaction of a damaged lichen stand closely parallels that of a coniferous forest.

Utilization of a range may be gauged aside from the physical depletion of the vegetation as a whole by indicator plants. Normal plant cover for any particular site must first be known. On sites of favorable atmospheric moisture, the presence of a predominance of crustose and short-growth lichens would indicate disturbance. In the case of herbaceous and shrub vegetation, disturbance usually results in replacement of the climax dominants, *Carex* and *Cladonia*, by a stand of *Eriophorum*, and in some cases *Ledum*. On wet sites in the interior, fire damage will temporarily bring in *Marchantia*, or in some places *Epilobium*, *Equisetum*, and grasses. Elsewhere on tundra areas, an unusual invasion of weeds and grasses probably indicates disturbance and change of site from wet to drier aspect, as a result of fire or trampling. Any disturbance of the physical surface has a tendency to change the site from wet to drier aspect. A change in plant cover on summer ranges is not serious, even if the disturbance results in permanent loss of lichens, and replacement by grasses and weeds. On the winter range, such change can have serious consequences. ...

Keywords: Alaska/ disturbance/ fire/ lichen regeneration/ lichen succession/ lichens/ rangeland / reindeer.

76. ---. 1945. The Alaska tundra and its use by reindeer. Not available: USDI Office of Indian Affairs.

Note: Section entitled "Lichen Reaction to Fire and Grazing" reproduced below.

Abstract: Lichen Reaction to Fire and Grazing
Studies of burned-over lichen ranges in the interior and of depleted lichen areas on the coast have been made by comparing them with virgin or untouched cover. Treated plots within exclosures to simulate varied degrees of grazing were established on the Bering Sea and Arctic coast as early as 1920. Known burned lichen areas in the interior employed for this study date back as far as 1900. Thus, over periods of as much as 24 and 44 years respectively, it is now possible to evaluate more accurately the lichen reaction to fire and grazing.

Effect of Fire on Lichens
Where fires occur the destruction of lichens is usually total, especially on the drier sites. Patches or islands within the general burn may remain untouched, particularly on the wetter sites. Where reached by the flames the lichens are entirely killed and recovery takes place by the invasion of new plants. Severe fires may destroy the lichen food base as well as expose the mineral soil. In such cases recovery is very slow. Depending on the degree of injury, the recovery in varying measure goes through three stages of succession to reach the original stand following destruction by fire. These are a primary, secondary and final or climax stage.

The primary stage is most pronounced on areas so severely burned as to expose the mineral soil and less apparent on areas less seriously injured. The primary stage comprises chiefly the crustose lichen forms. This is followed by the secondary stage which comprises the foliose and short growth lichens. The primary and secondary stages may be contemporary over a general area. The third and final stage follows the second stage in due course and comprises the tall growth lichen forms.

Effect of Grazing on Lichens
On depleted lichen range, i.e., where the lichens are completely eaten off, a similar effect is indicated as on burned-over range. This is shown in the examination of plots on the Bering Sea and Arctic Ocean coast as well as on pasture areas at a former reindeer experiment station near Fairbanks. These plots had been treated or grazed off in various years between 1920 and 1932. Protected portions had been established for check. Survey of these areas following twelve to twenty-four years and comparing the recovery with that on similar burned ranges gave parallel results. In the case of grazing, however, the lichen food base is not destroyed and the recovery is shown to be more rapid in tall growth forms but less so in short growth forms.

Species in the Stages of Succession
Species included in the various stages of lichen succession and the groupings as given in this study are chiefly as follows:

(1) Primary Stage

Crust lichens (Crustose)	Other lichens
Ochrolechia sps.	*Stereocaulon tomentosum*
Pertusaria sps.	*Stereocaulon alpinum*
Lepra sps.	*Cetraria nivalis*
Diploschistes sps.	*Cetraria hiascens*
Ephebe sps.	*Sphaerophorus coralloides*
Lecanora sps.	*Thamnolia vermicularis*
Baeomyses sps.	*Letharia* sps.

Psoroma sps.
Buellia sps.
Lecidea sps.
Siphula sps.
Gryophora sps.

(2) Secondary state

Short Growth Lichens
Cladonia squamosa sps.
" *decorticata*
" *fimbriata* sps.
" *verticillata*
" *cornuta*
" *cyanipes* sps.
" *cenotea* sps.
" *digitata* sps.
" *coccifera* sps.
" *bellidiflora* spa.
" *pyxidata* sps.
" *degenerans* sps.
" *defromis* sps.
" *gracilescens*
" *ochrochlora*
" *subsquamosa*
" *alpicola* sps.
" *furcata* sps.
" *cariosa cribosa*
" gracilis dilatata
" crispata

Leaf Lichens
Nephroma sps.
Lobaria sps.
Peltigera sps.
Parmelia sps.
Cetraria chrysantha
Cetraria aculeata

(3) Final Stage

Tall Reindeer Lichens
Cladonia sylvatica sylvestris
" *sylvatica*
" *rangiferina*
" *alpestris*
" *uncialis* sps.
" *amaurocraea* sps.
" *gracilis elongata*
" *delessertii*
" *coccifera* sps.

Other Tall Growth Forms
Cetraria cucullata
" *islandica*
" *islandica platyna*
" *islandica platyphylla*
" *richardsonii*
Alectoria jubata
" *nigricans*
" *ochroleuca*

Cycle of Lichen Recovery -

Detailed observations by transect and charting on 15 burned areas and 30 grazed areas indicate a requirement of from 40 to 65 years for full recovery of the destroyed or depleted lichens. The recovery may be to a changed composition with more short growth and less tall growth species present than in the original stand. The recovery in tall lichens requires less time on wet site than on dry site. This is due to less severe injury by fire because of the wet condition. On dry site the invasion of short lichens is a bit faster than on the wet site. On grazed range the lichen reaction is similar to that on burned-over areas but the invasion to short lichens is much less due to the moss mat or other vegetative base being left intact. Short growth lichens require an opening up of the ground cover, such as through fire, to permit ready invasion.

A full recovery in lichen composition comprising chiefly short growth forms takes place in from 25 to 50 years, but to attain a full stand of tall growth forms a period of 100 or more years may be required. For practical purposes of grazing management, however, the combined recovery of tall and short lichens to a full stand may be said to be reached in about 50 years. The decrease in tall forms in the composition and replacement by short forms is offset by the greater protein and

vitamin values of the short forms. Consequently, in nutritive value, complete recovery may be said to have been reached with a full stand of the combined forms.

Similarity of Lichen Recovery to that of Forest

In stages of succession and rates of recovery, the reaction of lichens to fire or depletion by grazing presents a close parallel to that of a coniferous forest. When such a forest of mature trees is destroyed by fire or cutting, a first invasion is to grasses, weeds, and shrubs. This is followed by the establishment of hardwood trees, such as, aspen and birch, accompanied by conifer reproduction. The final stage is a return to the original cover of mature conifer trees. A second growth stand of hardwoods and conifers may be reached in full density of cover in seventy years but the final or climax cover may require a hundred or more years for establishment. Similarly, a lichen cover, when destroyed by fire or grazing, goes through three stages of succession in recovery and at a parallel rate. What may be termed a second growth stand of chiefly short lichens may reach a full cover in 25 to 50 years and the final or climax stand of tall growth lichens may require 100 or more years for complete establishment. In a combined stand of tall and short lichens, full density may be reached in 40 to 65 years, or at an approximate average of 50 years.

Keywords: Alaska/ fire/ forest fires/ grazing/ lichen succession/ lichens/ post-fire succession/ reindeer/ tundra/ tundra fires.

77. -- 1940. Caribou versus fire in interior Alaska. Juneau, Alaska. 4 pp.

Note: Carbon copy of typed report; entire contents reproduced here.

Abstract: The fall run of caribou in the Fairbanks section failed to appear this year and people are asking "what has become of the caribou." Caribou migrate each spring and fall, the latter movement being the more spectacular because at this time animals are apt to appear in greater massed numbers. The runs vary considerably as to concentration of animals, character of movement, time of appearance and the local route or routes chosen. Within its particular range the individual herd moves in a same general direction. The routing may vary as to location within the range belt and may vary greatly as to the width of the advance. Within the general advance, the caribou may travel over several different local routes. The erratic behavior of caribou in migration is described by Murie in his caribou publication.

The migratory habit of the caribou is probably incidental to seasonal changes in vegetation and consequent need of search for palatable food by the animals. With the herbaceous and shrub vegetation, the change is often spotty as a result of uneven frosting or other climatic effect. Thus, on the same unit of range, both at high and low elevation, one may find in one patch a plant still blooming and yet in an adjoining patch the same species with seeds already shed. (Observed in Matanuska Valley, McKinley Park, on Big Delta River and at Fairbanks). More broadly, the vegetative change is in seasonal growth and development from first green growth in spring to the ripening of seed and drying of plants in fall. The change results in varying palatability of plants for caribou according to the season; and during winter when the herbaceous and shrub growth is dormant the lichens offer the more succulent food. It is this seasonal effect on the palatability of forage that undoubtedly results to a large degree in the movement of caribou from winter to spring and summer range and from summer to fall and winter range.

In favorable season, it is conceivable that the herbaceous and shrub vegetation may remain sufficiently palatable well into late fall and early winter to offset the need of hurried movement to winter lichen pasture. This may result in a slower, scattering infiltration between seasonal ranges rather than a hurried, mass migration. A delayed or light snow fall might be a complementary factor.

A destruction of forage on the seasonal ranges by fire, it is believed, may greatly disrupt the movement of the caribou and change the customary local routing. Such might be the case with the

Yukon-Tanana herd in the Fairbanks section. Many range fires in interior Alaska since 1895 and more recently in the very heart of the range occupied by the Yukon-Tanana herd have destroyed vast areas of lichen forage. Such accumulated destruction, by causing the caribou to seek food elsewhere, may have diverted or otherwise effected the run in this instance or served as a contributory cause. Continued burning of lichen range may change the entire complexion of the former migration and unquestionably in time will seriously effect the caribou population.

A burned over lichen range may require as much as 40 or more years for recovery. Where the fire is so serious as to destroy the lichen food base (sphagnum, mat, humus, or soil and debris mixture) it may require generations for recovery or the range may be permanently destroyed as far as the lichen forage is concerned. Many of the fires in Alaska are thus destructive. Fires in a dry season have been known to burn in the moss layer for months.

It is conjectured that destruction of winter lichen range in the Paxton Lake region might be responsible for diverting elsewhere a former annual run of caribou through the Big Delta section. It is reported that the caribou run via the Big Delta to winter range in the Paxton Lake-Upper Tanana River country took place annually for thirty years. The last big run occurred in 1928. In recent years only stragglers have come through. The last big run of caribou in the Forty Mile section is said to have been in 1925. In the immediate Fairbanks area the migration has often been in the region of Faith Creek and Chatanika. The run last year was through the Salcha River-Lake Harding and Goodpaster section. A similar run took place in 1927. This year only stragglers widely dispersed have been seen between Fairbanks and Circle and on the Big Delta.

Fires since 1895 in interior Alaska have burned over, it is variously estimated, from 20,000 to 36,000 square miles. The maximum figure is equal to approximately 10% of the interior range, which is estimated as 373,465 sq. mi. and it is equal to approximately the entire area of southeastern Alaska, which is estimated as 35,560 sq. mi. Much of the burned over area includes lichen range formerly occupied by caribou. Continued burning and destruction of lichen range may reach such proportion as to threaten the existence of the caribou in interior Alaska. If fires are not checked, we may see the vanishing of the caribou, not due to market hunting as in the case of the buffalo but because of destruction of winter lichen pastures.

Fire, it is claimed, drove the caribou from Kenai Peninsula and also from lower Susitna Valley. Caribou were reported as plentiful on Kenai Penin. in 1890. The first big fire occurred on the Peninsula in 1871, a second one in 1891 and the third in 1910. The last caribou was seen in 1906. In Susitna Valley wide spread and recurrent fires occurred at about the same time as on the Kenai Peninsula. Here the last caribou was reported killed near Fish Lake by a Land Office survey party in 1914.

There were many fires again this year throughout interior Alaska. Fires along the railroad and highways were put under control by the newly established fire service, but due to lack of funds and personnel the hinterland fires could not be reached. One particularly bad fire in the McGrath-Iditarod section on the Kuskokwim River burned 1,500,000 acres according to Mr. McDonald. This area is in the heart of the Kuskokwim country occupied by caribou as shown on Map #14 in Mr. Murie's caribou publication. Dr. Phillip Smith of the Geological Survey told me the smoke from this vast fire was so heavy and wide spread as to interrupt airplane service and seriously interfered with an aerial photographic survey in the Lake Manchumina region.

Mr. McDonald, in charge of the fire service, stated he was receiving only $27,000 for his set-up and could not possibly operate effectively on such meager funds. He had asked for $75,000. He needs aerial patrol and sufficient funds to enable control of fires in the back country. Fires destroy not only range and wildlife but interfere with aerial travel, now a big item in Alaskan development, including defense. Control of fire and thereby protection of range is particularly important to safeguard wildlife in the interior and this is especially so from the viewpoint of caribou maintenance.

Considering the caribou-fire relationship problem as crucial, I propose a study of burned-over and other caribou ranges in the interior next summer. I have in mind to investigate various aged burns and various degrees of burned over range to determine lichen recovery. I shall also consider grazing capacity and attempt to get a broad picture of fire effect on the caribou occupation and the future trend. Areas to be studied lie between Fairbanks and Livengood, between Fairbanks and Circle, in the Goodpaster section and in the vicinity of Paxton Lake.

L.J. Palmer

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Keywords: Alaska/ caribou/ caribou forage/ forest fires/ interior Alaska/ migration/ Rangifer.

78. -- 1926. Progress of reindeer grazing investigations in Alaska. USDA Department Bulletin No. 1423. U.S. Department of Agriculture, Washington, D.C. 36 pp.

Note: Major report sections are: Growth of the Reindeer Industry; Herd Owners; Reindeer as Grazing Animals; Breeds and Types of Reindeer; Sled Reindeer; Reindeer Meat; Feeding Experiments; Nature of Grazing Use; Nature of the Range; Influence of Climate on Reindeer Grazing; Soil Condition in Alaska; Forage Cover; Carrying Capacity and Range; Management; and Summary.

Short section about fire included in "Forage Cover" chapter (pp. 29-30); reproduced below.

Abstract: Range Fires: One of the greatest sources of injury to range and losses of forage in Alaska is in fires, which in most cases are deliberately set or are due to carelessness. Tundra fires along the coast are common, and burned-over range areas may be frequently found. Fires are often set by prospectors to clear off the vegetation and thus expose the underlying ground and rock or by Eskimos in an effort to be rid of mosquitoes. They are also caused by carelessly leaving a camp fire burning or tossing away a lighted match or cigarette.

Possibly on account of the immensity of the country and the sparse population the injury by fire does not appear very impressive nor a need of its suppression important. It has not, perhaps, been called sufficiently to people's attention in the past, although a Territorial law is in effect providing penalty for the deliberate setting of range fires. What is needed for Alaska is a general fire-prevention program, and in that connection a wide, educational propaganda against forest and range fires, particularly in the northern and western sections of the Territory, reaching the Eskimos through the schools.

Damage to range by fire involves not only loss of forage and trees but also of game and fur animals, since the small ground animals as well as the cover of vegetation are destroyed by fire. The damage to lichen range is particularly serious. It may take a burned-over lichen area as much as 25 years to come back; or where so badly burned that the cover of humus is destroyed, the changed site conditions may result in a recovered stand of inferior species, or virtually in a permanent removal of the lichens, so far as practical grazing use is concerned. In view of the importance of the lichen areas for winter grazing, it is vital to all reindeer men to guard against fires; and because of the damage to game and fur animals and to tree growth, it is the concern of everyone that fires be prevented and fire protection sought.

Keywords: Alaska/ fire/ furbearers/ lichen regeneration/ rangeland / reindeer.

79. ---. 1941. Progress report (Caribou versus fire in interior Alaska: A study of burned-over lichen ranges). Not Available: USDI Fish and Wildlife Service.

Note: 33 pp. Sections include: Introduction; Method of Study; Occupation by Caribou; Character

of Range; Lichen Occurrence; Burned-Over Range; Effect of Fire on Lichens; Effect of Overgrazing on Lichens; Species in the Stages of Succession; Transect Results; Rate of Recovery; Significance.

General comments are provided below, and the final paragraph of the "Significance" section is reproduced. The report also includes numerous tables of plant density in different aged burns. Much of the material in this progress report, including effects of fire on lichens, species encountered during different stages of lichen succession, and comparisons of lichen succession to forest succession, is repeated in Palmer (1945); "The Alaska tundra and its use by reindeer." (See annotation in this bibliography).

Abstract: General comments: Lichen cover varies with environmental conditions such as soils, moisture, and exposure, and the best lichen growth seems to be found between1,000 and 3,500 feet elevation. Above 3,500 feet, crustose or short lichen forms predominate. In the Fairbanks section, fair lichen growth formerly occurred in about 2/3 of the range, and about 75% of this had burned once or twice since 1900. At least 50% of the burned area suffered an extreme burn in which mineral soil was exposed; this usually occurred on southern exposures. The remaining burned sections were usually on moister northern exposures and bottomlands where the fire was less destructive.

Recovery patterns follow these general stages: aspen, birch, and willow regenerate, followed by rebuilding of debris, moss, and lichen base or undercover; spruce reproduction follows. Moss and lichen growth accelerates with increased shade and moisture-holding ability, and the aspen, birch, and willow gradually die out.

Significance (last paragraph): By inference, at least knowing the winter food requirements of caribou and reindeer, the slow growth habit of lichens and realizing the extensive destruction of range by burning, we may surmise that continuing fires are a serious threat to the future maintenance of both caribou and reindeer in Alaska. Further, overgrazing on the coastal ranges may be of similar and additional threat to a continued reindeer industry. Of course, other factors may enter in, such as disease and predation by man and wolves, but it is certain that destruction of lichen forage by fire or overgrazing must be considered a major factor in the reduction of caribou and reindeer populations. Such reduction is reported to be taking place.

Keywords: Alaska/ caribou/ fire/ interior Alaska/ lichen succession/ lichens/ reindeer/ Rangifer.

80. -- 1934. Raising reindeer in Alaska. Miscellaneous Publication. No. 207. U.S. Department of Agriculture 41 pp.

Note: Report deals primarily with reindeer herding issues. Section pertaining to fire is reproduced below.

Abstract: Range Reaction: A specific study of range reaction to fire and grazing is being made by the quadrat method. These investigations have not progressed far enough, however, to warrant more than general observations.

Certain ground conditions have undoubtedly been built up gradually during recent geological periods and maintained through the protection given by an undisturbed cover. The climate, however, has so moderated since glacial times, that when the cover is disturbed by plowing, mining, burning, grazing, or by other means, a marked change is likely to take place. Thus, where a heavy S*phagnum* moss and lichen forage in spruce climax has been built up (the moss bed perhaps 3 to 4 feet deep), the thick mat prevents the ground from thawing. Upon disturbance, the protection is removed, the ground thaws more rapidly, and the new set of conditions results in the growth of a different cover. The spruce climax will still hold, but the undercover will tend to change in character, the moss often giving way to shrubs, grasses, and weeds. In other cases the

moss is replaced by a greatly mixed cover, including numerous lichens of the short-growth type, particularly *Cladonia bellidiflora hookeri*, *C. gracilis dilatata*, *C. coccifera*, and species of *Peltigera*.

