# Tundra Ranges North of the Boreal Forest[1]

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## Highlight

**Tundra rangelands of Alaska and northern Canada occupy about 200,000 and 900,000 square miles respectively. The tundra supports far lower numbers of large grazers than other natural areas, averaging less than 100 lb per square mile. Forage quality of tundra plants is high because of rapid growth and wide variation in seasonal progression of growth. The native grazers, caribou and muskoxen, have evolved rapid growth rates and selectively feed on the highest quality forage available. Wild populations of caribou and muskoxen appear to offer the best potential for conversion of tundra vegetation into commodities utilizable by man.**

The recent discovery of apparently large reserves of petroleum on the northern coast of Alaska has crystallized an already building interest in the North American arctic. A full-fledged rush of men and materials into the North is now underway and may far surpass in magnitude the rush of gold seekers to the Yukon and Alaska at the turn of the last century. The impact of this activity on the people and the economy of the Arctic has been much discussed in the news media and in the halls of government. Very little attention, however, has been given to the land and its vegetation, either from the standpoint of the possible harmful effects of uncontrolled mineral exploration and development, or the potential contribution that the tundra may make to the economy and welfare of the increasing human populations in the Arctic.

The arctic tundra is often referred to as the "barren-grounds" or the "arctic desert," and in winter the bleak, windswept tundra landscape may take on the superficial appearance of a desert, barren of life. But the tundra is by no means lifeless. The artist-naturalist, Ernest Thompson Seton (1911), shortly after the turn of the century, coined the more descriptive term "arctic prairies" in his enthusiastic narrative of a canoe voyage into the barren-grounds northeast of Great Slave Lake. In summer, the tundra literally becomes alive with insect and bird life. The insects burst forth from eggs or other dormant stages that lie quiescent during the long arctic winter, but virtually all of the bird life arrives after extended migrations from milder southern climes. While some mammals, such as the arctic ground squirrel (*Citellus undulatus*), like the insects, are dormant during the winter, most mammals of the tundra remain active throughout the winter and continue to eke out their existence under the harsh conditions that prevail. Lemmings (*Lemmus* sp. and *Dicrostonyx* sp.) and many other rodents avoid

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FIG. 1. Aerial view of several thousand caribou in late April in the DeLong Mountains of arctic Alaska.

the extremes of weather by living beneath the snow-cover in a windless climate several degrees warmer than the air above. The large grazers, however, have become adapted through evolutionary changes for survival while exposed to the conditions of the arctic winter.

Tundra rangelands of Alaska and northern Canada occupy about 200,000 and 900,000 square miles respectively. The arctic tundra has supported large numbers, but few species, of large grazing mammals from Pleistocene times to the present. There is evidence that during the Pleistocene the tundra in unglaciated areas of Alaska was more productive than at present and included the bison (*Bison priscus*), horse (*Equus* sp.) and mammoth (*Elephas primigenius*) as important faunal components (Guthrie, 1968). Apparently, fire and high deposition rates of aeolian soils fostered deep annual thawing, soil drainage and rapid turnover of soil nutrients which maintained vegetation types dominated by grasses. The Pleistocene tundra was far more productive than the present tundra which is dominated by sedges and lichens. Permafrost now remains close to the surface throughout the summer and the resultant poor drainage and cold soils account for slow breakdown of organic matter and limited availability of minerals for plant growth.

### The Large Grazers

The present large grazers are characteristically social in nature and, in the case of the caribou (*Rangifer tarandus*), they are migratory as well. Although they reach high densities locally (Fig. 1), vast expanses of the tundra are unoccupied by large herbivores at any given time. In terms of biomass of large grazers, the tundra supports far lower levels than other natural areas. Estimates from the Alaskan and Canadian tundra are generally 100 lb per square mile or less, in contrast to over 100,000 lb per square mile for some African savannas where as many as nine species of large grazers jointly use the same range (Petrides and Swank, 1965).

Caribou and muskoxen (*Ovibos moschatus*) (Fig. 2) are the only large herbivores native to the North American tundra in Recent times. Present estimates of numbers of barren-ground caribou in Canada are 357,000 on the mainland and about 50,000 on the arctic islands (Thomas et al., 1968 and Tener, 1963). There are more than 10,000 muskoxen in Canada (Tener, 1965). Corresponding Alaskan figures are 500,000 caribou and 750 muskoxen. Alaskan caribou are probably near range capacity, while in Canada, where caribou are only recently recovering from a population low in the mid-1950's, the total potential range capacity

FIG. 2. Muskoxen on Nunivak Island, Alaska share the island with 10,000 reindeer. *Photo by G. Bos.*

may exceed two million animals. Fire has been a factor in the destruction of large expanses of caribou winter range in Canada and Alaska and has been associated with the alarming reductions of caribou in Canada in the 1950's and previously in Alaska.

Domestic reindeer (also *Rangifer tarandus*), first introduced to North America in 1891, reached 650,000 animals by 1932 in western and northern Alaska, and dwindled to approximately 25,000 by 1950 because of range deterioration, poor herding practices and the confused status of ownership. Reindeer now number approximately 40,000 in Alaska with about 23,000 in private ownership, 10,000 owned by the government and another 7,000 in feral herds on islands in the Aleutians and the Bering Sea. The only reindeer in Canada, the government-owned herd on the lower Mackenzie River, near Inuvik, numbered 1,800 according to a precalving count in the spring of 1968. Privately managed in the past through a contract with the government, the contract was recently revoked because the herd was allowed to decline to below the accepted level and management has reverted to the Canadian government.

The future possibilities for a reindeer industry in the North are obscured by social and economic problems which have continually proven to be obstacles to significant development beyond the subsistence level. These include the lack of a tradition of pastoralism among the Eskimo, the absence of a profit motive in their culture and the present motivation toward education and acculturation among the Eskimo youth. The picture is further complicated in Alaska by a federal law which restricts ownership of reindeer to persons of native blood. Nevertheless, local and federal agencies are actively supporting expansion of reindeer husbandry in both Alaska and Canada. In Alaska, cash income from the sale of reindeer meat and by-products in 1967 was approximately $225,000 (U.S. Bureau of Indian Affairs, 1967). About one third of this derived from the government herd on Nunivak Island. The sale of hides has produced increased income in the past few years, and antlers now bring good prices from Korean buyers who captalize on their supposed "medicinal" value. Early this year the first 240 live reindeer of a shipment that may total 1,000 were flown directly from Alaska to South Korea by jet aircraft where they were sold for breeding stock.

At the University of Alaska the muskox is undergoing experimental development as a domestic animal, primarily for wool production. A similar project, associated with the Alaskan venture, has also been started by the government of Quebec at Old Fort Chimo. Although the muskox appears adaptable to domestication as a tundra range animal, the problems facing its successful exploitation in the Arctic are similar to those of reindeer and are more economic and social than biological. The muskox appears suitable for a cottage economy such as existed in northern Scotland 100 years ago, but the lack of an animal husbandry tradition in the North American Arctic and the rapid acculturation of the native peoples that is taking place do not favor acceptance of pastoralism as a way of life in the future.

Unfortunately, in Alaska the muskox has become the subject of a controversy between those promoting its domestication and advocates of the species as an element of the native wild fauna. On Nunivak Island the muskox is apparently approaching the limitations of its range which is shared with 10,000 reindeer, and efforts to control the herd by hunting and transplantation to new habitat on the mainland have been opposed by the domestication interests. They fear competition from the development of any economy based on wild populations as well as the potential future competition for range lands between domestic and wild herds. The problem has been temporarily resolved through a compromise decision to take surplus animals this year for reintroduction to the Alaskan Arctic as well as for addition to the domestic herd at the University of Alaska. The threat of range deterioration from over-population will continue to exist on Nunivak Island, however, and other measures will have to be employed to control the population in the future.

### Characteristics of the Range

Tundra ranges differ significantly in plant composition from more southern ranges. Sedges replace grasses as the dominant monocots and low, creeping or prostrate forbs and shrubs are also important range components. Lichens are particularly unique in both their presence and importance on tundra ranges. Lichens have no root system and derive their nutrients primarily from the air. They have a high starch content and are high in available

energy but are low in protein. Caribou and reindeer are specially adapted physiologically to utilize them as a primary food source during the long arctic winters. Although many questions about caribou and reindeer nutrition remain unanswered, in Scandinavia, where lichens have been used for centuries as forage for domestic stock, studies show that reindeer make more efficient use of this forage than either cattle or sheep (Nordfeldt et al., 1961).