Removing moss and lichens on tundra seems to make way for sedges and grasses. Over much of the Alaskan range disturbances tend to reduce the available soil moisture, and the trend therefore is toward replacement of moisture-loving plants by drier-site plants. Fire causes a marked disturbance, particularly when it eats below the surface of the ground, into heavy humus, S*phagnum* mat, or a peaty soil. Where there is a sheet of ice 3 to 4 feet below the tundra surface, as is often the case along the Bering Sea and Arctic coast, or in the valleys of the interior, disturbance by grazing, fire, mining, or water action may thaw this ice, making the soil cave in and changing the subsequent cover.

When reindeer were first introduced into Alaska, the immediate coastal areas contained a considerable cover of lichens. In these areas lichens have now largely disappeared, owing probably to the earlier close confinement of the herds to the coast. The new cover consists almost entirely of herbaceous and shrubby vegetation- sedges, low species of browse, and grasses. On some other ranges similar changes due to grazing and fire may be expected- changes that on the whole will probably prove beneficial to summer pasturage but detrimental to the maintenance of winter forage. The injury, however, may be reduced to the minimum through the avoidance of overstocking the winter areas and through protection against fire.

The summer-range forage plants, chiefly grasses, sedges, weeds, browse, and other herbaceous and shrubby vegetation, are eminently suited to grazing. They are highly organized, seed-bearing plants of strong tissue and are firmly rooted. Most of the Alaskan species are perennial, reproducing both vegetatively and from seed. They grow rapidly, produce substantial foliage, are not readily injured by grazing, and so supply an annual forage crop.

Lichens, on the other hand, differ from the herbaceous and shrubby vegetation in character and in reaction to grazing. They do not furnish a renewed forage crop from year to year, but require a long period to recover from one season's cropping. They are not seed-bearing plants, but reproduce by means of spores, or vegetatively from fragments of old plants. Although lichens attain great age, they are of low and slow growth. They are comparatively delicate in structure, not firmly anchored to the soil and are easily destroyed either by trampling or cropping, particularly under summer conditions, when they often become dry and brittle. When moist or wet they are almost spongy in texture and less easily injured.

Lichens spread and increase rapidly, reproduction and growth occurring whenever there are favorable conditions of high moisture, usually in spring and fall. In a wet season the plants may continue to grow throughout the summer; but ordinarily the summers are dry and hot, and the lichens then lose their moisture, become brittle, and stop growing. Growth may continue into the winter, also, in sheltered rocky situations where the action of the sun on the frozen surface makes the ground moist.

As a rule, lichens spring up the first year after the ground has been cleared of the matted growth, giving them a chance to begin their development. Where the top of the plant is cropped, offshoots generally result in a bushy, deformed top. By killing a large part of the growing plant, cutting or cropping the lichen cover causes considerable damage. Even light cropping or trampling may result in much damage, and heavy trampling in summer when the plants are dry and brittle may kill all the lichen cover. Winter ranges must, therefore, have complete protection from grazing during the late spring, summer, and early fall- particularly when the surface is thawed and the lichens are dry and brittle. During the winter, on the other hand, the lichens again have a moist consistency, and the ground is frozen together with the base of the plant, thus affording considerable protection against ready destruction.

Quadrat observations made on the coastal tundra indicate that recovery of lichen range following

full cropping may take possibly 15 or 20 years. On higher ground, where a dry, rocky soil offers less favorable conditions for good growth, recovery undoubtedly will take much longer- perhaps as much as 25 or even 40 years. The rate of recovery of a lichen range depends much on the site. Further information on forage plants is contained in Department of Agriculture Bulletin 1423, Progress of Reindeer Investigations in Alaska.

Keywords: Alaska/ disturbance/ fire/ grazing/ reindeer.

81. Palmer, Lawrence J. and Rouse, Charles H. 1945. Study of the Alaska tundra with reference to its reactions to reindeer and other grazing. Research Report 10. USDI Fish and Wildlife Service; U.S. Government Printing Office, Washington, D.C. 48 pp.

Note: Major report sections are: Introduction; List of Tundra Plants; Method of Study; Types of Tundra Vegetation; Summary and Conclusions.

Abstract and Summary and Conclusions sections reproduced below.

Abstract: The Alaska tundra varies in width from a few miles to 200 miles along the Bering Sea and from 100-150 miles along the Arctic coast. Plant composition is largely lichens, grasses, sedges, alpines, and shrubs, of which 16 distinct vegetative types are described in this report.

Studies were initiated in 1920 to work out the principal range and range requirements of the reindeer. Subsequent disturbance by grazing and fire, accompanied by climatic changes, has resulted in general confusion in plant mixture and occupation. Recovery of lichen range, injured by grazing or fire, may require from 20-40 years for restoration to original density and height. Reestablishment of vascular plants is rapid. Moderate grazing by open herding and rotational use will permit sustained utilization of undamaged tundra.

Summary and Conclusions: The northern and western parts of Alaska support a varied and abundant vegetative cover that serves as forage for numerous native animals as well as for the introduced reindeer. The interior of this region is occupied principally by the boreal forest, although extensive areas of tundra prevail in the valleys and on upland slopes. The tundra, a treeless, prairielike plain along the coast, varies in width from a few miles to approximately 200 miles and extends from the Aleutian Islands northward to Point Barrow and eastward along the Arctic coast into Canada.

In study of reindeer management, particular attention was given to the tundra and to the lichen vegetation that is so important as winter forage. This report presents the data obtained from 77 test quadrats, some of which were observed over a period of 14 years. These plots were distributed within the tundra belt bordering the Bering Sea and Arctic Ocean from Nunivak Island on the south to Choris Peninsula on the north.

The vegetative types considered are beach-transition, sand-dune and sandspit, grass-browse, wet and dry tundra (including sedge), lichen heath, woodland, and alpine. The tundra is a patchwork of plant societies representing varying degrees of composition and stages in succession. Where the tundra immediately along the coast formerly supported an abundance of lichens, now as a result of summer grazing the lichen cover has largely been replaced by cotton-sedge, mainly *Eriophorum callithrix*, and by shrubs. The average plant composition of the tundra as a whole is about as follows: Lichens 30 percent, shrubs 25 percent, sedges 25 percent, and grasses, weeds, and mosses 20 percent.

Of the lichens, chiefly the forms of taller growth are herein treated. Species of *Cladonia* predominate, followed in order by those of *Cetraria*, *Alectoria*, and *Stereocaulon*. The lichen stand is often considerable and forms the principal winter food of the reindeer. Sampling of numerous areas indicated a forage production of 5 to 7 tons, air-dry weight, to an acre. Areas

sampled were those in which the lichens comprised from 50 to 90 percent of the vegetation. *Cladonia*, because it was most abundant and of taller growth, generally gave the largest yields.

Shrubs form an important part of the tundra plant composition. On the wet sites, prostrate willows are abundant. In drier places, ground birch is a prominent shrub, being of taller growth in the interior. In addition, crowberry (*Empetrum nigrum*), Alaska tea (*Ledum*), blueberry and cranberry (*Vaccinium*), cloudberry (*Rubus chamaemorus*), and bearberry (*Arctous alpina*) occur frequently throughout.

Moderate utilization of the beach-transition, sand-dune, and coast-sandspit types tend to stabilize the cover to a composition of grasses and weeds. Such cover produces more palatable spring and summer forage than do the browse-lichen and browse-moss associations of the adjoining tundra. Overgrazing opens the stand to invasion of mosses, reduces the quantity of forage, and exposes the soil to erosion by wind and rain.

In the tundra-lichen types, the range is quick to react to any disturbance. The length of time required for its recovery is directly proportional to the degree of disturbance. Trampling has a greater damaging effect upon lichens than has grazing or even removal of the plant cover. Disturbance of the lichen cover on a moist site is followed by an almost immediate invasion of vascular plants, chief of which is cotton-sedge (*Eriophorum*). The rate of invasion is in direct proportion to the amount of disturbance. On dry sites, the reduction of lichens through grazing is followed by an accelerated growth of shrubs. The recovery of lichens is more rapid on dry, than on moist, sites.

In the tundra-sedge type, even moderate grazing tends to retard the vegetation of denuded or badly depleted areas on the drier sites. Summer grazing reduces the quantity of sedges and permits increased growth of browse species. On moist sites, however, the vegetation readily recovers after denudation of an area, an almost pure stand of *Carex* coming in first. Under protection, the density of cover increases and an invasion of grasses seems to follow. One season without protection was sufficient to undo the progress of 4 years and render the area substantially as it was when the studies started.

The grass-browse type will bear heavy grazing. Following denudation of a plot the recovery to grass is rapid.

The heath type is unstable. After denudation of an area the initial invaders were mosses and *Equisetum*. Opening of the stand allows an increase in weeds. The shrubs recover slowly.

In the lichen browse type, recovery is rapid under light cropping but slow under heavy grazing. On this type open herding should be practiced and the range should not be used during the summer and early fall when the lichens are dry and brittle and thus easily destroyed by trampling.

Opening of the woodland moss stand allows competition of the mosses with the lichens. In this type recovery after overgrazing is slow, but a recovered stand contains a large proportion of lichens.

In the alpine-*Dryas* type recovery after denudation of an area is slow. Invasion is by *Dryas*, weeds, *Carex*, bluegrass, and lichens.

On overgrazed browse-lichen tundra the browse species are the most aggressive in recovery followed by lichens. It is indicated that complete recovery would require probably 25 years or more.

Substantial recovery was noted on overgrazed sedge-weed tundra (moist site) in 4 years.

Very slow recovery occurred on denuded browse-grass tundra (dry site) during a 4 year period.

Invasion by grasses and sedges was most active.

Further study of the complex nature of the Alaska tundra is needed. The climax association of the Arctic tundra, ordinarily given as *Cladonia-Carex,* is not readily verifiable, the present cover being unstable, although this may be due, in part, to grazing. Disturbance by grazing and fire, accompanied perhaps by climatic changes, has resulted in a general confusion in the plant mixture and occupation. The removal or depletion of the insulating plant cover allows the subsoil to thaw to greater depths and opens the surface to drainage. This, no doubt, contributes largely to alteration of site conditions and causes further vegetative changes. The advance of tree growth on the tundra indicates that the formation is as yet unstabilized.

The wet tundra seems less stable than the dry tundra. On both the recovery of lichens from grazing or fire injury is slow, whereas the invasion and reestablishment of vascular plants are rapid. A depleted lichen range under complete protection requires from 20 to 40 years for restoration to the original density and height growth. Moderate grazing by open herding and rotational use, however, will permit sustained utilization of undamaged tundra range.

Keywords: Alaska/ climatic change/ disturbance/ Eriophorum/ fire/ grazing/ lichen-tundra/ lichens/ management/ rangeland/ reindeer/ tundra/ tundra fires/ vegetation types/ winter range.

82. Polozova, T. G. 1986. Forest fire effect on southern subarctic tundras in western Chukotskyy Peninsula. Botanicheskii Zhurnal. 71(12):1657-1663.

Note: In Russian. Citation from the Cold Regions - CRREL bibliographic database.

Abstract: Not available.

Keywords: forest fires/ lichens/ mosses/ post-fire succession/ soils/ tundra.

83. Racey, Gerald D. and Armstrong, Edward R. 1996. Towards a caribou habitat management strategy for northwestern Ontario: Running the gauntlet. Rangifer. Special Issue No. 9:159-170.

Note: Paper presented at the Sixth North American Caribou Workshop, Prince George, B.C., Canada, 1-4 March 1994.

Management strategy discussed in the paper includes a "mosaic concept" which recognizes the importance of fire in maintaining a habitat mosaic within the boreal forest.

Abstract: A management strategy for woodland caribou (*Rangifer tarandus caribou*) habitat is being developed in northwestern Ontario. This strategy is based upon a set of draft Timber Management Guidelines for the Provision of Woodland Caribou Habitat. These guidelines recommend maintaining a sustainable supply of winter habitat within large tracts of old forest, protecting calving areas and minimizing human disturbance. Due to the large temporal and spatial scale of caribou habitat management, an ecosystem-based approach is recommended. Public response to the strategy shows a strong dichotomy between environmental and utilitarian values among all the major stakeholder groups. The major issues raised by the public include security of industrial wood supply, quality of the knowledge base, level of awareness of caribou, economic impacts on remote communities, concern about environmental impacts and silvicultural know-how. The government is responding to these concerns as the strategy evolves. Current emphasis is placed on increasing awareness of the public, training resource managers in caribou biology, management and habitat planning, implementing interim habitat management prescriptions and studying the potential impact on wood supply. The final direction for a northwestern Ontario strategy to conserve woodland caribou habitat has yet to be decided, although a commitment has been made to strive for the conservation of woodland caribou populations and their habitat.

Keywords: boreal forest/ Canada/ caribou/ forest management/ habitat management/ *Rangifer*.

84. Racine, Charles H. 1979. The 1977 tundra fires in the Seward Peninsula, Alaska: effects and initial revegetation. BLM-Alaska Technical Report 4. Bureau of Land Management, Anchorage, Alaska. Pages 1-51.

Note: Report mostly concerned with vegetation analysis, but discusses potential impacts of fire on the reindeer industry.

Abstract: Abstract: During summer 1977, wildfires burned extensive areas of maritime tundra in the Seward Peninsula. This study was initiated in July 1978 to determine the effects of these fires on tundra soils and vegetation and to establish permanent plots in which to monitor postfire succession. Fifteen 10 m x 1 m permanent belt transects were established at four different burn sites in the Seward Peninsula. Nine of these were located along a topographic transect on a hill where soils and vegetation had been quantitatively sampled in 1973, thereby providing pre-fire comparisons. Two other sample sites were located in a 1971 tundra burn. Soil characteristics and plant density and cover were determined in or near each of the 150 1 m x 1 m quadrats.

Tundra burn patterns were generally patchy, with unburned communities, unburned patches within burned communities, and in most areas of tussock-shrub tundra, less than one half of the accumulated organic soil layer was removed. Except where organics were removed, thaw depths were not greatly increased but unlike the pre-fire situation, after the fire, thaw depths reached into the mineral soils. Frost features were made more conspicuous, if not reactivated, and soil nutrient concentrations (K and P) increased locally. Revegetation in tussock-shrub tundra was rapid, mainly as a result of tussock resprouting, but was much slower in drier low shrub areas where organic soils were largely removed. Some of the implications of these results to vegetation changes, fire management policy, commercial reindeer herding, and off-road vehicle use are discussed.

Keywords: Alaska/ post-fire succession/ reindeer/ soils/ tundra fires/ tundra vegetation .

85. ---. 1981. Tundra fire effects on soils and three plant communities along a hill-slope gradient in the Seward Peninsula, Alaska. Arctic. 34(1):71-84.

Note: Fire effects on vegetation, including lichen regeneration.

Abstract: During summer 1977, wildfires burned extensive areas of low arctic tundra in the Seward Peninsula, Alaska. The present study was initiated in July 1978 to determine the effects of these fires on tundra soils and vegetation. Nine 10 m x 1 m permanent belt transects were established at regular intervals along the topographic gradient of a burned hill-slope in the central Seward Peninsula near Imuruk Lake. Soil characteristics and plant species density and cover were determined in each of the 90 1-m^2 plots on this slope during July of both 1978 and 1979.

Soils and vegetation had been quantitatively sampled on this slope in 1973, thereby providing pre-fire comparisons: a sedge tussock-shrub tundra community with mud circles occupied the poorly drained footslope and a birch and ericaceous shrub tundra community with elongate turf-banked frost boils had developed on the moderately well-drained backslope. The broad, poorly-drained summit of this slope was occupied by sedge-shrub tundra with low-centered polygons.

The severity of burning in July 1977 varied along this slope with moderate to heavy burning of the birch and ericaceous shrub tundra and light to moderate burning of the sedge tussock-shrub tundra and sedge-shrub tundra communities. Post-fire (1978 and 1979) changes in plant cover, species composition and soil thaw depths are shown to vary with position on the slope and burning

severity. The relationship of these changes to natural succession in the absence of fire is discussed.

Keywords: Alaska/ post-fire succession/ soils/ tundra fires/ tundra vegetation.

86. Racine, Charles H.; Johnson, Lawrence A., and Viereck, Leslie A. 1987. Patterns of vegetation recover after tundra fires in northwestern Alaska, U.S.A. Arctic and Alpine Research. 19(4):461-469.

Note: Vegetation study; includes information on lichen regeneration and re-examines 1977 fires reported on previously by Racine.

Abstract: Studies of lightning-caused tundra fires were carried out between 1977 and 1983 in three areas of northwestern Alaska (Seward Peninsula [65° 35' N], Noatak River [68° 00'N], and Kokolik River [69° 30'N]) representing a latitudinal gradient of 460 km. Postfire vegetation and permafrost recovery rates were documented in both tussock and low-shrub tundra ecosystems burned up to 10 yr prior to sampling.

Within 5 to 6 yr following 1977 tundra fires, total vascular plant cover reached 50 to 100% of the unburned control at all sites with the slowest recovery at the northernmost Kokolik River site. This difference may be accounted for by the greater severity of burning at the Kokolik River sites where the fire occurred late in the season (1 August) and where there is a longer interval between fires. Postfire increases in soil thaw in tussock tundra appeared to stabilize or return to prefire levels within the same 5- to 6-yr time span.

Many tundra plants appear to be well adapted to fire through one or a combination of strategies described. *Eriophorum vaginatum* tussocks may be dependent on fire for removal of competing low shrubs and mosses. Seed and seedling fluxes of certain species increase dramatically following fire. A model is presented which relates species fire survival strategies to the severity of burning and the seasonal timing of fire.

Keywords: Alaska/ *Eriophorum*/ post-fire succession/ soils/ tundra fires.

87. Rouse, W. R. and Kershaw, Kenneth Andrew. 1971. The effects of burning on the heat and water regimes of lichen-dominated subarctic surfaces. Arctic and Alpine Research. 3(4):291-304.

Abstract: Areas of ground lichen in the subarctic are particularly susceptible to fire either by man's activity or by natural causes. Experimental evidence from the Hudson Bay lowlands gathered in the summer of 1970 indicates that the burning of lichen has a pronounced effect on the ground water regime. Soil moisture measurements made in a mature lichen woodland with thinly spaced trees, and in areas of recent and older burning indicate that the soil moisture under the lichen-dominated surface was at least 40% greater than in either of the burned areas. This suggests that a mature lichen cover offers a high resistance to the evaporation of soil moisture. The nature of the evaporation regime was determined using the energy budget (Bowen Ratio) approach over each surface. These data were augmented by measurements of the moisture content of the lichen made at three levels with the canopy. The evidence indicates that lichen dominated surfaces act as an effective mulch in preventing evaporation from the subsurface zone whereas the burned areas which are able to evaporate more water into the atmosphere when moist, also develop strong resistances to evaporation as the soil surface layers become drier. The role of ground lichen in the water budget of northern lands is significant because of its extensive cover and its destruction by fire must exert an important influence on the hydrologic and atmosphere water regimes.

Keywords: fire/ fire ecology/ lichens/ soil moisture/ water regime.

88. Rowe, John Stanley and *chk pgs 1979. Large fires in the large landscapes of the north. Pages 8- *in* Turcott, George L.; Rowe, J. Stan; Vogl, Richard J.; Komarek, Edwin V. Sr.; Johnson, Von J., and Mutch, Robert W., eds. Fire management in the northern environment symposium. Anchorage, Alaska, 19 Oct 1976-21 Oct 1976. USDI Bureau of Land Management. Anchorage, Alaska.

Note: Abstract and section of Rowe's paper pertaining to lichen plateaus are reproduced below.