Lichens grow notoriously slow and recovery from grazing or from range fires is, therefore, much longer than it is for sedges or other tundra plants. Since reestablishment of lichens takes place from the living parts of the plants that remain, fire can be particularly destructive to lichen range if all living parts of the lichens are burned. Studies by Pegau (1968a) of lichen growth on the Seward Peninsula of Alaska show that lichens grow somewhat more rapidly in open forest than on treeless tundra but average less than one quarter of an inch of linear growth per year. Virgin lichen range can yield as much as 3,000 lb per acre of forage if complete cropping of the lichens is allowed, but under such grazing practices 30 to 50 years is required for recovery before the areas can be regrazed. If only top cropping is permitted, approximately 45% of the living portion of the lichens can be removed and the rotation cycle can be reduced to 3 to 5 years. Proper rotational grazing of lichen range can, therefore, result in a 530% increase in efficiency of range use over complete cropping, which can mean the difference between maintaining 200 or over 1000 reindeer on each 100 acres of winter range.

Trampling of lichens by reindeer can often be harder on the range than the effects of their feeding. Pegau (1968b) conducted experiments with a reindeer herd near Nome in 1966 and found that close herding of reindeer on their summer range resulted in dislodging and shattering of 15% of the lichens on wet or moist days and 35% when the lichens were dry. Reindeer make only limited use of lichens in the summer and do not use them at all when they are dry and brittle, but in this latter condition they can suffer the greatest damage from trampling.

Poor herding practices have resulted in inefficient and destructive use of reindeer winter range in Alaska in the past, and herders today have little understanding of principles of range management and of the special characteristics of lichen range. However, the U.S. Bureau of Land Management, the agency involved in leasing and management of grazing lands in Alaska, has recently undertaken an intensified program to develop and put into practice a range management program that is suited to the unique conditions of tundra range.

Areas of the tundra occupied by muskoxen differ somewhat from typical caribou and reindeer ranges and there is relatively little competition between the two species for food (Tener, 1965). Lichens are not an important food item for muskoxen and sedges, although used, assume less importance than they do for caribou. Low and prostrate shrubs, such as willow (*Salix* spp.), blueberry (*Vaccinium* spp.) and crowberry (*Empetrum nigrum*), are important winter foods for muskoxen and grasses are used extensively in both summer and winter. Generally, muskox ranges have more low shrubs and more grasses and fewer sedges than caribou range. Lichens are often not an important component of the vegetation on muskox ranges.

### Nutrition and Growth

All northern ungulates characteristically undergo seasonal physiological changes which adapt them to the yearly variations in quality and quantity of their food supply. The result is a cycle in the annual physiological regimen with highest metabolic demands occurring in the spring and early summer when plant growth is most rapid and nutritive quality of the forage is highest. Growth rates of young animals are most rapid at this time and the dietary demands for antler growth, recovery from the rigors of winter, and lactation in females are greater than at any other time of the year. Both reindeer and muskoxen are known to produce milk of extremely high butter fat and protein content (reindeer—22% fat and 10% protein; muskox—11% fat and 5% protein; domestic cow—3 to 5% fat and 4% protein) which accounts both for the rapid daily gains of the nursing young and the high dietary requirements of the lactating females (Tener, 1965).

Rate of gain for reindeer fawns during their first summer on high quality range averages a pound a day (Krebs and Cowan, 1962) from a birth weight of about 10 pounds. This compares with about ½ pound per day for domestic sheep with a similar birth weight, while Hereford cattle, with a birth weight seven times that of reindeer also average only a pound a day (Brody, 1945). Correspondingly rapid rates of growth have been observed among captive muskoxen (Tener, 1965).

While rapid rates of growth, with high dietary protein requirements, are characteristic of arctic ungulates during the brief polar summers, these animals enter a state of virtual physiological dormancy during the long winters. Even in captivity, when offered unlimited quantities of high quality food, caribou voluntarily reduce their food intake as winter approaches, growth rates level off and metabolic rates drop to a relatively low level (McEwan and Wood, 1966). Winter dietary requirements for protein are therefore greatly reduced over the summer, and energy requirements from

carbohydrates become of paramount importance in the diet to meet the needs of basal metabolism, locomotion and maintenance of body heat. These changes in requirements coincide with the change in availability from summer vegetation of high protein content to lichens of low protein and high starch content which are consumed during the winter.