Abstract: Land management goals in the North ought to stem from a land ethic, a care for the terrain. They ought to take account of the historical forces that have produced landscape variety. The occurrences of fires in space and in time have created a patchwork mosaic and thus, have renewed continuously "between-site diversity."

Major weather systems interact with terrain to produce regional fire patterns that have certain predictable characteristics. Fires resulting from air mass weather often seem to be more numerous and larger than those resulting from frontal activity. Most of the area burned in years of average fire frequency is the result of a few lightning-ignited fires.

It is important to relate fire effects to different types of landscapes and not just to vegetation communities. For example, inorganic permafrost terrain is often rendered unstable by fires, especially on slopes, while

Lichen peat plateaus: Within the subarctic lichen woodland, and increasingly northward, treeless lichen-covered peatlands are a prominent kind of terrain. Such "lichen peat plateaus" appear as islands in forested peat plateaus, their white and yellow surfaces of *Cladonia* and *Cetraria* lichens contrasting with the sombre tones of the surrounding black spruce. Usually, they occupy level areas but they sometimes appear on the crests of low rises or on gentle side slopes. A frequent size is several hundred metres in diameter. Occasionally, they contain small melt-out pockets marked by tarns, but thawing and infilling seem to be less common than on forested peat plateaus.

Several surface features are of interest. A network of irregularly spaced fissures marks the surfaces of some lichen peat plateaus, forming raised-centre polygons. Small spruce, bog birch, and green mosses appear in the fissures. Also, rounded erosional depressions, one half to one metre in diameter, appear in dark clusters on some surfaces, as if a giant shotgun had been discharged from the air. Some of the smaller holes examined were crisscrossed with suspended shrub roots, suggesting that the peat had oxidized away without disturbing them.

Lichen peat plateaus show evidence of past burning. There are charcoal lines in the peat and charcoal flecks in the black erosional hollows. Furthermore, burned tree stubs can usually be found poking through the lichen mat. At the outer edges, in the transition to treed organic terrain, remnants of fire-killed forest often bear burn scars. It appears that this particular kind of terrain can be the result of fire.

The idea that lichen-rich peatland can be increased as a result of fire was proposed by Ahti and Hepburn (1967) from their research in northern Ontario. Our studies support their hypothesis that fire, by killing the surface *Sphagnum* peat mosses, provides a favourable substratum for the large lichens, especially in the climatically severe regions of the subarctic. The probable sequence of events is as follows:

A forested peat plateau is the first necessity because only a hot crown fire can generate sufficient back-radiation to kill the surface *Sphagnum* mounds. The environment thus produced is unfavourable for the regeneration of spruce and of *Sphagnum*, possibly because of limited propagules as well as the exposed surface conditions. Dwarf shrubs survive the fire and resprout but after a number of years, they senesce, particularly if fire does not reoccur. Meanwhile, the caribou lichens thicken, and as the surface ages and the *Sphagnum* mounds settle, they become more and more prominent. At this stage, further fires probably perpetuate the type or extend its

limits into the black spruce woodlands at its margins.

Literature Cited:
Ahti, T. and R.L. Hepburn. 1967. Preliminary studies on woodland caribou range, especially on lichen stands in Ontario. Res. Rpt. (Wildl.) No. 74, Ontario Dept. of Lands and Forests. 134 pp.

Keywords: Canada/ fire/ fire ecology/ fire history/ fire mosaic/ post-fire succession.

89. Rowe, John Stanley and Scotter, George Wilby. 1973. Fire in the boreal forest. Quaternary Research. 3:444-464.

Note: Review paper with numerous references. Overview of fire in the boreal forest, with brief sections on the effect of fire on lichens and wildlife. Abstract and discussion about caribou reproduced below. Other species of wildlife also discussed in the paper.

Abstract: The boreal forest in North America owes much of its floristic and faunistic diversity to periodic fires ignited by lightning and by man since he appeared on the scene. The indirect evidences of burning in vegetation and soils, and recent direct observations of fires, are reviewed. Fire is shown to exert a significant effect on vegetational composition, on soil chemical properties and thermal regime, and on animal populations through the particular mosaic of habitats created. In turn, fire is itself influenced by the nature of geographic landscape ecosystems according to their surface forms, accumulations of organic materials, and susceptibility to drought. It is concluded that fire should be viewed as a normal ecological process in the boreal forest. A thorough understanding of its long-term role in terrestrial and aquatic ecosystems is needed.

Caribou: The effects of fire on species such as barren-ground caribou (*Rangifer tarandus groenlandicus*) are equivocal. Some caribou herds normally depend on foliose [?] lichens such as *Cladonia mitis, C. alpestris*, and *C. rangiferina* as their principal forage during the winter. In addition, arboreal lichens, such as *Alectoria* spp. and *Usnea* spp., which drape old unburned trees, are an important source of forage for caribou, particularly during the late spring or periods when snow is deep or crusted (Scotter 1964). Recovery of these lichens following fire is exceedingly slow and has been reviewed by Scotter (1963, 1971).

However, fires are not detrimental to all caribou habitat. In the southern limits of the barren-ground caribou's winter range, fire sometimes destroys thick carpets of bryophytes in upland forests and in muskegs, thereby making those forests more productive for lichens and other forage plants. Ahti and Hepburn (1967) suggest that the lichen supply could be increased for caribou in the northern boreal lichen belt of Ontario by burning the *Sphagnum fuscum* peatlands, treeless bogs, or wooded muskegs, and farther south by burning the black spruce-feather moss forests and the black spruce muskegs.

Literature Cited:
Ahti, T. and R.L. Hepburn 1967. Preliminary studies of woodland caribou range, especially on lichen stands in Ontario. Res. Rept. (Wildl.) No. 74.

Scotter, G.W. 1963. Growth rates of *Cladonia alpestris*, *C. mitis*, and *C. rangiferina* in the Taltson River region, N.W.T. Canadian J. Botany 41:1199-1202.

Scotter, G.W. 1964. Effects of forest fires on the winter range of barren-ground caribou in northern Saskatchewan. Canadian Wildl. Serv. Wildl. Manage. Bull. Series 1, No. 18.

Scotter, G.W. 1971. Fire, vegetation, soil, and barren-ground caribou relations in northern Canada. Pages 209-230 in C.W. Slaughter, R.J. Barney, and G.M. Hanson, eds. Proceedings, fire in the northern environment-a symposium. USDA Pacific NW For. and Range Exp. Stn.,

Portland, Oregon.

Keywords: boreal forest/ caribou/ fire/ fire mosaic/ soils/ wildlife/ Rangifer.

90. Rupp, Scott, Olsen, Mark, Henkelman, Jonathan, Adams, Layne G., Dale, Bruce W., Joly, Kyle, Collins, William B., and Starfield, Anthony. **IN PREP**. Simulating the influence of a changing fire regime on caribou winter foraging habitat.

Note: Manuscript was "**in prep**" at the time this bibliography was put together. Abstract presented is preliminary.

Abstract: Computer simulations performed using a spatially explicit vegetation succession model indicate that changes in the frequency and extent of fire in interior Alaska may substantially impact the winter habitat of caribou. Simulated increases in fire frequency (i.e., more frequent fires) on the winter range of the Nelchina Caribou Herd in eastern interior Alaska suggest large decreases in available foraging habitat, relative to currently available habitat, in both the short- and long-term future. A 30% increase in fire frequency resulted in a 72% increase in annual total area burned and an associated 41% decrease in the amount of spruce-lichen forest found on the landscape. More importantly, simulations with more frequent fires produced a relatively immature age structure – relative to the currently observed age structure – with few forest age classes older than 100 yr. These age structures are at the lower limits of preferred stand age classes based on observations of forage selectivity by caribou from the Nelchina Herd. Projected changes in fire regime due to climate warming and/or land-use change could substantially alter the winter foraging habitat of caribou in interior Alaska and lead to changes in winter range use and/or population dynamics.

91. Russell, Don E.; Martell, Art M., and Nixon, Wendy A. C. 1993. Range ecology of the Porcupine Caribou Herd in Canada. Rangifer. Special Issue No. 8:1-167.

Note: Report covers different aspects of caribou ecology, divided by season. Sections about fire and lichens reproduced below.

Abstract: Winter: Results - Fire History
Sixty-eight sites were sampled for fire history and summarized by community type. The longest interval since a major fire event was 343 years in a *Picea mariana-Ledum-Vaccinium* community. Of sites sampled 23% had been burned in the last 50 years, 42% in the last 100 years and 63% in the last 150 years.

The mean interval between fires (for those stands where at least one fire scar was recorded) was 120 +/- 95 years. However it was evident that not all fires caused scarring. Intensive examination of areas known to have been burned recently revealed only dead trees and healthy, undamaged specimens.

Even though too few stands were sampled to relate age of stand to understory vegetation characteristics, a few generalizations emerged. All subalpine shrub communities sampled were young stands. Whether this phenomenon resulted from a greater frequency of fires in the zone or a greater susceptibility to scarring of trees in the subalpine than elsewhere, was uncertain.

For the purpose of our analysis stand age was divided into five age classes for the 68 stands where age was determined. Mean total lichen biomass declined with age class although the high variation with each class resulted in no significant differences between classes.

Although no significant differences were noted between classes, stands in the oldest age class had about one half as much *Cladina* biomass as those in younger age classes. *Cladonia* spp. biomass declined with age after an initial peak between 51-125 years. Again, no significant differences wer noted. *Cetraria* biomass, on the other hand tended to increase with age, while *Stereocaulon* decreased significantly with age class.

Winter: Discussion - Lichen Biomass

... Of major concern in this study was the effect of fire (or age of stand) on the lichen component in the understory. Much controversy has surfaced in the last 25 years over the relationship between fire and lichens and caribou populations. What seems clear is that fire has both long and short term benefits and drawbacks to lichen abundance and distribution (Klein 1982). Of key importance is the perpetuation of a mosaic of age class stands. According to the literature, lichens are greatly reduced after fire, increase in abundance up to 125-175 years and decrease as canopy closes and microclimate for moss and shrubs improve. Therefore, although initially causing a decline in lichen biomass, fires ensure that large tracts of land do not succeed to lichen-poor forest moss communities. Our study noted a general decline in fruticose lichen biomass with age class of stand. However, the only species that declined significantly was *Stereocaulon*, virtually absent in stands greater than 200 years old. Because sample size was too small to split the youngest class into more classes, the majority of the early recovery rate dynamics documented by Scotter (1970) could not be assessed.

Literature Cited:

Klein, D.R. 1982. Fire, lichens and caribou. J. Range Manage. 35:390-395.

Scotter, G.W. 1970. Wildfires in relation to the habitat of barren-ground caribou in the taiga of northern Canada. Ann. Proc. Tall Timbers Conf. 10:85-106.

92. Saperstein, Lisa B. 1996. Winter forage selection by barren-ground caribou: Effects of fire and snow. Rangifer. Special Issue No. 9:237-238.

Note: Brief communication; paper presented at the Sixth North American Caribou Workshop, Prince George, British Columbia, Canada. 1-4 March, 1994. Communication reprinted in its entirety.

Abstract: Debate over the role of wildfire in the ecology of barren-ground caribou (*Rangifer tarandus*) has generated both questions and controversy. In summer 1988, a wildfire burned 84615 ha of the Selawik National Wildlife Refuge in northwestern Alaska. Portions of the burned area have been used historically as a migratory corridor by the Western Arctic Caribou Herd. The objective of this study was to address the effects of fire on caribou on a tundra range in late winter (March through April) by comparing vegetative cover, production, and snow characteristics at feeding and control sites in burned and unburned habitat. I also compared the protein content and digestibility of a sedge species collected in burned and unburned habitat.

Replicate plots (30 x 30 m), each containing feeding craters and undisturbed snow, were established in burned and adjacent unburned tussock tundra in late March through April 1990 (n=20 burned, 20 unburned) and 1991 (n=16 burned, 16 unburned). Craters were located from the air when possible or by following caribou trails. Plots were randomly oriented with respect to direction and distance from edges of craters. Within each plot, I measured snow depth and hardness at 10 points along the least disturbed edges of feeding craters and at 10 randomly located points in undisturbed snow. Randomization of undisturbed points was achieved by randomly selecting intersections of x, y coordinates spaced at 0.1 m intervals along two edges of the plot; coordinates intersecting in craters were discarded. I collected vegetation from craters in both burned and unburned plots in 1991 for analysis of crude protein content and *in vitro* digestibility. Caribou fecal pellets were collected and microhistologically analyzed to estimate winter diet in the

general area.

In late July-August, I revisited plots and established up to 10-0.25 m^2 quadrats within former craters and centered quadrats on the 10 randomly located points sampled in late winter. Species lists were compiled for each quadrat and I calculated the relative frequency of occurrence for each plant species in a plot. Percent relative frequency was defined as follows:

Relative frequency of species A= (No. quadrats containing species A/Sum of frequency values of all species) x 100.

I also clipped above-ground vegetation in 5 of the randomly located quadrats to estimate biomass.

Years were analyzed separately, and stepwise discriminant function analysis (DFA) was used to select key variables prior to making statistical comparisons. Based on the results of DFA, snow depth and hardness and the relative frequencies of occurrence of lichens and bryophytes were selected as important variables in both 1990 and 1991. In addition, relative frequency of *Eriophorum vaginatum* was selected as a variable in 1991.

Multiple analysis of variance (MANOVA) indicated that there were significant differences in snow depth and hardness and in plant relative frequency data between burned and unburned plots and between craters and unused areas within plots in both years. I performed ANOVAs to determine which variables contributed to these differences.

Snow depth and hardness were the most influential factors determining selection of feeding areas by caribou in both burned and unburned plots. Snow was shallower and softer at edges of caribou feeding craters than at adjacent undisturbed points in both years. There was little difference in snow depth or hardness between burned and unburned plots.

Frequencies of particular plant taxa were only significant in influencing selection of crater sites in unburned plots in 1990k when caribou craters had higher relative frequencies of lichens and lower frequencies of bryophytes than unused areas. Lichens were primarily in the genera *Cladina*, *Cetraria*, and *Cladonia*.

Relative frequency and biomass of most vascular plants were reduced in burned plots, with the exception of post-disturbance species. Biomass and relative frequency of *Eriophorum vaginatum* were greater in burned plots than in unburned plots in 1991. Also, protein and *in vitro* digestibility levels were significantly enhanced in samples of this species collected from burned plots in 1991. Bryophytes had greater relative frequencies in burned plots than in unburned plots, but species composition differed between the two areas. Bryophytes in unburned plots consisted mostly of *Sphagnum* spp. and feather mosses; in burned plots, post-disturbance species in the genera *Ceratodon*, *Polytrichum*, and *Marchantia* dominated. Although lichen biomass was significantly reduced in burned plots in both years, lichens composed 74% and 59% of caribou diet in 1990 and 1991, respectively.

Both long- and short-term consequences should be considered when examining the effects of fire on the foraging behavior of caribou. Post-fire increases in protein content, digestibility, and availability of *E. vaginatum* make burned tussock tundra an attractive feeding area for caribou in late winter. These benefits are likely short-lived, however. Lowered availability of lichens and increased relative frequency of bryophytes will persist for a much longer period.

Keywords: Alaska/ caribou/ lichens/ *Rangifer*/ snow/ tundra fires.

93. ---. 1993. Winter forage selection by barren-ground caribou: Effects of fire and snow. University of Fairbanks-Alaska. Fairbanks, AK. 79 pp.

Note: M.Sc. Thesis.

Abstract: Snow depth and hardness were the most influential factors in selection of feeding areas by caribou (*Rangifer tarandus*) in late winter in northwestern Alaska. Following a 1988 fire, plots were established in late March through April in burned and unburned tussock tundra in 1990 and 1991. Snow in both burned and unburned plots was shallower and softer at edges of caribou feeding craters than at adjacent undisturbed points in both years. There was little difference in snow depth or hardness between burned and unburned plots, although caribou cratered in shallower snow in burned plots than in unburned plots in 1990. Crater area was greater in unburned plots in 1990, but there was no difference in crater area between burned and unburned plots in 1991. Frequencies of particular plant taxa were only significant in determining selection of crater sites in unburned plots in 1990, when caribou craters had higher relative frequencies of lichens and lower frequencies of bryophytes than unused areas. Fire reduced relative frequency and biomass of most plant taxa, with the exception of post-disturbance species, which occurred primarily in burned plots. Lichens were reduced in burned plots, and lichens composed 59-74% of the late winter diet of caribou, as determined by microhistological analysis of fecal pellets. Biomass and relative frequency of *Eriophorum vaginatum* was greater in burned plots than in unburned plots in 1991, and protein and *in vitro* digestibility levels were enhanced in samples of this species collected from burned plots in late winter.

Keywords: Alaska/ caribou/ *Rangifer*/ snow/ tundra fires/ winter range.

94. Saperstein, Lisa B. and Klein, David R. 1992. Characteristics of caribou feeding craters in burned and unburned habitat on the Selawik flats, Alaska. Rangifer. 12(3):169-170.

Note: Expanded abstract; poster presented at the First Arctic Ungulate Conference, Nuuk, Greenland. 3-8 September, 1991. Abstract presented in its entirety.

Abstract: There has been debate over whether fire has a negative effect on caribou winter range. In June and July 1988, a wildfire burned 84,615 ha of the Selawik National Wildlife Refuge, located in northwest Alaska. Portions of the burned area have been used historically as a migration corridor by the Western Arctic Caribou Herd. The objective of this study was to assess possible effects of the fire on caribou use of vegetation in early spring. To accomplish this, the following variables were measured inside and outside of the burn perimeter: 1) density of feeding areas, 2) snow depth and hardness at feeding craters and at random undisturbed points, 3) presence-absence of representative plant species, and 4) above ground plant biomass.

Replicate plots (30 x 30 m), each containing cratered and undisturbed snow, were established in April 1990 (n=20 burned, 20 unburned) and 1991 (n=16 burned, 16 unburned). Ten points were randomly located at undisturbed areas within each plot; these are referred to as "random points." Random points, and the least disturbed crater edges ("cratered points") were sampled for snow depth and hardness using a Rammsonde Penetrometer. Four transects, each 50 km in length and consisting of both burned and unburned habitat, were flown in late April of both years to estimate feeding area density. Feeding areas (one large or numerous smaller craters) were counted and a t-test was performed to compare density in burned and unburned habitat.

Each following summer, 0.25 x 0.25 m quadrats were established on the 10 random points and on 10 points located within former craters. Species lists were compiled for each quadrat and all vegetation except for moss and liverworts was clipped in five of the random quadrats to estimate biomass. Vegetation was sorted into current and previous years growth, dried, and weighed.

Snow data were analyzed using ANOVA. These data were then combined with relative frequency of plant species and analyzed using MANOVA to test for overall differences due to burning and use (craters vs random). Stepwise regression and discriminant analysis were used to select key variables prior to performing the MANOVA.

Snow was shallower and harder in 1991 than in 1990. Burned plots had shallower snow than unburned plots only in 1990, but this may be an artifact due to caribou foraging on exposed *Eriophorum vaginatum* tussocks on windswept ridges in the burn. There were no other differences in snow cover due to fire history. In both years, snow near craters was softer and shallower than at random points. Flight transect data suggested that there were more feeding areas in unburned than in burned habitat in 1990 ($p<0.05$). There may have been more feeding areas in unburned habitat in 1991 as well, but sample size ($n=4$) was insufficient for statistical testing.

Stepwise discriminant analysis selected snow depth and hardness, and the relative frequencies of *Cetraria* spp., *E. vaginatum*, and bryophytes to be entered in the MANOVA for 1990 data. *Cladonia*/*Cladina* spp. were not included due to culticolinearity with *Cetraria* spp., but these genera include important winter forage species. The overall MANOVA was significant for the burn effect ($p<0.0001$) and the use effect ($p<0.0019$). In the absence of snow variables, *E. vaginatum* and lichens were found significantly more often in unburned quadrats, while bryophytes were more common in burned, random quadrats ($p<0.05$, ANOVA). Lichens and *E. vaginatum* had greater biomass in unburned plots ($p<0.05$, ANOVA).

Caribou appear to select sites to crater based on a combination of the following: the presence of soft, shallow snow, the presence of lichens and *E. vaginatum*, and a minimal amount of bryophytes. Observations suggest that caribou my detect and crater for burned lichens. Fire history has little or no effect on snow cover, but it reduces the occurrence and biomass of early spring forage species and lichens, and increases the occurrence of bryophytes and other species that are not used by caribou in spring.

Keywords: Alaska/ caribou/ snow/ tundra fires/ winter range/ Rangifer.

95. Schaefer, James A. Fire and woodland caribou. Winnipeg, Manitoba, 31 Oct 1984.

Note: Paper presented at the Northern Studies Symposium, University of Manitoba, Winnipeg. Information about the paper derived from ASTIS bibliographic database. Document not seen by ASTIS; citation from Northern Scientific Training Program Bibliographies. Abstract attributed to the author.

Abstract: This project seeks to determine the effects of wildfire on woodland caribou through an intensive investigation of the range of a known population of woodland caribou. Taiga range is being appraised by estimating the relative capacities of recently-burned (i.e. 1980) woodland and by mature habitats able to support caribou, and by quantifying patterns of caribou habitat utilization. The summer and fall of 1984 were devoted largely to estimating productivity within the study area.

Keywords: Canada/ caribou/ fire/ habitat use/ taiga / Rangifer.

96. --- 1988. Fire and woodland caribou habitat in southeastern Manitoba. Pages 163-165 *in* Cameron, Raymond D.; Davis, James L., and McManus, Laura M., eds. Proceedings of the third North American caribou workshop. Chena Hot Springs, Alaska, 1987. Wildlife Technical Bulletin. No. 8. Alaska Dept. of Fish and Game. Juneau, Alaska.

Note: Expanded abstract; reproduced in its entirety.

Abstract: The effects of fire on the Aikens Lake population of woodland caribou (*Rangifer tarandus caribou*) were studied over a 2-year period. The population had been studied intensively (Stardom 1975, Darby and Pruitt 1984) prior to a 1980 fire which essentially consumed its entire pre-fire range. Appraisal of habitat was the primary objective of this study: quantity, quality, and

accessibility of forages were estimated in recently burned (5-year) stands, and compared with those in intermediate (37-year), and old-growth (>90-year) condition. Appraisal measurements were correlated with patterns of habitat utilization by caribou over 2 winters.

Comparative range evaluation was based on a vegetation map depicting 4 strata of upland plant communities. Productivity of forage was determined in each community by harvesting and weighing the current growth of vascular plants and the standing crop of arboreal and terrestrial lichens. Relative quality of forages in summer and winter was inferred from (1) published digestibility studies of *Rangifer*, and (2) the relationship between digestibility and content of acid detergent fiber.

Estimating the relative accessibility of forage consisted of 2 aspects: snow conditions and the density of windfallen trees (deadfalls). Standard snow profiles were obtained over 2 winters to calculate values of the Varrio Snow Index (VSI); straightline transects were established to tally the intersection rate and stacking height of windfallen trees.

Results indicate that burned habitats have undergone a decline in the quality and accessibility of winter forages due to the combustion of *Cladina* lichens, an increase in snow thickness and hardness, and the accumulation of deadfalls. These alterations imply increased energetic costs for caribou to obtain the more scattered and less accessible forage after fire.

Overwintering Aikens caribou exploited the remnant lichen supply, but abandoned their burned range in late winter. Five and one-half years after fire, the population occupied an area entirely exclusive of its pre-fire range and essentially outside the 1980 burn. A synergistic effect of snow accumulation and windfallen trees is implicated. The effects on caribou distribution can be modeled with an evaluative index that combines VSI and deadfall frequency.

In the oldest growth stands (160 years), lichen and vascular plant abundance was diminished. Yet these habitats exhibited the most favorable nival conditions and may be important refuges during late winter.

This study underscores earlier contentions that both short- and long-term effects should be considered when evaluating the impacts of fire on caribou habitat. Taiga range is unsuitable for woodland caribou in its early and intermediate successional stages (up to 50 years following fire); yet periodic fire may be necessary to maintain optimal lichen resources. Moreover, the eventual effects of burning may not be immediately evident. Fires frequently leave unburned or partially burned inclusions which provide some remnant lichen forage, and because deadfalls will not accumulate for a few years, the detrimental effects of fire may not be fully realized for at least 5 years after a burn.

For woodland caribou, abandonment of range appears to be the fundamental adaptation to burning of their taiga habitats; thus, local fire history must be considered in the development of a management strategy. Current knowledge suggests that an average of 4 km^2 of sufficiently mature (>50 years old) winter habitat is required for each woodland caribou. Protection of range from fire may be necessary if alternative, lichen-dominated stands are unavailable.

The author wishes to thank the Canadian Committee of the 4th International Reindeer/Caribou Symposium whose travel grant made possible the presentation of this paper.

Literature Cited:

Darby, W.R. and W.O. Pruitt, Jr. 1984. Habitat use, movements and grouping behavior of woodland caribou, *Rangifer tarandus caribou*, in southeastern Manitoba. Can. Field-Nat. 98:184-190.

Stardom, R.R.P. 1975. Woodland caribou and snow conditions in southeast Manitoba. Pages 324-341 in J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White, eds. Proc 1st Intl.

Reindeer/Caribou Symp. Biol. Pap. Univ. of Alaska, Fairbanks. Spec. Rep. No. 1.

Keywords: Canada/ caribou/ fire/ caribou forage/ lichens/ *Rangifer*/ snow/ winter range.

97. ---. 1987. Fire and woodland caribou (*Rangifer tarandus caribou*): An evaluation of range in southeastern Manitoba. University of Manitoba. Winnipeg, Manitoba.

Note: M. Sc. Thesis. Citation and abstract from ASTIS bibliographic database.

Abstract: The effects of fire on the Aikens Lake population of woodland caribou were studied over a two-year period. Quantity, quality, and accessibility of forage were determined in recently-burned (5-year old) habitats, and compared to those in intermediate (37 years) and old-growth (90+ year) condition. These measures were correlated to patterns of habitat utilization by Aikens caribou over two winters. Forage productivity was determined by harvesting current growth of vascular plants and biomass of lichens. Quality of forage was inferred from content of acid detergent fibre and published digestibility studies of *Rangifer*. Accessibility of forage was estimated from the Varrio Snow Index (VSI), and from intersection frequency of windfallen trees. Burned habitats have suffered a decline in the quality and accessibility of winter forages due to the loss of *Cladina* lichens, the increase in snow thickness and hardness, and the accumulation of deadfalls. The oldest stands (160 years) showed decreased forage abundance but the most favorable nival conditions. Aikens caribou exploited the remnant lichen supply within the burn, but abandoned burned range in late winter; a synergistic effect between the accumulation of snow and deadfalls is implicated. This behavior can be modeled with an index that combines VSI and deadfall frequency.

Keywords: boreal forest/ Canada/ caribou/ caribou forage/ deadfall/ fire ecology/ lichens/ *Rangifer*/ snow.

98. Schaefer, James A. and Pruitt, William O. Jr. 1991. Fire and woodland caribou in southeastern Manitoba. Wildlife Monographs. 116:1-39.

Abstract: The effects of fire on the Aikens Lake population of woodland caribou (*Rangifer tarandus caribou*) were studied over a 2-year period. Quantity, quality, and accessibility of forages were determined in recently-burned (5-yr-old) habitats and compared to those in intermediate (37 yrs) and old-growth (90-160 yrs) stands. These measures were correlated with patterns of habitat use by Aikens caribou over 2 winters. Forage productivity was determined by harvesting the current growth of vascular plants and standing crop of arboreal and terrestrial lichens. Quality of forage was inferred from the content of acid detergent fiber and published digestibility studies of *Rangifer*. Accessibility of forage was estimated from the Värriö Snow Index, including hardness and thickness of snow cover, and from the intersection frequency of windfallen trees. Principal components analysis revealed that original floristic distinctions between jack pine (*Pinus banksiana*) and mixed forest communities persisted after fire. Compared to old-growth stands (90 yrs), most burned upland habitats exhibited enhanced productivity of summer forages but a decline in quality and accessibility of winter forages. This deterioration of winter habitat for caribou resulted from the loss of lichens (*Cladina* spp.) in the predominant jack pine communities, the increase in both thickness and hardness of snow cover, and the accumulation of deadfalls. The oldest stands (160 yrs) showed the lowest forage productivity, including lichens, but had the most favorable nival conditions. Caribou winter travel and feeding were significantly skewed towards use of lakes, old-growth uplands and bogs, and away from burned uplands. In both winters of study, Aikens caribou continued to exploit the remnant lichen supply in old-growth bogs and crown-burned habitats within the limits of the 5-year-old burn. In late winter, however, caribou shifted their activity entirely outside the recent burn in favour of stands GTEQ55 years old. The heightened accumulations of snow and deadfalls are implicated in this late-winter range abandonment. The winter range of the population, 5.5 years after fire, was

mutually exclusive with its prefire range. Taiga in southeastern Manitoba is not suitable for woodland caribou in its recently-burned and intermediate stages (up to 50 yrs following fire). Yet fire may be necessary to maintain optimal, long-term lichen resources. Due to the remnant lichen supply in burned areas and the delay in the accumulation of windfallen trees, the short-term detriments of fire may not be fully realized until 5 years or more after burning. Woodland caribou adapt to these short-term effects by abandoning their range. Local fire history--in particular, proximity to alternative, lichen-rich stands--must be considered in the management of woodland caribou habitat.

Keywords: Canada/ caribou/ forest fires/ jack pine/ lichens/ *Rangifer*/ snow/ taiga.

99. Schimmel, Johnny and Granstrom, Anders. 1996. Fire severity and vegetation response in the boreal Swedish forest. Ecology 77 (5):1436-1450.

Note: Excerpts from abstract reproduced below

Abstract: variation in depth of burn will have a long-lasting impact on the vegetation; The precise response patterns of boreal vegetation in burn depth will depend on characteristics of the species present; The results indicate that in boreal forest, depth of burn is a more important variable than fire front intensity for the understory vegetation, in contrast to the situation in ecosystems with little accumulation of organic material on the mineral soil

Keywords: boreal forest/ burn depth/ disturbance/ fire intensity/ regenerating strategies/ seed bank

100. Scotter, George Wilby. 1967. Effects of fire on barren-ground caribou and their forest habitat in northern Canada. Trans. N. Amer. Wildl. Nat. Resour. Conf. 32:246-259.

Note: Check original publication before citing this reference.

Abstract: The destruction of winter rangelands by fire has been suggested by several writers as one possible cause for the decline of the caribou herds. This study evaluates the effects of fire on four key wintering areas within the coniferous forest, or taiga, of northern Canada. It was begun by the writer for the Canadian Wildlife Service in 1959 as part of an intensive caribou research project. Some of the primary objectives of the study, as reported here, were (1) to determine what portion of the winter range has burned and whether the amount has increased in recent years, (2) to determine the effects of fire on the usable standing crops of terrestrial forage and arboreal lichen, and (3) to determine the effects of fire on range use by barren-ground caribou and moose (*Alces alces*). Although damage by fire to winter range of caribou occurred before the white man came to North America, the increased rate of forest destruction by fire accompanying settlement and exploitation, as well as possible changes in the summer weather patterns, has contributed to the loss of habitat for barren-ground caribou. Fires adversely effect the standing crop of both terrestrial and arboreal forage utilized by the caribou. Lichens appear to be more seriously affected by fire than other forage plants because of their slow growth rates. In considering only two big-game species, fire appears to reduce the quantity of winter range for barren-ground caribou and improve it for moose on upland forests of the study areas. Based on the pellet group data collected during this study, the biomass of caribou per acre of mature forest appears higher than that of moose on early subclimax forests on upland sites. Thus in terms of meat production, the upland forests may be best suited to barren-ground caribou use. Referring to the winter range of caribou in interior Alaska, Leopold and Darling (1953a) wrote, ...fire had played so dominant a part in destroying the lichen range that we feel quite safe in attaching to that one factor the major blame for caribou decrease (quote). Research data from northern Canada may not justify the same bold conclusion. Data are insufficient to determine the extent to which forest fires have influenced directly the recent decline of the barren-ground caribou population. With the effect of fire on the standing crop of forage, plant succession, and animal use there can be little doubt that forest fires

have been one of the principal causes of the decline. Regardless of the reason for the recent decline, the present winter range, with its vast fire-destroyed areas, will not permit a large increase in numbers for several years. The reduced carrying capacity of the winter range does not appear to be the factor limiting the caribou population at the present low levels, however. And yet it may well have been the factor which caused the reduction of caribou numbers until men, wolves, and other factors were effective in maintaining the population at low levels. More prevention and control of forest fires would seem desirable in light of the small caribou population and the long-term destruction of winter range by fire.

Keywords: arboreal lichens/ Canada/ caribou/ forest fires/ *Rangifer*/ winter range.

101. ---. 1968. Effects of forest fires on the lichen winter habitats of barren-ground caribou in northern Canada. Utah State University. Logan, Utah. 136 pp.

Note: Ph.D dissertation.

Abstract: The devastation of the winter habitat by forest fires has been suggested as a possible cause of the caribou decline. Four areas in northern Canada were selected for studying the effects of fire on lichen rangelands. A literature review, forest cover maps, fire control records, and examinations of the forests themselves indicate that fire is a natural phenomenon and not a new factor in the ecology of the region. During a period that extended from 1961 through 1964 there were 1,250 known forest fires that burned over 5,005,872 acres of potential winter range. The cover-map data on forest age classes suggested that the amount of destruction in recent years has increased 1.4 times over the three age classes from 16 to 75 years of age, where the annual rate of fire destruction was almost constant, and 3.1 times over the 76-120-year age class. Destruction rate in the three age classes from 16 to 75 years of age was 2.2 times greater than in the 76 to 120-year age class.

The standing crop of usable forage was determined for six forest age classes. The average standing crop of usable air-dried forage was 177, 348, 589, 752, 783, and 1,085 pounds per acre in the 1 to 10, 11 to 30, 31 to 50, 51 to 75, 76-120, and 120-plus-year age classes. The standing crop of high-value lichens in the same age classes was 1, 15, 147, 319, 291, and 560 pounds per acre. This reduction of lichens is critical because of their slow succession, their slow growth rates, and their importance as winter forage for barren-ground caribou.

In northern Saskatchewan, the standing crop of arboreal lichens within 10 feet of the ground was estimated to be 605 pounds per acre in mature black spruce forests and 339 pounds per acre in mature jack pine forests. Destruction of these extremely slow-growing plants by fire must be considered a serious loss of caribou winter forage.

Effects of forest fires on chemical and physical soil properties were determined in the northern Saskatchewan study area. Four recently burned-over areas were compared with adjacent areas covered with mature forests. Mid-day summer temperatures at the 1-inch and 3-inch depths in the burned-over soils averaged 10.5 and 9.8 degrees Fahrenheit higher than the temperatures under unshaded areas in mature forests. Erosion following fire was slight. Total exchange capacity decreased on three of the four burned-over soils, when compared with those of mature forests. Exchangeable hydrogen was reduced and available phosphorus increased on each of the burned-over soils. Exchangeable calcium increased on three of the four burned-over soils. On the burned-over areas, acidity decreased at 1-inch depths and 3-inch depths.

Burning did not affect all game populations alike as shown by the densities per acre of barren-ground caribou and moose pellet groups. In forests over 120 years old, 722 caribou pellet groups per acre were found compared with only 18 per acre on the 1 to 10-year age class. There were 49 moose pellet groups per acre in the 11 to 30-year age class and only three per acre in forests over 120 years old. Moose apparently preferred habitats in early stages of succession while barren-

ground caribou favored those in later stages of succession.

Because of the effects of fire on the standing crop of forage and plant succession, there can be little doubt that forest fires were one of the principal causes of the decline in caribou numbers. More prevention and control of forest fires would seem essential to increasing caribou numbers to a high level.

Keywords: Canada/ caribou/ forest fires/ jack pine/ lichens/ biomass/ *Rangifer*/ winter range.

102. -- 1964. Effects of forest fires on the winter range of barren-ground caribou in northern Saskatchewan. Wildlife Management Bulletin. Series 1. No. 18. National Parks Branch, Dept. of Northern Affairs and National Resources, Ottawa. 111 pp.

Note: No abstract; summary and conclusions section reproduced below.

Abstract: 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, than 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.

Keywords: arboreal lichens/ biomass/ boreal forest/ Canada/ caribou/ fecal pellets/ fire/ fire history/ forest fires/ lichens/ population decline/ post-fire succession/ *Rangifer*/ soils/ wildlife/ winter range.

103. --- 1978. Fire and caribou in northern Canada. Pages 12-13 *in* Dube, D. E., eds. Proceedings - Workshop on fire ecology in resource management. Edmonton, Alberta, 6 Dec 1977-7 Dec 1977. Information Report. NOR-X-210. Northern Forest Research Center.

Note: Report reproduced in its entirety.

Abstract: The devastation of the winter habitat by forest fires has been suggested as a possible cause of the decline of barren-ground caribou. Four areas in northern Canada were selected for studying the effects of fire on lichen rangelands. A literature review, forest cover maps, fire control records, and examination of the forests themselves indicate that fire is a natural phenomenon and not a new factor in the ecology of the region. During a period that extended from 1961 through 1964, there were 1,250 known forest fires that burned-over 5,005,872 acres of potential winter range. The cover-map data on forest age classes suggested that the amount of destruction in recent years has increased.

The standing crop of usable forage and high-value lichens was determined for six forest age

classes. Destruction of the extremely slow-growing arboreal lichens by fire must be considered a serious loss of caribou winter forage.

Burning did not affect all game populations alike, as shown by the densities per acre of barren-ground caribou and moose pellet groups. In forests over 120 years old, 722 caribou pellet groups per acre were found compared with only 18 per acre on the 1- to 10-year age class. There were 49 moose pellet groups per acre in the 11- to 30-year age class and only three per acre in forests over 120 years old. Moose apparently preferred habitats in early stages of succession, but barren-ground caribou favored those in later stages of succession.

[references provided, mostly consisting of Scotter's previous reports, but not reproduced here].

Keywords: Canada/ caribou/ fire/ lichens/ *Rangifer*/ winter range.

104. --- 1972. Fire as an ecological factor in boreal forest ecosystems of Canada. Pages 15-24 *in* Fire in the environment symposium proceedings. Denver, Colorado, 1 May 1972-5 May 1972. USDA Forest Service.

Note: Portions pertaining to caribou or lichens reproduced below. Paper includes 7 photographs of different stages of forest succession.

Abstract: Bryophytes and Lichens: Bryophytes are abundant in the boreal forest region, reproducing by spores or vegetatively. Species such as *Ceratodon purpureus*, *Polytrichum commune, P. juniperinum*, *P. piliferum*, and *Marchantia polymorpha* invade burned-over areas rapidly following fire.

Lichens, which are highly flammable when dry, add to the fire hazard in upland sites. Lichen colonization following a fire is initiated by crustose species soon after a fire, but many of the forge species important for caribou and reindeer require several years for regeneration. The presence of arboreal lichens adds to the susceptibility of the trees to destruction by fire.
Wildlife: Effects of fire on animals are both direct and indirect. Direct effects involve destruction or injury of animals which is dramatic but less important than destruction of habitat. It is necessary to remember that faunal succession exists just as does plant succession. There is an optimum habitat for every animal and that habitat is restricted to a particular stage of plant succession. Therefore both the short-term and long-term effects of fire on animals should be considered.

As already suggested, fires influence animals by killing individuals but this is seldom, if ever, an important influence on the population as a whole. Reliable data on direct loss of animals because of wildfire in the boreal forest do not appear to be available.

Indirect short-term effects of forest fires are caused by the reduction of food and shelter for many animals. As a consequence there can be a shortage of food for species favoring early successional stages for a short time or for the so called "climax species" such as caribou for a much longer period of time.

Following the period when food and shelter are deficient, there may be great increases in forage production which is superior in quality to that found in mature forests. For example, the crude protein content of browse species, collected by the author from near the east arm of Great Slave Lake, was always higher in recent burns than in mature forests adjacent to burns. ...

... While fires create a habitat that is favorable to species preferring early and middle successional stages of forest succession, it adversely affects the habitat of "climax species" such as barren-ground caribou. Caribou normally feed during the winter on foliose (?) lichens such as *Cladina mitis*, *C. alpestris*, and *C. rangiferina*. Such lichens form the principal, but by no means the total

forage, of these animals during the winter months. Recovery of these lichens following fire is exceedingly slow and has been reviewed by Scotter (1964, 1967, 1971). In addition, arboreal lichens, such as *Alectoria* spp. and *Usnea* spp., are an important source of forage for caribou, particularly during the late spring or periods when snow is deep or crusted (Scotter 1964). Despite the fact that fire has the potential of markedly reducing the carrying capacity of the lichen winter range for supporting barren-ground caribou, there is little evidence that caribou numbers are presently being limited by the amount of winter forage available.

Fires are not detrimental to all caribou habitat. In the southern limits of the barren-ground caribou's winter range, fire sometimes destroys thick carpets of bryophytes in upland forests thereby making them more productive for lichens and other forage plants. Fires also improve certain muskeg areas by destroying *Sphagnum* spp. and other bryophytes which are replaced with forage more preferred by caribou. Ahti and Hepburn (1967) suggested that lichen supply could be increased for caribou in the northern boreal lichen belt of Ontario by burning *Sphagnum fuscum* peatlands, treeless bogs, or wooded muskegs; and farther south by burning the black spruce-feather moss forests and black spruce muskegs.

Literature Cited:

Ahti, T. and R.L. Hepburn. 1967. Preliminary studies on woodland caribou range, especially on lichen stands in Ontario. Res. Rpt. (Wildl.) No. 74, Ontario Dept. of Lands and Forests. 134 pp.

Scotter, G.W. 1964. Effects of forest fires on the winter range of barren-ground caribou in northern Saskatchewan. Can. Wildl. Serv., Wildl. Mange. Bull. Ser. 1, No. 18.

_____. 1967. Effects of fire on barren-ground caribou and their forest habitat in northern Canada. Trans. North Amer. Wildl. Nat. Res. Conf. 32:246-259.

_____. 1971. Fire, vegetation, soil, and barren-ground caribou relations in northern Canada. Pages 209-230 in Slaughter, C.W., R.J. Barney, and G.M. Hansen, eds. Fire in the northern environment - a symposium. Pac. NW For. Range Exp. Sta.

Keywords: Canada/ caribou/ fire/ forest fires/ lichens/ post-fire succession/ wildlife/ Rangifer.

105. --- 1971. Fire, vegetation, soil, and barren-ground caribou relations in northern Canada. Pages 209-226 *in* Slaughter, C. W.; Barney, Richard J., and Hansen, G. M., eds. Fire in the northern environment - a symposium. University of Alaska-Fairbanks, 13 Apr 1971-14 Apr 1971. U.S. Forest Service Pacific Northwest Forest and Range Experiment Station. Portland, Oregon.

Note: Abstract and conclusions reproduced below.

Abstract: The devastation of the winter habitat by forest fires has been suggested as a possible cause of the decline of barren-ground caribou. Four areas in northern Canada were selected for studying the effects of fire on lichen rangelands. A literature review, forest cover maps, fire control records, and examination of the forests themselves indicate that fire is a natural phenomenon and not a new factor in the ecology of the region. During a period that extended from 1961 through 1964, there were 1,250 known forest fires that burned-over 5,005,872 acres of potential winter range. The cover-map data on forest age classes suggested that the amount of destruction in recent years has increased.

The standing crop of usable forage and high-value lichens was determined for six forest age classes. Destruction of the extremely slow-growing arboreal lichens by fire must be considered a serious loss of caribou winter forage.

Burning did not affect all game populations alike as shown by the densities per acre of barren-

ground caribou and moose pellet groups. In forests over 120 years old, 722 caribou pellet groups per acre were found compared with only 18 per acre on the 1- to 10-year age class. There were 49 moose pellet groups per acre in the 11- to 30-year age class and only three per acre in forests over 120 years old. Moose apparently preferred habitats in early stages of succession, but barren-ground caribou favored those in later stages of succession.

Conclusions: Although fire damaged winter range of barren-ground caribou before white man came to North America, its destruction rate has increased with the growth of settlement and exploitation. In addition, changes in the summer weather pattern may have contributed to the loss of potential habitat. Fires adversely affect the standing crop of terrestrial and arboreal forage, apparently affecting lichens more seriously than other forage plants because their reestablishment is delayed and their growth rates are slow.

Fire appears to reduce the winter range for barren-ground caribou and increase it for moose on upland forests studied. The biomass of caribou per acre of mature forest appears higher than that of moose on early subclimax forests on upland sites. Thus, for meat production, the upland lichen forests may be best suited to barren-ground caribou.

Research data from northern Canada are insufficient to determine the extent to which forest fires have directly influenced the recent decline of the barren-ground caribou population. But forest fires so affect the standing crop of forage, plant succession, and animal use that they may have been among the principal causes of the decline. The present winter range, with its vast fire-destroyed areas, will not permit an increase in numbers to the level of 60 or 70 years ago. Reduced potential carrying capacity does not appear to be the factor limiting the caribou population to the present low levels yet may have reduced it to the point at which men, wolves, and other factors could keep the numbers low.

Keywords: Canada/ caribou/ fire/ lichens/ moose/ *Rangifer*.

106. Scotter, George Wilby* 1965. Study of the winter range of barren-ground caribou with special reference to the effects of forest fires. Progress Report. 3. Canadian Wildlife Service, Edmonton. 81 pp.

Note: Citation from BOREAL bibliographic database.

Abstract: Studies in northern Saskatchewan and Manitoba.

Keywords: boreal forest/ Canada/ caribou/ forest fires/ *Rangifer*/ reindeer/ wildlife.

107. Scotter, George Wilby 1971. Wildfires in relation to the habitat of barren-ground caribou in the taiga of northern Canada. Pages 85-105 *in* Komarek, E. V., eds. Proceedings Annual Tall Timbers Fire Ecology Conference: No. 10. Fredericton, New Brunswick, Canada, 20 Aug 1970-21 Aug 1970. Tall Timbers Fire Ecology Conference. 10. Tall Timbers Research Station. Tallahassee, FL, 336.

Abstract: NO ABSTRACT AVAILABLE. SECTIONS INCLUDE: The Study Areas; Methods (Survey of History and Extent of Forest Fires, Determining Effects of Fire on the Standing Crop of Forage, Determination of Range Use by Caribou and Moose); Results (History and Extent of Fires on Caribou Ranges, Effects of Fire on the Forage Supply, Effects of Fire on Range Use by Caribou and Moose); Discussion; and Conclusions.

FROM THE TEXT: The Canadian Wildlife Service's intensive caribou research program included an evaluation of the effects of fire on four key upland wintering areas within the taiga. Some primary objectives were: (1) to determine the portion of burned winter range and whether it has increased in recent years; (2) to determine the effects of fire on the usable standing crops of

terrestrial forage and arboreal lichens; and (3) to determine the effects of fire on range use by barren-ground caribou and moose (*Alces alces*).

FROM THE CONCLUSIONS: Although damage by fire to winter range of barren-ground caribou occurred before the white man came to North America, the increased rate of forest destruction by fire accompanying settlement and exploitation, as well as possible changes in the summer weather pattern, has contributed to the loss of potential habitat. Fires adversely affect the standing crop of both terrestrial and arboreal forage utilized by the caribou. Lichens appear to be more seriously affected by fire than other forage plants because of their delay in re-establishment and slow growth rates. In considering only two big-game species, fire appears to reduce the quantity of winter range for barren-ground caribou and improve it for moose on upland forests of the study areas. Based on the pellet group data collected during this study, the biomass of caribou per acre of mature forest appears higher than that of moose on early subclimax forests on upland sites. Thus, for meat production, the upland lichen forests may be best suited to barren-ground caribou. Referring to the winter range of caribou in interior Alaska, Leopold and Darling (1953a) wrote . . . fire had played so dominant a part in destroying the lichen range that we feel quite safe in attaching to that one factor the major blame for caribou decrease. Research data from northern Canada may not justify the same bold conclusion. Data are insufficient to determine the extent to which forest fires have influenced directly the recent decline of the barren-ground caribou population. With the effect of fire on the standing crop of forage, plant succession and animal use there can be little doubt that forest fires may have been one of the principal causes of the decline. Regardless of the reason for the recent decline, the present winter range, with its vast fire-destroyed areas, will not permit an increase in numbers to the level of 60 or 70 years ago. However, the reduced potential carrying capacity of the winter range does not appear to be the factor limiting the caribou population to the present low levels. And yet it may well have been the cause of the reduction of caribou numbers until men, wolves, and other factors were effective in maintaining the population at low levels.

Keywords: boreal forest/ Canada/ caribou/ distribution/ fire history/ forest fires/ habitat types/ *Rangifer*/ wildlife/ winter range.

108. Sharpe, M. 1986. Post-fire succession in the lichen woodlands of the Schefferville area, Quebec. McGill University. Montreal, Quebec.

Note: B. Sc. Thesis.

Abstract: The post-fire recovery sequence in 21 spruce-lichen woodland and spruce-moss stands in the Schefferville area, Quebec is described. Black spruce was the dominant species in the woodlands (69% of the basal area) while white spruce was more abundant in the closed forests (67%). Seven of the woodland stands were over 150 yrs of age, while four were over 200 yrs, indicating a relatively long fire cycle. Early successional sites (up to 150 yrs) were characterised by *Ledum groenlandicum*, *Betula glandulosa*, *Vaccinium angustifolium*, *Cladonia deformis*, and a relatively high proportion of *Larix laricina* and *Picea mariana*. Mature woodlands were dominated on the ground by *Cladina stellaris*, with *Cladina mitis*, *Cladina rangiferina*, *Empetrum nigrum*, *Stereocaulon paschale*, and *Dicranum fuscescens* also present. In the spruce-moss stands, the lichens are replaced by the mosses *Hylocomium splendens*, *Ptilium crista castrensis*, and *Polytrichum* spp. The lichen woodlands in the Schefferville area maintain their open structure despite the low fire frequency. Some of the spruce-moss stands may have succeeded from woodlands through increasing canopy closure, but most probably represent fast growth and early divergence from the woodland successional sequence.

Keywords: Canada/ fire ecology/ lichens/ post-fire succession/ taiga.

109. Sirois, Luc and Payette, Serge. 1991. Reduced postfire tree regeneration along a boreal forest-forest-tundra

transect in northern Quebec. Ecology. 72(2):619-627.

Abstract: The large 1950s fires that burned > 5500 km² of land across a south-to-north climatic gradient in northern Quebec provided an opportunity to evaluate the role of fire in forest-tundra development on a demographic basis. The tree population density before and ~30 yr after fire was estimated by censusing trees in plots of 400 m² located in upland and lowland within four representative ecoregions of northern Quebec. The analysis of tree recruitment before and after fire, in 410 randomly selected sites along a transect crossing the upper boreal forest and forest-tundra zones, indicated that wildfires induced substantial depletion of tree populations. Taken as a whole, fires have significantly reduced the density of black spruce populations in forest-tundra uplands, but not in the lowlands. A reduction in tree population density of GTEQ 75% was observed in 22% of upper boreal forest sites, and 45% and 93% of sites located in the forest and shrub subzones, respectively, of the forest-tundra zone. Complete excursion of tree populations by fire was observed in 43% of upland sites in the northern part of the transect, while complete removal was a rare event in the southern part. Sustained reduction of tree population density after several destructive fires appears as one of the main deforestation processes in the subarctic zone. This leads to the patchy distribution of forest stands and scattered tree populations typical of the forest-tundra biome. Comparisons with paleoecological data suggest that the impact of the 1950s fires contributed to the expansion of the forest tundra into the upper boreal forest. The ecological impact of these fires was probably similar to those fires responsible for development of the forest tundra during the Holocene. It is suggested that the fire-climate interaction should be considered in order to predict the ecological impact of warming climate on high-latitude forest ecosystems.

Keywords: Canada/ climatic change/ deforestation/ forest fires/ forest tundra/ lichen woodland/ *Picea*/ post-fire succession/ subarctic.

110. Skoog, Ronald Oliver. 1968. Ecology of the caribou (*Rangifer tarandus granti*) in Alaska. University of California, Berkeley. Berkeley, California. 699 pp.

Note: Ph.D. dissertation. Includes information on many aspects of caribou ecology, and focuses on the Nelchina Herd (reflected in abstract). Abstract and section related to fire reproduced below.

Abstract: Alaska's caribou population consists of six regional subpopulations and eleven herds. For each region the author hypothesizes a center of habitation, which consists of optimal caribou habitat, supports the main herd, and acts as a focal point for population buildup and dispersal. As density increases the movements become more erratic and extensive, and the animals begin to utilize marginal areas. If other population "controls" are not evoked, eventually an emigration to other regions occurs. After the decline, remnant herds may be found in certain portions of the region, but the main sub-population remains at the center. A herd is defined as any group of caribou which uses one calving area repeatedly over a period of years, distinct from the calving area of any other group. An historical review of caribou distribution and numbers revealed a considerable flux of animals between all six regions. It was believed that the population shifts noted merely reflected the normal vagility of this species, which becomes accentuated at densities between 5 and 10 animals per square mile. Population highs were evident during the 1860's and 1920's, and lows during the 1890's and 1940's. The exact causes for these changes in numbers are not known, but food shortage was not an important factor. Caribou densities have remained far below the carrying capacity suggested by the forage available. The estimate for caribou numbers (calves excluded) in Alaska for June, 1964, was 600,000 animals.

This study was based upon 12 years of field-work, 1952-1964, although the main study period encompassed 1955-1962. Emphasis was placed on the Nelchina herd in southcentral Alaska. The population data obtained from that herd constitute the central theme of this dissertation, and the results are summarized below.

1) The Nelchina range is a highly diversified region, having a variety of climatic conditions and vegetation types and thus offering a number of different habitats to caribou. Twelve major vegetation types have been identified, four of which- Dwarf Birch, Dwarf Heath, Sedge Meadow, and Willow- comprise about 51 per cent of the range vegetation and are of most importance to the caribou. Overgrazed areas are few, and abundant year-round forage remains.

2) The seasonal distribution centers about the traditional calving grounds. With increasing densities the movements have become more extensive, and the herd has split seasonally into several major groups. Excursions outside the normal range have occurred, and a shift in winter-use has occurred to the northwest and east.

3) Sex-ratios were as follows: Secondary (at birth), 51 per cent males; Tertiary (at 12-months), 55 per cent males; Quaternary (at 24-months), 50 per cent males; Quinary (at 10-years+), 23 per cent males. In 1962, males comprised 39 per cent of all animals 1-year+ , 35 per cent of those 2-years+, and 30 per cent of those 3-years+.

4) The peak of rutting activity occurred about October 6. The fertility rate was found to be 72 per cent of all females 1-year+, 84 per cent of those 2-years+, and 89 per cent of those 3-years+. Natality was assumed equal to the fertility rate. The peak of calving occurred about May 25. Each October calves comprised an average of 21 per cent of the herd.

5) During the first year of life, an average of 40 per cent of the calves died; of those, 70 per cent died between June and October. Mortality among animals older than calves averaged 14 per cent annually: hunters, 8 per cent; wolf predation, 2 per cent; and other mortality, 4 per cent.

6) Total numbers increased from 40,000 animals to 71,000, at an average annual rate of 9 per cent. Yearling production averaged 22 per cent. The maximum annual increase for the herd under "natural" conditions (i.e., disregarding hunter losses) would have been 20 per cent.

7) Weather, predation, and emigration were considered to be the main factors controlling caribou numbers in Alaska.

Factors Influencing Movements

Exogenous Factors

Banfield (1954) has discussed in detail the effects of forest fires upon the movements of barren-ground caribou in northern Canada. He noted their avoidance of burned areas during migrations and attributed some of the major population shifts to extensive fires on winter ranges. In Alaska these effects are not so evident, because the principal burned areas are restricted mostly to regions not normally frequented by caribou (i.e., the broad river valleys of the Tanana, Yukon, and Kuskokwim Rivers). In other sections the burns are quite discontinuous in distribution due to the interspersion of extensive alpine areas, tundra, meadows, and wet black-spruce (*Picea mariana*) muskeg. ...

POPULATION CHANGES

Influential Factors

Fire

The devastation by fire of the forests over the interior of Alaska has been widespread. Lutz (1956) reviewed thoroughly the fire history in this region since the intrusion of the white man, and concluded (p. 14-15) that at least 2,000 square miles of spruce forest burned annually between 1898 and 1955. From his account it is evident that most of the interior forests have burned at least once in that time. Leopold and Darling (1953: 56-57) noted that about 80 per cent of the white spruce (*Picea glauca*) had been burned. One might suppose a similar proportion of the extensive black spruce stands has burned as well, although the frequently wetter sites probably would make this species less vulnerable. Nevertheless, no one flying over the interior of Alaska can help but be impressed with the vast acreage that has been touched by fire in recent times.

Most of the extensively burned sections of Alaska, however, occur in lowland areas not used commonly by caribou, such as the river valleys of the Kuskokwim, Yukon, Porcupine, Tanana, and Susitna Rivers, plus their associated "Flats." Other areas have been burned also, of course, but these usually are not extensive in terms of linear miles, and thus are not necessarily barriers to caribou movements. Nelchina caribou, for example, commonly traverse burned sections on the Lake Louise Flat, and, lately, along the Copper River. Similar movements by caribou of the Fortymile herd (Region V) also have been observed by the writer. In Alaska, the wide interspersion of alpine areas, rivers, lakes and bogs limits both the extent and the effects of fire on the main caribou ranges. A vast area remains untouched by fire on the arctic slopes, along the Brooks and Alaska Ranges, in the highlands of Regions V and VI, and in other alpine/tundra areas. The only instances where extensive tundra fires are known to have occurred were on the Seward Peninsula during the late 1890's and early 1900's, and these caused severe damage to the lichen cover near the mining operations (Jackson, 1898-1904). Elsewhere the tundra seems to have been unaffected; the alpine areas also have been immune, because the fires invariably stop at or near timberline. In addition there are numerous stands of spruce scattered throughout interior Alaska, which for some reason have escaped, and continue to support excellent stands of lichen. By far the most valuable supply of lichens in interior Alaska, however, occurs in the wide-spread dwarf birch (*Betula glandulosa*) zone lying immediately above timberline, on the gentle alpine slopes. My travels throughout all six caribou regions of Alaska have indicated that there remains abundant winter forage, in spite of the loss due to fire. Much of this forage occurs in areas not being utilized by caribou at present. Perhaps a brief account of each of the six regions would be desirable.

The Alaska Peninsula (Region I) has not been affected much by fire because the forested areas are limited mostly to north of the Naknek River system. The caribou herd has remained south of this line since prior to 1900. Practically the entire forested area along the Kvichak River, and much along Lake Iliamna, was destroyed by fire in 1935 (Heintzleman 1936: 592; Lutz 1956: 16). In 1960 I noted that the effects of fire were still quite evident and that lichens were particularly scarce. At the same time, however, lush stands of lichens were present along the highlands south of Lake Iliamna to Naknek Lake, which are not being utilized by caribou. The Alaska Peninsula herd winters mostly in the Lake Becharof area to the south, where lichens are rather scarce; the diet is mostly sedge. Farther south, forage lichens are extremely scarce, and the diet is almost exclusively sedges and grasses. The burned area along the Kvichak River and the shores of Lake Iliamna very definitely constitutes a barrier of sorts to caribou movement between the mainland and the Alaska Peninsula, because of the general lack of forage there. There is no indication, however, that caribou ever "tested" this barrier.

In western Alaska (Region II) spruce forest comprises the major vegetation type over much of the area. As one might suppose, fires have been widespread, although mostly limited since the 1940's to the areas surrounding the relatively few towns and mining operations remaining. Black-spruce bogs are rather common and some of these support good lichen stands, especially in the Lake Minchumina area where the McKinley herd frequently winters. Burned sections extend throughout the Kuskokwim Mountains, however, and these may have inhibited a buildup of caribou there. Alpine areas there are limited, and caribou must utilize the spruce forests for part of their subsistence, as the Beaver herd does today. On the other hand, the extensive spruce forest would indicate rather marginal habitat for a sustained, year-round population, and therefore the effect of fire probably is secondary. If the population to the east (center of habitation) were to reach high densities, however, it would require these spruce forests for winter range. At present the potential utilization has been severely restricted because of fire damage. The abundant lichen and sedge stands present along the Alaska Range are more than adequate for the population now.

Northwestern Alaska (Region III) has not been affected much by fire except in the southeastern quadrant. This burned area extends northward from the Yukon River to encompass much of the Koyukuk River valley as far as Bettles. There, extensive fires have occurred periodically during the past 50 years, and the lichen cover generally is poor, as viewed from the air. In spite of that caribou have wintered there several times during the 1960's; presumably the black-spruce bogs

and the alpine areas supplied the forage, which must have been mostly sedges in this case. Extensive stands of lichen are present in the spruce along both sides of the Kobuk River, however, and the herd has been utilizing these since the late 1940's. Fire has been uncommon along the Kobuk. Prior to the 1940's the herd wintered exclusively to the north, frequently on the arctic coastal plain; the animals must have subsisted mostly on sedges, because forage lichens are quite scarce north of the Baird and Endicott Mountains.

Northeastern Alaska (Region IV) has been burned extensively from the Yukon River-Black River-Porcupine River flats northward onto the south slopes of the eastern Brooks Range (southwest quadrant). Fortunately, this section has not been utilized much by caribou in historical times, although once again the potential utilization value has been reduced. Sedge areas remain abundant, however, in the lake-pond-bog terrain. In the Yukon, fires have burned portions of the Old Crow Flats, an important wintering area for these caribou. Perhaps this loss has caused the animals to move into the alpine areas farther south, although these appear to have been utilized frequently in the past anyway. Abundant alpine vegetation remains in this region, and the loss of winter forage by fire thus seems insignificant relative to the population present.

East central Alaska (Region V) was more or less the center for the gold mining industry during the late 1800's and the first 20 years of this century. Fires have been a common phenomenon since prior to 1890. Earlier I had computed (Skoog 1956: 28) the extent of fire damage to the main portion (35,000 square miles) of the Fortymile herd's range; between 1920 and 1955 approximately 20 percent of this area had burned. In addition, of course, much had burned previous to that time as well. In fact, considering the great amount of activity in the region prior to 1920, it seems likely that fires were more common then. In 1959 a range reconnaissance by the author revealed that many of these old burns were reforested, and in some the forage lichens had returned to rather fair growth (20-50% cover; 1"-2" height). Alpine areas are abundant, but in the Alaska portion of this region lichens are not particularly abundant except in the dwarf birch zone; alpine sedge meadows, however, are numerous. Limited flights over the mountains of adjacent Yukon seemed to indicate a similar vegetation distribution. The rapid increase of this caribou population prior to 1930 during the midst of intense mining activity suggests that fires, hunting, and the other disturbances accompanying this industry development had little effect on numbers or distribution. The northward shift of this population during the 1930's occurred after these disturbances had been reduced considerably. The loss in winter forage due to fires could have been a factor in this shift, although the high population density seems a more likely cause.

Fires in south central Alaska (Region VI) have been limited mostly to the terrain adjacent to the Tanana, Copper, and Susitna Rivers. These areas have not supported permanent caribou populations in historical times, although periodically caribou have passed through them. Large fires on the Kenai Peninsula were thought to have been the principal factor in the loss of caribou there (Palmer 1941). This opinion seems valid, because the limited alpine areas suitable for caribou winter grazing would force the animal to rely heavily upon the spruce forests. On the other hand, as discussed earlier, I consider the Kenai to be a marginal habitat for a sustained caribou population, so perhaps the fires merely hastened what might be considered an inevitable decline. The Lake Louise Flat, extending eastward and southeastward to and beyond the Copper River, has been subjected to widespread fires periodically since before the white man arrived. Glenn stated (Glenn and Abercrombie 1899: 59) as he approached the Lake Louise Flat in 1898, "We entered what we called the 'burned district,' which seemed to extend as far as the country is visible toward the Copper River, and to the northward almost to the Alaska Range... none of the Indians we encountered remembered it as being in any other condition than it is at the present time." He noted, however, the lichen cover and growth were quite good throughout the Flat. Several fires since that time, plus numerous winters of grazing by caribou, have left the lichen cover in rather poor condition; yet there is still abundant forage and the caribou still utilize the Flat for early winter feeding. Elsewhere in the region winter forage is abundant, and excellent lichen stands occur both in the dwarf birch zone and in other alpine areas. A large proportion of this region lies near or above timberline, and hence fires have not significantly damaged the caribou range.

The actual effect of fire upon caribou distribution and numbers is somewhat difficult to evaluate. It is obvious, of course, the animals cannot subsist within recently burned forests (burns less than about 10 years old), except in certain bog/muskeg types. Where the burns are extensive they can inhibit caribou movements. In much of Alaska, however, the irregular topography and the interspersion of fire "barriers" have permitted many areas containing abundant winter forage to escape destruction. These areas, including in particular the alpine/tundra zones, comprise a considerable acreage. This situation is in contrast to much of the rather flat taiga of northern Canada, where fires can sweep for miles across the continuous spruce forests. Additionally one must consider the fact that fire long has been a major factor in the ecology of the boreal forests (Lutz 1956, Scotter 1960), although it is acknowledged as well that the rate of fire destruction increased considerably during the first half of this century due to modern man's activities. Nevertheless, the caribou would seem to be admirably adapted to the irregularities of this destructive "ecological" force by being able to utilize a variety of plant foods and to shift its distribution as necessary to find adequate forage.

One cannot deny that fire destroys valuable winter habitat. By eliminating the forage lichens in spruce forests, fires reduce the potential carrying capacity of the total range. This aspect has been reviewed thoroughly by Leopold and Darling (1953) and by Scotter (1960). Yet, all who have discussed caribou-range relationships have implied that lichens are required by caribou and that the relative abundance of these plants sets the carrying capacity of the range. There seems to be adequate information available to dispute this idea.

[Several pages discussing situations where caribou have survived where lichens were scarce or absent were omitted]

... In conclusion it can be stated that fire has indeed destroyed rather large expanses of potential winter range in Alaska. It must be stressed again, however, that many of the burns are located in areas which caribou have used but infrequently during historical times, even when the population was high. Theoretically, the carrying capacity of the total caribou range has been reduced temporarily due to this destruction of winter forage. In reality, the caribou population seems to have maintained densities much lower than the maximum dictated by food alone, and hence the reduction in total range becomes less meaningful. The fact that Alaska caribou are not dependent upon the lichen growth in spruce forests and can utilize the extensive sedge forage on the tundra, alpine meadows, bogs, and lake-shores greatly mitigates the losses due to fire. The maintained low densities and periodic population shifts have assured an adequate food supply thus far. It is possible that fire has been a factor in the population shifts noted, by causing the animals to seek new food sources in unburned areas. It is doubtful, however, that fire has influenced much the fluctuations in numbers that have occurred, because food has not been the central factor in this case.

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Keywords: Alaska/ boreal forest/ caribou/ caribou distribution/ carrying capacity/ fire/ forest fires/ habitat/ lichens/ migration/ reindeer/ winter range/ Rangifer.

111. ---. 1956. Range, movements, population, and food habits of the Steese-Fortymile Caribou Herd. University of Alaska-Fairbanks. Fairbanks, Alaska. 145 pp.

Note: M. Sc. thesis. Abstract and comments about fire and caribou reproduced below.

Abstract: The Steese-Fortymile caribou (*Rangifer arcticus stonei* Allen) form one of the most economically important herds in Alaska. This study of the herd took place from September, 1952, to December, 1955, under the auspices of the Alaska Cooperative Wildlife Research Unit at the University of Alaska and of the Federal Aid in Wildlife Restoration branch of the United States Fish and Wildlife Service, Project W3R.

The Steese-Fortymile range occupies about 35,000 square miles of east-central Alaska and the Yukon Territory, lying mainly between the Tanana and Yukon Rivers. The terrain is mountainous, but not rugged; roads and towns are scarce, and a maximum of 60,000 people live on the fringes. Seven major plant communities comprise the range vegetation, three of them covering 60 to 70 per cent of the area and furnishing the bulk of the food for caribou. The carrying capacity is computed to be 70,000 to 90,000 caribou.

The erratic and continual movements of caribou characterize this game species. Their movements vary from day to day and season to season. Most of the traveling takes place during the early morning and late afternoon; major seasonal movements take place in the spring and fall. Past and present data provide a general picture of the movement pattern of this herd throughout the year.

The Steese-Fortymile herd dwindled from a peak of about 500,000 animals in the late 1920's to a low of 10,000 to 20,000 in the early 1940's. The decline is attributed to a population shift. The present population contains at least 50,000 animals and is increasing steadily. Reproduction was high during the years 1950 to 1955. The rut takes place during the first two weeks of October; most of the calves are born during the latter half of May, following a gestation period of about 33 weeks. Valuable information on caribou behavior during the calving period is presented. Counts taken in May show that at least 50 per cent of the calves survive the first year. Wolf and man are the most important mortality factors affecting this herd. The total annual mortality, excluding calves, is estimated at eight per cent. Sex and age data from composition counts and hunter-checking-station operations indicate that this herd is young and that the sex ratio approaches 100:100. The annual increment for the herd is computed to be 10 to 15 per cent.

Caribou are cursory feeders and eat a wide variety of plants. The main periods for resting and feeding occur during the middle portions of the day and night. The caribou's diet hinges upon the available food supply, and thus varies with the seasons. In winter, the diet consists mostly of lichens, grasses, and sedges, with browse plants of some importance; data from 23 stomach-samples are presented. In spring, the new shoots of willow, dwarf birch, grass, and sedge are most important; information is based only on field observations. In summer, a wide variety of plants are eaten; willow and dwarf-birch foliage are of greatest importance, followed closely by grasses

and sedges; data from 27 stomach-samples are presented. In fall, the diet shifts from a predominance of woody plants and fungi in late August to one of lichens, grasses, and sedges in late September; data from 70 stomach-samples are presented.

The problems of data-gathering are discussed, as related to management practices. The contributions made by this report are outlined, and the important information still needed for proper caribou management is listed.

Carrying Capacity
... The Steese-Fortymile range grows an abundance of the browse and sedges, but frequent fires during the past half-century have destroyed much of the lush lichen growths once prevalent. Palmer (1941) believes that caribou require at least 50 per cent lichens in their diet for maintenance of condition during the winter months. Because lichens apparently play such an important role during the winter, a caribou on this depleted range needs much more land for forage than does a reindeer in western Alaska.

Palmer (1941) indicated that fair lichen growth formerly occurred on about two-thirds of the Steese-Fortymile range, but that fires since 1900 had burned over, once or twice, about 75 per cent of the lichen forage. This former lichen growth might have been similar to that of western Alaska in 1945. On a range having such a growth, which is considered a lichen index of 1, a caribou requires a maximum of about 85 acres during the winter when on a diet of almost 100 per cent lichens. Fires, however, have reduced the lichen index on the Interior range to .25. Solving the proportion 1/.25=x/85 results in the value of 340 acres as the winter requirement for each caribou of the Steese-Fortymile herd. But a caribou supposedly needs only a 50 per cent diet of lichens, so the winter requirement might then be lowered to 170 acres. The addition of Palmer's estimated summer requirement of 15 acres brings the yearly range requirement of each caribou to 185 acres. The three plant communities which furnish the bulk of the caribou's food cover an area of from 13,400,000 to 16,700,000 acres. Therefore, the range should be able to support in the vicinity of from 70,000 to 90,000 caribou.

This estimate for range capacity arises primarily from Palmer's belief that caribou require at least a 50 per cent lichen diet during the winter. Information from Nunivak Island, however, tends to contradict that belief. There, the reindeer long ago used up the available lichens and now exist largely on a sedge diet during the winter; yet they manage to maintain their vigor. If caribou can live satisfactorily on a winter diet of sedges, the range could conceivably support a denser population than that indicated above. But caribou seem to prefer lichens at that time of year (Palmer 1941), and, not being herded or confined as are the reindeer, may well move to find the plant-type they desire, even if it means finding a new range. Supposedly, a lack of lichens forced caribou from the Kenai Peninsula during the last decade of the nineteenth century, after extensive fires had destroyed most of the lichen growth. Exact information, however, is lacking, and so the problem of the influence of food supply upon the caribou remains for future investigations.

Literature Cited:
Palmer, L.J. 1941. Caribou versus fire in interior Alaska. Unpub. manuscript in files of the U.S. Fish and Wildl. Serve. 14 pp.

Keywords: Alaska/ caribou/ carrying capacity/ fire/ lichens/ reindeer/ Steese-Fortymile Caribou Herd/ winter range/ Rangifer.

112. Spindler, Michael A. 1989. Draft. Distribution and abundance of caribou on Selawik National Wildlife Refuge, Alaska, 1984-1989 . Progress Report SNWR 89-5. Kotzebue, Alaska. 30 pp. (additional 50+ pages of telemetry locations attached).

Note: Draft report, not known if final report produced.

Abstract: The Selawik NWR caribou surveys were conducted primarily to evaluate effects of the Waring Mountains Burn and to assess potential conflicts with possible reindeer grazing. Survey results are presented in four separate sections: (1) distribution, (2) Refuge population estimates, (3) Waring Mountains Burn caribou-fire study, and (4) radio-telemetry. Aerial surveys have shown considerable annual and seasonal variability in extent of caribou distribution and timing of movements. Typically, in the last five years Selawik NWR has been used intensively by caribou for a few months during spring and fall migration as the herd moves between the Utukok River calving grounds and the Nulato Hills wintering grounds. Three prominent routes have been used: (1) from the Noatak River mouth along the north shores of Kobuk Lake and Selawik Lake thence across the western Selawik Flats to the Selawik Hills; (2) from the Squirrel River and Kalarichuk Hills past Kiana to just east or west of Selawik, and thence across the western or central Selawik Flats to the Selawik Hills; and (3) Across the Kobuk River near Onion Portage past Ambler and Shungnak thence parallel to the north-south flowing portion of the Kugarak River, thence across the Kugarak or Rabbit Rivers to cross the Selawik River between Upinigvik and Ingruksukruk Creek, thence either east to Purcell Mountains and the upper Selawik River or south to the upper Huslia River. From radio-telemetry two general types of movements were noted for individual caribou during migration: a "leapfrog" from one intensive use area to another, or a steady, gradual, evenly spaced movement. Population estimation transects showed that Selawik NWR hosted 1%-32% of the total Western Arctic Caribou Herd during migration, depending on the month and year. Maximum number estimated was 72,800 in September 1987. Wintering caribou abundance was much less, with a minimum of about 1,000 and a maximum of about 10,000 using the refuge between mid-November and late February. The Hotham Peak area has wintered caribou in all of the five years of study. The Kuchuk Creek-Kugarak River area and upper Selawik River areas have had wintering caribou in three out of the past five winters.

Transects over the Waring Mountains Burn in 1988-89 showed that September and May caribou densities were similar in the burned and unburned habitats but were more than twice as high in the edge habitat, the border between the burn and unburned area. Density was also highest at the edge in early June, but it was twice as high in the unburned as compared to the burned.

Recommendations for future caribou work were presented.

Keywords: Alaska/ caribou/ fire ecology/ habitat use/ Kobuk River/ migration/ *Rangifer*/ Selawik National Wildlife Refuge/ Selawik River/ taiga/ tundra/ tundra fires.

113. Strang, R. M. 1973. Succession in unburned subarctic woodlands. Canadian Journal of Forest Research. 3:140-143.

Abstract: A preliminary comparison of burned and unburned tracts in the northern boreal forest of the lower Mackenzie River valley indicates that, without periodic fires, trees will be eliminated and the climax vegetation will be a moss/lichen association. The implications for land management are adumbrated.

Keywords: boreal forest/ Canada/ climax vegetation/ fire/ forest management/ lichens/ mosses/ plant associations .

114. Swanson, David K. 1996. Fruticose lichen distribution in the Kobuk Preserve Unit, Gates of the Arctic National Park, Alaska. Technical Report NPS/AFA RNR/NRTR-96/28. National Park Service, Anchorage, Alaska. 22 pp.

Abstract: The distribution of fruticose lichens in the upper Kobuk River valley is strongly influenced by soil conditions and disturbance; lichen cover is highest where disturbance is infrequent and poor soils reduce competition by vascular plants. Lichen cover is low on flooded soils as a result of burial by sediment and enhanced competition by deciduous vascular plants on

rich floodplain soils. Lichen cover is also low on steep mountain slopes as a result of snow avalanche disturbance or dense vascular vegetation. Lichen cover is high on dry, stable infertile soils unless there has been a recent burn. These soils occur mainly on bedrock ridges and on Pleistocene glacial deposits in the study area. Lichen cover increases for at least 100 years after fire on dry, unflooded soils; *Polytrichum* spp. moss and *Cladonia* spp. lichens dominate during the first half-century after fire, while *Cladina rangiferina* and *C. stellaris* lichens dominate thereafter. Wet soils generally have low to moderate lichen cover, probably as a result of competition by mosses and sedges. Exceptions include 1) palsas and peat plateaus, where droughty conditions due to drainage of water into thermokarst pits, and very acid soils allow lichens to dominate; and 2) sloping unforested areas in the lowland forest-tundra ecotone of the western part of the study area, where moss competition is apparently reduced due to lack of a tree overstory.

Keywords: Alaska/ fire/ lichens/ soils .

115. ---. 1996. Susceptibility of permafrost soils to deep thaw after forest fires in interior Alaska, U.S.A., and some ecologic implications. Arctic and Alpine Research. 28(2):217-227.

Note: Vegetation/soils study. Abstract and portion of discussion on vegetation reproduced here.

Abstract: Some soils with permafrost thaw deeply and become drier after forest fires in interior Alaska, while others change little. Soils with permafrost on the coldest and wettest landscape positions (concave to plane, lower slope positions, and north-facing midslopes) usually failed to thaw deeply after fires in the study area. Soils with permafrost on warmer and drier positions (convexities, crests and shoulders, and east-, west-, or south-facing midslopes) thawed deeply in some instances and not in others, presumably as a function of fire severity or frequency. The driest soils (those on convex, upper slope positions, usually with sand and gravel at shallow depth) lack permafrost regardless of time since fire. Postfire vegetation changes on soils that fail to thaw are weaker than on soils that thaw deeply after fire or were dry and originally free of permafrost. Soils with permafrost that fail to thaw show little postfire increase in cover of the plants browsed by moose. More cover and forage for voles are present on soils with permafrost and soils that thaw deeply after fires than on those that are always dry and permafrost free.

Discussion excerpt: In contrast to the vascular plants, the moss-lichen layer on dry sites is heavily impacted by fire and recovers slowly; hence the cover by nonvascular plants 10-50 yr after fire differs markedly from that present >100 yr since fire. This is probably due to the fact that the live mosses and lichens are readily consumed by fire along with the dry surface organic horizons, and then the late-successional species require considerable time to recolonize the area. Black and Bliss (1978) also noted that succession in spruce-lichen woodlands is visible mainly in the moss/lichen layer.

The prefire vegetation on sites that thawed due to fire probably resembled that of the unburned (>100 yr) frozen sites, perhaps with greater abundance of some dry-site plants, such as *Cladina* lichens. Thus comparison of the vegetation on the thawed sites with that of both unburned frozen and unburned dry sites gives some idea of the changes brought about by fire and thaw. Both presumed precursors show moderate similarity to the thawed vegetation, with the dissimilarity concentrated in the nonvascular layer. The deep burns that lead to thaw apparently destroy the moss-lichen layer, and subsequent recovery of that layer is slow. The vascular plants are more similar between the thawed and the two unburned site groups, mainly as a result of rapid resprouting of shrubs and reseeding by black spruce. However, in contrast to the frozen sites, after a fire on thawed sites aspen or birch could become established by seeding, or resprout and spread from old, persisting trees. The changes in soil conditions favoring the growth of these more nutrient- and heat-demanding deciduous trees on thawed sites include the change in soil moisture and temperature regimes due to the thaw itself, as well as the significant release of nutrients after burning of the thick organic surface layer (Dyrness and Norum 1983). As discussed above for dry sites, however, complete replacement of black spruce forest by deciduous forest is unlikely.

Literature cited:
Black, R.A. and L.C. Bliss 1978. Recovery sequence of *Picea mariana-Vaccinium uliginosum* forests after burning near Inuvik, Northwest Territories, Canada. Can. J. Bot. 56:2020-2030.

Dyrness, C.T. and R.A. Norum 1983. The effects of experimental fires on black spruce forest floors in interior Alaska. Can. J. For. Res. 13:879-893.

Keywords: Alaska/ fire/ interior Alaska/ non-vascular plants/ post-fire succession/ soils.

116. Swanson, J. David and Barker, Marilyn H. 1992. Assessment of Alaska reindeer populations and range conditions. Rangifer. 12(1):33-43.

Note: Paper presented at the First Arctic Ungulate Conference, Nuuk, Greenland, 3-8 September 1991. Abstract and paragraph about fire presented here.

Abstract: Populations of reindeer (*Rangifer tarandus*) have fluctuated greatly since their introduction to Alaska in 1891. In the 1930's, reported numbers exceeded 600,000. Presently, 38,000 reindeer graze 6.2 million ha of rangeland and woodland in Western Alaska (from 66° 54'N to 52° 07'N latitude). Condition of winter range producing fruticose lichens (*Cladina rangiferina*, *Cladina arbuscula*, *Cladina stellaris*, *Cetraria cucullata*, *Cetraria islandica*) is of major concern. Monitoring programs have been established for vegetation, fire, reindeer, and wildlife. Reindeer have overgrazed lichen resources on some Bering Sea Islands. Wildfires have had the greatest impact on lichen range depletion on the mainland. Overgrazing has been a problem in localized areas. Moose (*Alces alces*) and muskox (*Ovibos moschatus*) rarely contribute to major lichen depletion. 60-80% of the mainland and 5-30% of most island winter lichen ranges are presently estimated to be in good to excellent ecological condition. Procedures for assessing condition of the lichen ranges are being further refined.

Page 37, information on the Seward Peninsula: Lightning-caused fires in stands yielding high lichen biomass have resulted in loss of lichen forage. For example, in 1977, approximately 360,000 ha of mostly winter lichen range burned. Assessment of those areas two years after the fire revealed that *Calamagrosits canadensis* yielded >3,000 kg/ha (air-dry) annual production. Cover and biomass of *Eriophorum vaginatum* and *Ledum decumbens* have increased; however, to date, lichens have not made any significant recovery. The vegetation on the northern part of the peninsula is characterized by a complex pattern of seral stages as a result of fires. Unburned climax stands of lichens occur in many areas on the peninsula. In unburned and ungrazed decadent stands total lichen biomass accumulation has been found to exceed 27,000 kg/ha (Swanson *et al*., 1985). (Decadent lichen stands contain over-mature lichens with >75% dead lichen biomass). Although lichen forage is lost for the long term by fire, it is a natural cyclic event which occurs periodically on most Seward Peninsula tundra ranges. The resultant reduction of lichens by fire and subsequent plant succession stages are complex. Lichen recover and appropriate grazing system information is being collected for burned areas.

Keywords: Alaska/ winter range/ lichens/ population dynamics/ sampling techniques.

117. Thomas, Donald C. 1991. Adaptations of barren-ground caribou to snow and burns. Pages 482-500 *in* Butler, C. and Mahoney, S. P., eds. 4th North American caribou workshop. St. John's, Newfoundland, 31 Oct 1989-3 Nov 1989. Newfoundland and Labrador Wildlife Division, Dept. of Environment and Lands. Newfoundland, 529 pp.

Abstract: Movements of the Beverly Herd of barren-ground caribou (*Rangifer tarandus groenlandicus*) were monitored intensively over 4 winters starting in 1982. The main

concentrations moved 9-16 km/day in early winter and slowed progressively as snow thickened. The herd's movement patterns apparently has adapted to avoid greater average snow depths in late winter in the eastern half of the range. Most movements were not a response to snow characteristics at the time, though caribou generally avoided areas with >65 cm of snow. Unusual movements occurred in 1979-80 when a ground-fast, icy layer occurred in parts of the winter range. Such icy layers occurred in at least 3 of 8 winters but were not range wide. Caribou freely crossed individual burns up to 25 km in width throughout the winter but avoided large regions mostly burned in the previous 50 years because of scarcity of forage therein. Wide-ranging movements and winter tundra use in the 1980s may have been a response to high burn rates since 1969 combined with high herd numbers.

Keywords: Beverly Herd/ Canada/ caribou/ fire/ fire history/ *Rangifer*/ snow/ winter range.

118. -- 1998. Fire-caribou relationships: (V) Winter diet of the Beverly herd in northern Canada, 1980-87. Technical Report Series. No. 313. Minister of Public Works and Government Services Canada, Edmonton, Alberta. 41 pp.

Note: Fifth in a series of 8 reports on fire-caribou relationships.

Abstract: I explored variability associated with the microhistological technique and with population and environmental variables in assessing diet of barren-ground caribou (*Rangifer tarandus groenlandicus*) in the 1980s on winter range in north-central Canada. Variables with little or no effect on relative densities of total lichen fragments included duplicate samples; age, sex and physical condition of the caribou; season (December *vs.* March); and year at a given location. Delayed necropsies and expression of rumen fluids through cheesecloth reduced lichen densities in the residual rumen material. Variability was observed among three major habitat types. Decreases in lichens and increased use of shrubs and graminoids occurred in the sequence: forest, forest-tundra ecotone, and tundra. Differences in fragment densities in paired, composite rumen and fecal samples (n=20 comparisons) were small for *Cladina*-type lichens and total lichens, which usually comprised 72-88% and 84-95% of the samples, respectively. Relationships between rumen and fecal data sources for minor and trace forages often were inconsistent and highly variable because of inadequate microscopic sampling (number of fields). *Cetraria*-type lichens were overestimated in fecal samples, whereas *Peltigera* and *Usnea* types were grossly underestimated. A review of error sources in using the macrohistological technique indicates probable gross underestimates of lichens in the diet. Microhistological analysis of feces of caribou on winter range may be the most accurate technique provided that mosses comprise a small proportion of the diet.

Keywords: Beverly Herd/ Canada/ caribou/ caribou diet/ fecal pellets/ lichens/ microhistological analysis/ *Rangifer*/ rumen.

119. -- 1998. Fire-caribou relationships: (VII) Fire management on winter range of the Beverly herd: final conclusions and recommendations. Technical Report Series. No. 315. Minister of Public Works and Government Services Canada, Edmonton, Alberta. 100 pp.

Note: Seventh in a series of 8 reports on fire-caribou relationships.

Abstract: This report consists of a series of conclusions and recommendations concerning winter ecology of caribou and effects of fire on winter range of the Beverly herd of barren-ground caribou (*Rangifer tarandus groenlandicus*). The herd summers mostly in the drainage of the Thelon River, Northwest Territories (NWT), and winters from northern Saskatchewan and the northwest corner of Manitoba to the Great Slave Lake region of NWT. A study in 1980 through 1988 focused on caribou diet and forage digestibilities, on fat reserves and physical characteristics in early and late winter, on winter movements and distribution in relation to burns, snow

characteristics, and regeneration of lichens in forests after fire. Performance and behavior of caribou, as measured by fat reserves and responses to burns and snow, was considered to be the best indicator of the state of winter range. Main conclusions were that lichens comprised the main forage of the herd in winter; that range was not limiting current herd numbers; that fat reserves remained about constant from December to March, while the herd was on winter range; that fire had markedly influenced winter distribution of the herd because lichens preferred by caribou were absent or sparse in young forests; that caribou were not reluctant to travel through burns of various sizes and ages; that snow affected use of habitat on regional and local scales; that the herd used areas of greater snowfall early in winter before snow restricted forage availability; that 41-60 years were necessary after fire to recover adequate cover and biomass of lichen species generally favored by caribou; and that highest use was made of forests 151-250 years post fire. Zones of priority for fire suppression were mapped based on current caribou management plans. A change in caribou management strategies to more-intensive management, for example to optimum sustained yield, would necessitate a change in recommendations for fire management and herd monitoring.

Keywords: Beverly Herd/ body condition/ Canada/ caribou/ caribou management/ fire/ fire management/ lichens/ *Rangifer*/ snow/ winter range.

120. -- 1998. Fire-caribou relationships: (VIII) Background information. Technical Report Series. No. 316. Minister of Public Works and Government Services Canada, Edmonton, Alberta. 104 pp.

Note: Eighth in a series of 8 reports on fire-caribou relationships.

Abstract: (Identified as a Forward, not a true abstract): This report was drafted in 1980, added to in 1982, and edited and printed in 1998. It was initiated in response to two initiatives. In 1977, a review of fire management in northern Manitoba was requested by Joe Robertson, a Conservation Officer who worked for many years in northern Manitoba for the Department of Natural Resources. In 1980, Rich Golden, a manager in the same department initiated a multi-agency panel to review fire management and Steve Kearney and I were assigned the task of reviewing the literature.

The 1980 survey estimate of 38,000 to 40,000 for the Kaminuriak herd initiated a start to a status report for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). There was a possibility that the herd would be classified as "rare" or "threatened."

The much higher survey results for the Kaminuriak herd in 1982 caused both initiatives to be suspended. The Manitoba government decided not to attempt to control fire on the forested winter range of the Kaminuriak herd.

This report is presented here because it contains some historical information that is difficult to obtain by most scientists. Some of the publications and reports referred to here are out of print and many of them are unknown to most researchers. It also presents data by earlier researchers in new ways.

There are conflicting viewpoints about the value of historical information. On the one hand, it provides information on such things as maximum and usual distribution of caribou, which is important in defining historic range. We may even try to establish cause and effect of changes in distribution, numbers, or recruitment using demographic, climatological, fire history, or hunting data. On the other hand, historical data may have little value in predicting future events if global warming or higher variability in weather variables continue to occur. Additionally, the range is gradually being influenced by industrial developments and human activities.

Keywords: Canada/ caribou/ fire management/ historic range/ Kaminuriak Herd/ *Rangifer*/ winter range.

121. ---. 1982. The winter ecology of barren-ground caribou in north-central Canada: a short review of current knowledge. NA:19 pp.

Note: Photocopy of unpublished article. Abstract from ASTIS bibliographic database, but attributed to author.

Abstract: This is a brief review of some of the things that are and are not known about caribou winter range, caribou in the winter, and the relationships between them. It is written for scientists. ... Most of the remarks apply only to the winter ranges of barren-ground caribou in the Beverly and Kaminuriak herds. ...[Topics discussed include range carrying capacity, use of burned areas, distribution and movement patterns, and diet and behavior, as they relate to better caribou management.] ...

Keywords: Beverly Herd/ Canada/ caribou/ caribou diet/ distribution/ Kaminuriak Herd/ *Rangifer*.

122. Thomas, Donald C. and Armbruster, H. J. 1998. Fire-caribou relationships: (VI) Fire history of winter range of the Beverly Herd. Technical Report Series. No. 314. Minister of Public Works and Government Services Canada, Edmonton, Alberta. 94 pp.

Note: Sixth in a series of 8 reports on fire-caribou relationships.

Abstract: Burns were mapped on forested winter range of the Beverly herd of caribou. The general study area was north of 58°N in Saskatchewan, Alberta, and Manitoba to forest limits and between 102°W and 114°W. Burn ages were obtained from numerous sources including all jurisdictions responsible for fire management. Age reliability for burns over 20 years old was excellent in NWT but only fair in the provinces where decade classes are more appropriate than specific years of fires before 1970. Ages were obtained on the ground at more than 484 sites, most of them in Northwest Territories.

Proportions of potential caribou range older than 50 years was calculated for forest areas within each of 31 map sheets, scale 1:250,000. Areas of large lakes, tundra, and outside "normal" range were excluded from potential caribou range. Small lakes, that generally comprise 14-21% of landscape in the Precambrian Shield portion of winter range, were included as potential caribou range because some of them are enclosed in burns.

In western sections of winter range, average interval between burns increased from 69 years around Thekulthili Lake, to 95 years around Nonacho Lake, and 137 years near the forest limit in the Porter Lake region. The longest average interval, 144 years, was in eastern sections of winter range around Selwyn Lake. Length of fire cycles appeared to be linked to several factors including climate (for example, distance from the forest limit); surface materials (bedrock to thick till types); topography (lowland wet areas *vs.* uplands); and forest type, which is an expression of the other factors plus fire.

Keywords: Beverly Herd/ Canada/ caribou/ fire/ fire history/ *Rangifer*/ winter range.

123. Thomas, Donald C.; Barry, S. J., and Alaie, G. 1996. Fire - caribou - winter range relationships in northern Canada. Rangifer. 16(2):57-67.

Note: Proceedings of the Second International Arctic Ungulate Conference, Fairbanks, Alaska, 13-17 August, 1995.

Abstract: We needed data on temporal changes in caribou forages after fire and relative use of age-classes of forests by caribou to help devise a fire suppression priority strategy for caribou

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

Keywords: Beverly Herd/ Canada/ fire/ habitat/ lichens/ post-fire succession/ *Rangifer*.

124. Thomas, Donald C. and Beverly and Qamanirjuaq Caribou Management Board. 1996. A fire suppression model for forested range of the Beverly and Qamanirjuaq herds of caribou. Rangifer. Special Issue No. 9:343-350.

Note: Proceedings of the Sixth North American Caribou Workshop, Prince George, British Columbia, Canada, 1-4 March, 1994.

Abstract: A fire suppression model was developed for forested winter range of the Beverly and Qamanirjuaq (formerly Kaminuriak) herds of barren-ground caribou (*Rangifer tarandus groenlandicus*) in north-central Canada. The model is a balance between total protection, as voiced by some aboriginal people, and a let-burn policy for natural fires advocated by some ecologists. Elements in the model were caribou ecology, lichen recovery after fire, burn history, community priorities for caribou hunting, and fire cycle lengths. The percent ratio of current productive caribou habitat to the goal for the habitat determines whether fire should be suppressed in a specific area. The goals for productive caribou habitat, defined as forests older than 50 years, were scaled by fire cycle length and community priority ranking. Thus, the model is an example of co-management: traditional knowledge combined with science in a joint forum, the Beverly and Qamanirjuaq Caribou Management Board.

Keywords: Beverly Herd/ Canada/ caribou management board/ co-management/ fire/ Kaminuriak Herd/ *Rangifer*.

125. Thomas, Donald C. and Kiliaan, H. P. L. 1998. Fire-caribou relationships: (I) Physical characteristics of the Beverly Herd, 1980-87. Technical Report Series. No. 309. Minister of Public Works and Government Services Canada, Edmonton, Alberta. 178 pp.

Note: First in a series of 8 reports on fire-caribou relationships.

Abstract: We investigated adequacy of forested winter range of the Beverly herd of barren-ground caribou (*Rangifer tarandus groenlandicus*) to support the then-current population. A concern was that forest fires in the past 20 years, and particularly in 1979, had destroyed too much range. Range condition was evaluated indirectly by comparing over-winter changes in condition variables of the Beverly herd with those measured in 1966-68 in the adjacent Kaminuriak herd, when only a small percentage of that herd's winter range had burned in the previous 50 years or so. Samples were obtained from 856 female and 402 male caribou in December (1982-1986) and March (1980-87). The over-winter trends in condition indicated stability (females) and slight decreases (males) in total body weight, approximate stability in back-fat depths, and increases in kidney fat. In a comparable study in the late 1960's, declines occurred in all those variables in the

adjacent Kaminuriak herd. We concluded, therefore, that winter range of the Beverly herd was adequate for the population in the 1980s. Condition indices based on kidney fat should be adjusted to compensate for body size of caribou by using body weight or femur lengths rather than kidney weights. For unknown reasons, kidney weights increased sharply and then decreased over the period of this study. Therefore, we prefer a body size index such as femur length that is easily and accurately measured and is independent of the nutritional state of an animal. Antler weight changes reflected varying environmental conditions during the non-winter period. Condition of caribou in December was affected by degree of warble fly (*Oedemagena tarandi*) harassment as reflected by numbers of warble larvae. Changes in condition during winter were less pronounced than during the remainder of an annual cycle. Two segments of the Beverly herd sampled in March 1984 differed significantly in condition indices and pregnancy rates. Therefore, the two groups varied in fat reserves at the rut in October. There was no indication that parasites and diseases other than warble flies were a factor in the well-being of the herd.

Keywords: Beverly Herd/ body condition/ Canada/ caribou/ fire/ Kaminuriak Herd/ *Rangifer*/ winter range.

126. Thomas, Donald C. and Kiliaan, H. P. L 1998. Fire-caribou relationships: (II) Fecundity and physical condition of the Beverly Herd. Technical Report Series. No. 310. Minister of Public Works and Government Services Canada, Edmonton, Alberta. 96 pp.

Note: Second in a series of 8 reports on fire-caribou relationships.

Abstract: This report details reproductive processes in barren-ground caribou (*Rangifer tarandus groenlandicus*) and how they are influenced by variables that reflect physical condition of caribou. Samples were obtained from 856 female caribou in the Beverly herd between March 1980 and 1987.

The pregnancy rate increased from 12% in yearlings (1.5-2 years old) to 91% in females over 11 years old. Fecundity (pregnancy rates) varied considerably in all age classes over the eight winters. In yearlings, it varied from zero to 33%; in females over 4 years old, from 78 to 100%. About 55% of calves were produced by age classes 3 through 6 years. Two of 854 reproductive tracts had developmental problems rendering those females barren, that is, incapable of producing young. One resorption was suspected in 420 pregnancies examined in March. Late conceptions, as assumed from occurrence of fetuses weighing less than 800 grams in mid March, occurred in 4.8% of females, including one estimated to have conceived in January.

The sex ratio of fetuses sampled in March was related to age of mother but not to her fatness. Young females (2-4 years) produced more female fetuses (61 M:100 F), whereas the opposite occurred in old (10+ years) females (207 M: 100 F).

There was a strong relationship between fecundity and weight, back fat depth, kidney fat, femur marrow fat, mandibular water content, antler weights, and indices based on two or more of those variables.

Poor relationships were the rule for regressions based on means of condition variables and fecundity in individual samples from December for age classes 2.5-3, 3.5-4, and older than 4 years. The few regression points (five), the sometimes small sample sizes, and atypical results in the December 1982 sample were responsible for poor correlations. Some correlation coefficients as high as 0.96 were obtained for females 2.5 years old in December samples. Significant relationships between fecundity and most condition variables were found in the seven March samples and 12 combined December and March samples for females in age classes 2.5-3, 3.5-4, and older than 4 years. Exceptions were femur marrow fat and mandibular water content, which produced no and few significant fits, respectively. Fecundity was best predicted from combinations of condition variables including back fat depths and kidney fat, or those fat variables

plus body weight, and possibly those combinations plus antler weights (not tested). An alternative approach was to compare sample means with curves depicting the relationship between means for condition variables and pregnancy rates of females older than 1 and/or 2 years in December and/or March, as appropriate. Strong relationships were found for all condition variables with this approach. Further statistical treatments of these data will be pursued and published.

Keywords: Beverly Herd/ body condition/ Canada/ caribou/ pregnancy rate/ *Rangifer*.

127. Thomas, Donald C. and Kiliaan, H. P. L. 1998. Fire-caribou relationships: (IV) Recovery of habitat after fire on winter range of the Beverly Herd. Technical Report Series. No. 312. Minister of Public Works and Government Services Canada, Edmonton, Alberta. 115 pp.

Note: Fourth in a series of 8 reports on fire-caribou relationships.

Abstract: The cover and biomass of surface vegetation was measured at 197 sites located on winter range of the Beverly herd of barren-ground caribou (*Rangifer tarandus groenlandicus*). The primary objective was to explore the relationship between abundance of caribou forages and time since fire, between those two factors and indices of caribou use, and between plant cover and biomass (dry weight). Various species of lichens attained peak biomass at various periods after fire--as early as 40-60 years for *Cladonia* spp. (except *Cl. uncialis*), to as late as 220-240 years for *Stereocaulon* spp. Total lichen biomass increased with age of forest until 180 years. Biomass was about constant after 60 years for lichen species given weighted values according to their perceived importance to caribou and seemingly preferred by caribou. *Cladina mitis* was considered to be the most important lichen for caribou throughout the winter range. It reached maximum biomass and height at 60-80 years after fire. *Stereocaulon* spp. was several times more abundant in eastern portions of the winter range than in the west. It was lightly grazed and then seemingly only incidentally because other species of lichens such as *Cetraria nivalis* were associated with it. The biomass of low evergreen shrubs that were eaten in small amounts by caribou did not change appreciably with age of forest. There were, with one exception, significant correlations at the site level between estimated cover and biomass of caribou forages. It is feasible, therefore, to assess caribou ranges relatively quickly by estimating cover of forages known to be important to caribou. Arboreal lichen abundance increased with time after fire until about 70 years and then stabilized. Caribou pellet groups were detectable for 2-3 years and 3-5 years in mesic and xeric sites, respectively. Forest stands became productive in terms of caribou forage as early as 40-50 years after fire but data for densities of pellet groups and field observations indicated that caribou made most use of forest stands 151-250 years old. Use of forests under 50 years old was negligible. In contrast, forests 21-40 years post-fire contained the highest density of moose (*Alces alces*) pellets. There was no clear relationship between age of forest and pellet densities of hare (*Lepus americanus*) or grouse/ptarmigan (*Canachites canadensis*/*Lagopus lagopus*). In western sites, there were trends towards greatest use by hares of forests in age classes 41-150 years; by grouse/ptarmigan, 41-100 years post fire.

Keywords: Beverly Herd/ biomass/ Canada/ caribou/ caribou forage/ fire/ lichens/ plant cover/ *Rangifer*.

128. Thomas, Donald C.; Kiliaan, H. P. L., and Trottier, T. W. P. 1998. Fire - caribou relationships: (III) Movement patterns of the Beverly Herd in relation to burns and snow. Technical Report Series. No. 311. Minister of Public Works and Government Services Canada, Edmonton, Alberta. 176 pp.

Note: Third in a series of 8 reports on fire-caribou relationships.

Abstract: Movements and distribution of the Beverly herd of barren-ground caribou (*Rangifer tarandus groenlandicus*) were monitored intensively each winter from 1982-83 through 1986-87

and sporadically in other years since 1979-80. Caribou in the main concentration typically entered the forest from mid October to mid November and departed it from mid March to mid April. The main concentrations, consisting of all elements except mature (>3 year) bulls, stayed in the Northwest Territories (NWT). Only relatively small numbers of caribou entered the northwestern corner of Saskatchewan, with the exception of 1979-80 when the main herd spent most of the winter around north Wollaston and Pasfield lakes. The herd ranged more widely east and west than previously recorded, occupying the outer 150 km (94 miles) of the Transitional Forest Zone (Taiga Shield) from Nueltin Lake (100°W) to Gordon Lake (113°W) near Yellowknife, a distance of 800 km (500 miles). Within the forest, caribou ranged from the limit of trees to a depth of about 150 km (94 mi) in the west to 200 km (120 mi) in the east. The Beverly herd spent part of each winter on the tundra, which coincides with their withdrawal from the Boreal Forest Zone, approximately 200 km from tree line.

The most common movement pattern was for the main concentration to spend the early part of winter in eastern portions of the winter range and to travel to the western half of the range before January. This movement pattern appeared to be a behavioral adaptation to avoid deeper snow in the east in late winter. The northwestern winter range was used every year with the greatest concentrations around Nonacho Porter, Eileen, and Tent lakes in the Snowdrift River Valley.

The herd moved at a rate of 9-16 km/day (6-10 miles/day) in November and early December and slowed progressively as the snow deepened. Most movements during the study did not appear to be a response to the current snow characteristics except that caribou were reluctant to move into areas with more than about 65 cm of snow. However, distribution may have been affected in 1979-80 when a ground-fast, icy layer occurred at least in parts of the winter range. Such hard-snow layers also were detected in two of five winters during this study. Distribution of the icy layers was localized and caribou were able to find feeding spots even within the zone of hard snow.

Caribou freely crossed burns of all sizes but spent little time in them. One large (161,000 ha) burn may have deflected, split, slowed, and temporarily stopped a migration in October 1982. Caribou tended to stay out of large (>10,000 ha) burns if they were on the periphery of winter distributions. Travel through burns was on a few parallel trails or on water systems and lowlands. Surface crusting in burned areas in late March and April slowed travel unless there were existing trails or the temperature rose above freezing. The main concentration of caribou did not winter in areas that were extensively burned. It was concluded that the withdrawal from former southern and southwestern range was caused primarily by historically unprecedented burn rates in the 1970s and 80s and , to a lesser extent, in the 1940s and 1950s.

Keywords: Beverly Herd/ Canada/ caribou/ distribution/ fire/ *Rangifer*/ snow/ winter range.

129. Timoney, K. P.; La Roi, G. H., and Dale, M. R. T. 1993. Subarctic forest-tundra vegetation gradients: the sigmoid wave hypothesis. J. Veg. Sci. 4(3):387-394.

Note: Check original publication before citing this reference.

Abstract: Spatial changes in tree and upland tundra cover in response to a complex environmental gradient and to landscape factors were investigated in the high subarctic forest tundra of NW Canada. Vegetation and terrain studies provided ground truth for a grid of 1314 air photos which covered 24% of the Canadian high subarctic and some of the adjacent low subarctic and low arctic. Across the high subarctic, gradual spatial change in % cover of tree and upland tundra vegetation is typical at both high and low cover values, with more rapid change occurring at intermediate cover. Cover gradients of zonal tree and tundra vegetation in the forest-tundra region in general follow a sigmoid pattern. Tundra and tree patch sizes increase in area and variability with higher tundra and tree cover, respectively.

Keywords: boreal forest/ Canada/ fire/ snow/ treeline.

130. Tsvetkov, V. F. 1972. Forest fires and young growth in the lichen taiga of the Kola Peninsula. Lesnoi Zhurnal. 5:34-37.

Note: In Russian. Citation from CRREL bibliographic database. No abstract available.

Keywords: forest fires/ lichens/ taiga .

131. Uggla, E. 1974. Fire ecology in Swedish forests. Pages 171-190 *in* Komarek, E. V., eds. Proceedings Annual Tall Timbers Fire Ecology Conference: Number 13. Tallahassee, FL, 22 Mar 1973-23 Mar 1973. Tall Timbers Fire Ecology Conference. 13. Tall Timbers Research Station. Tallahassee, FL, 521 pp.

Note: Check original publication before citing this reference.

Abstract: NO ABSTRACT AVAILABLE. SECTIONS INCLUDE: Introduction; Temperatures During Controlled Burning (Soil Temperatures, Tree Layer Temperatures, Air Temperatures); Forest Fire Areas in Lapland; Effects of Fire on a Thin Layer of Raw Humus; and Comparative Studies of Burned and Unburned Clearings.

FROM THE INTRODUCTION: In Scandinavia, prescribed burning is practiced on inactive raw-humus sites mainly in the sparsely-populated northern areas. It is now generally accepted that on ground that is not too dry a properly conducted prescribed burn is the most efficient method of accelerating the ripening of the humus of a clearing (E. V. Komarek 1970). However, forest fires on poor, dry soils can have devastating effects, resulting, for instance, in soil degeneration. In this paper I shall only try to give a short summary of some investigations which I hope will illustrate both the unfavourable and the favourable effects of forest fires and prescribed burning.

Keywords: lichens/ livestock grazing/ prescribed fires/ Sweden.

132. Van Daele, Lawrence J. and Johnson, Donald R. 1983. Estimation of arboreal lichen biomass available to caribou. Journal of Wildlife Management. 47(3):888-890.

Note: Short communication.

Abstract: Not available.

Keywords: arboreal lichens/ *Rangifer*/ fire/ logging/ biomass.

133. Van Waggoner, K. and See, Marianne 1985. Effects of fire on a dwarf shrub-sedge tussock community in interior Alaska BLM-Alaska Open File Report. BLM/AK/OF-85/10. 11 pp.

Note: BLM internal report. No abstract available. Sections reprinted here: Background, Objectives, Effects of Fire on Lichens, and Effects of Fire on Caribou.

Abstract: Background: In 1977 the Bear Creek Fire burned approximately 142,000 hectares. It burned with differing severities and intensities, and burned many vegetation types. Since the area was accessible via the FAA airstrip at Farewell, BLM managers and resource specialists realized that the Bear Creek Burn provided an excellent opportunity to study the effects of fire on natural resources in Interior Alaska. This is the seventh report on fire effects.

Objectives: The immediate, short-term objective of this study is to determine the extent of recovery of a dwarf shrub-sedge tussock plant community after fire. Our long-term objectives in this area are to monitor ecological succession and recovery of vegetation after fire, to evaluate the effects of caribou grazing on winter ranges, and to determine how the Bear Creek fire affects caribou distribution. The sampling results reported in this paper are to be used as baseline data to meet the long-term objectives.

Effects of Fire on Lichens: Rowe and Scotter (1973) characterize the post-fire lichen recovery in three general stages: (1) colonization by crustose lichens that bind soil; (2) dominance of fast growing but small *Cladonia* species; and (3) replacement of these colonizing species by slow growing *Cladina* lichens. The number of years in each time period varies with the dominant species and the geographic location, but Rowe and Scotter feel that Ahti's (1959) time scale for Newfoundland correctly describes the general sequence occurring after a fairly severe fire. Ahti delineates a *Cladonia* (horn lichen) phase between 10 and 30 years post-fire; a first reindeer lichen phase dominated by *Cladina mitis*, *C. rangiferina*, and *C. uncialis* between 30 and 80 years after fire; and a second reindeer lichen phase beginning after 80 years, which is dominated by *Cladina alpestris* (*Cladina stellaris*). Kershaw and Rouse (1976) stated that generalization should not be made. There has been almost no recovery of lichens from the Bear Creek Fire. This could be consistent with the 10 to 30 year development phase described above.

Effects of Fire on Caribou: On the burned sites, the fire consumed nearly all of the lichens, an important component of caribou winter diet. However, unburned inclusions on the burned area have been used by caribou during winter on the burn since 1979 (Hinkes 1979). Hinkes reported that the diet of animals feeding within the burn was composed of 60 to 77 percent lichens. Our observations and observations by others familiar with the burn area and the caribou population concur that this fire has had little impact on caribou. We believe this is due to two factors: the fire burned in such a manner that many unburned islands were left, and the caribou herd was far below the range's carrying capacity at the time of the burn. Because the study area is utilized by caribou, the exclosures should enable us to evaluate the effects of grazing subsequent to fire.

Keywords: Alaska/ caribou/ fire/ lichens/ winter range/ Rangifer.

134. Viereck, Leslie A. 1983. The effects of fire in black spruce ecosystems of Alaska and northern Canada. pp. Pages 201-220 *in* Wein, Ross W. and MacLean, David A. The role of fire in northern circumpolar ecosystems. John Wiley and Sons; New York.

Note: Sections within chapter are: 11.1 Introduction; 11.2 Climate; 11.3 Fire regime in the black spruce type; 11.4 Adaptation to fire; 11.5 Effect of severity of burn; 11.6. Revegetation following fire in the black spruce type; 11.6.1 The black spruce-feather moss type; 11.6.2 The black spruce-lichen woodland; 11.7 Relationship with other vegetation types; 11.8 Succession and climax; 11.9 Effects of fire on ecosystem components and processes; 11.10 Summary; and 11.11 References. Includes extensive list of references.

Abstract: Fire in the black spruce ecosystem of northern Canada and Alaska is characterized by large and frequent fires that usually kill the overstory trees and most, if not all, of the vegetation aboveground. Most species within the black spruce ecosystem show adaptations to fire, and black spruce stands are usually perpetuated by fire. Depending on the site, revegetation follows one of two primary patterns, although under some conditions there may be intervening stages of birch, aspen, or lodgepole pine. In general, the succession on dry sites develops as open lichen woodland with a nearly continuous cover of fruticose lichens. On moist sites, the development is that of a closed forest with a forest floor dominated by dense feather mosses and with a buildup of an organic mat. The final or climax vegetation that develops depends on site and climate and may vary from treeless bogs through feather moss types to open lichen woodlands. In some areas, balsam fir replaces the black spruce. Fire reduces the organic layer on the forest floor and causes higher soil temperatures, an increase in available nutrients, and an increase in productivity for a

period following fire.

Keywords: Alaska/ boreal forest/ Canada/ fire/ lichens/ mosses/ *Picea*.

135. ---. 1973. Wildfire in the taiga of Alaska. Alaska Quaternary Research. 3:465-495.

Note: Overview of fire in the taiga ecosystem with numerous references. Major sections are: I. Introduction (A. Vegetation, B. Environmental factors, C. Fire); II. Ecological Effects on Vegetation (A. Successional sequence and relationships, B. Present mosaic of vegetation, C. Autoecological relationships); III. Effect on Soil (A. Permafrost, B. Soil nutrients); IV. Effects on Hydrology and Siltation; V. Effects on Wildlife (A. Caribou, B. Moose, C. Sheep and goats, D. Small mammals, E. Fur bearers, F. Black bear, G. Showshoe hares, H. Waterfowl, I. Grouse); VI. Effects on Insects; VII. Effects on Recreation and Esthetic Values; VIII. Discussion; IX. Recommendations for the Future; X. Action for the Present.

Abstract: The taiga of Alaska consists of a vegetation mosaic resulting primarily from past wildfires. Today, both lightning- and man-caused wildfires burn an average of 400,000 hectares annually, creating vast areas of successional ecosystems. However, although the number of reported fires is increasing, fire control is becoming more effective in limiting the average size of fires and the total area burned. One of the important influences of fire in the taiga ecosystem is its effect on permafrost and the soil nutrient cycle. Construction of firelines in permafrost areas has a greater effect on soil erosion and siltation than does the fire itself. Some wildlife species, such as moose and snowshoe hare, depend upon fire and its resultant successional plant communities, whereas fire may have deleterious effects on caribou winter range. Fire has both positive and negative effects on esthetic and recreational values. Fire has always been a part of the Alaskan taiga ecosystem; if it is totally excluded from the environment, some major ecological changes will result. Fire-suppression alternatives are discussed and additional research on fire effects suggested.

Keywords: Alaska/ caribou/ fire ecology/ fire history/ fire management/ fire mosaic/ forest fires/ post-fire succession/ soils/ taiga/ wildlife/ Rangifer.

136. Viereck, Leslie A. and Schandelmeier, Linda A. 1980. Effects of fire in Alaska and adjacent Canada - a literature review. BLM-Alaska Technical Report 6. Bureau of Land Management, Anchorage, Alaska. 124 pp.

Note: Includes sections on fire effects on caribou and lichens.

Abstract: Alaskan land and resource managers are moving from a policy of fire control to one of fire management. To use fire as a tool to reach resource management objectives, managers need information on fire effects and the role of fire in the northern environment. The authors searched and reviewed all the available literature on fire effects in Alaska and adjacent Canada, in both the northern forest (taiga) and the tundra. They report and interpret this literature, discussing fire effects information sources, fire history and fire regimes, and the effects of fire on soils, watersheds, vegetation, and animal life. They also point out information gaps that need to be filled.

Keywords: Alaska/ birds/ boreal forest/ Canada/ caribou/ fire bibliography/ fire ecology/ forest fires/ furbearers/ moose/ post-fire succession/ *Rangifer*/ soils/ tundra fires/ vegetation types/ wildlife.

137 Ward, Paul C., and Mawdsley, William. 2000. Fire management in the boreal forests of Canada. Kasischke, Eric S., and Stocks, Brian J. eds. in Fire, climate change, and carbon cycling in the

boreal forest. Springer-Verlag, New York. pp. 66-84.

Abstract: The vast boreal forest ecosystem is composed of fire-dependent and fire-adapted species. Case studies are used to highlight fire management programs and problems. Fire is an important consideration for wildlife management, especially for the conservation of woodland caribou habitat which is a major issue in the country.

138. Zvonkova, A. A. 1984. Changes in specific composition and abundance of moss-lichen covers in relation to forest fires in pine forests of the north. pp. 96-101 *in* Chertovskoi, V. G. ed. Study and preservation of vegetation in the north.

Note: In Russian; citation from the Cold Regions - CRREL bibliographic database.

Abstract: Not available.

Keywords: forest fires/ lichens/ mosses/ post-fire succession/ taiga.