A paradox may seem to exist between the remarkable growth rates of ungulates during the arctic summer and the relatively low productivity of the tundra mentioned earlier. A teleological explanation for the rapid growth rates is that they are essential if the animals are to attain sufficient size and condition during the brief summers in order to prepare them to survive the long winters. Natural selection could therefore account for the tendency toward rapid growth in arctic species. But more than genetic potential alone is required for an animal to grow. Realization of this potential comes about through the natural high nutritive quality of tundra forage and the feeding behavior of the animals which results in selection of the highest quality forage available. The high nutritive quality of arctic plants results from the following factors: 1) Like the animals, arctic plants have evolved rapid growth rates which normally enables them to complete their growth and reproductive cycle in a single season (Bliss, 1960). This is made possible by the long day length of arctic summers. We know that rapid growth in plants yields high quality forage. 2) Arctic plants are small and low-growing, therefore, significant growth of high quality vegetation per plant can be made on a limited supply of soil nutrients. The net result can be high quality forage although overall productivity from the land may be low. 3) The tundra terrain is usually irregular; often mountainous, hilly or at least undulating, with breaks caused by stream channels and from frost action. This irregularity results in variations in exposure and snow cover which can greatly alter the seasonal growth pattern of vegetation. On south-facing slopes plants begin growth weeks ahead of plants on level areas and in depressions or other areas of excessive snow accumulation. North slopes are correspondingly delayed in the initiation of plant growth. Since highest nutritive quality of forage coincides with the beginning of plant growth, the tundra offers high quality forage throughout the summer to those grazing animals that are able to range widely over the irregular terrain to take advantage of variations in growth stages of the vegetation. 4) In summer, vegetation in arctic regions under 24-hour daylight does not undergo catabolic nighttime metabolism which, in lower latitudes where nights are warmer and dark, can result in substantial reductions in concentrations of carbohydrate levels in the growing leaves. This could be an important factor for animals grazing during the night or early morning hours.

Under natural conditions grazing animals tend to select the highest quality forage available to them. We have observed this among caribou and feral reindeer in Alaska and it has been reported from more temperate regions among both wild and domestic herbivores. In summer this habit is of the utmost importance to tundra grazing animals by assisting them to meet the high nutritive requirements that their rapid growth rates require.

The ability to select forage of high quality is dependent upon a moderately low density of animals so that competition between them does not occur. Competition among caribou, which being social are found in groups or bands, is overcome through their wide-ranging feeding behavior. When reindeer are closely herded, fenced or confined to restricted ranges on small islands, the opportunity for them to graze selectively is lost because of competition between individuals for the limited supply of high quality forage. This has been demonstrated in our studies of populations of feral reindeer introduced to islands in the Aleutians and the Bering Sea (Klein, 1968). Under low population densities, soon after the introductions, the reindeer were free to select the highest quality forage and the resultant growth rates and body sizes were amazing. On St. Matthew Island, 13 years after their introduction body weights of feral reindeer exceeded those of reindeer in domestic herds by 24–53% among females and 46–61% among males. By 1963, when the population had increased by a factor of four and density reached 47 per square mile, body weights had decreased from the 1957 level by 38% for females and 43% for males and were comparable to weights of reindeer in domestic herds.

### Control of Population Size

The upper limits of numbers of animals that can be supported on tundra range under natural conditions are determined by several factors acting jointly or independently. In the case of caribou and muskoxen, snow conditions affect the availability of food and can account for population fluctuations. In east Greenland at the turn of the last century, increased winter snowfall, associated with the absence of adjacent sea ice, has been blamed for the extinction of caribou and a large reduction in numbers of muskoxen (Vibe, 1967). The effects of wolf predation, parasitism, and disease are related to the density and condition of the prey or host species which in turn are related to the food supply. In the caribou ranges of northern Alaska where there are now over 300,000 caribou, wolves were greatly reduced through aerial

hunting in the late 1950's. This was followed by an apparent increase in the numbers of caribou, increased incidence of parasites and disease and finally lowered productivity through decreased calf production and survival (Skoog, 1967). With partial protection, wolves have now increased to near their previous levels and the symptoms of over-population among the caribou are disappearing.

Man is also an important factor in the regulation of caribou populations either through direct harvest or through his effect on the habitat. In Alaska and Canada many Eskimos and Indians are still dependent upon the caribou as an important item in their subsistence economy. The annual harvest of caribou for these purposes is currently about 25,000 in Alaska and probably a similar number are taken in Canada. The Canadian harvest is, however, considerably reduced from the high kills of close to 100,000 that occurred in the late 1940's and early 1950's at the same time that the herds were undergoing an alarming population reduction (Kelsall, 1968).

On islands in the Bering Sea where reindeer have been allowed to increase unchecked by predation or adequate harvest, food supply, through interaction with winter snow conditions, has been the primary factor limiting the populations (Klein, 1968). Reindeer introduced to St. Matthew Island in 1944, increased from 29 animals to 6,000 in the summer of 1963, nineteen years later, and underwent a crash die-off the following winter to less than 50 animals. The population had responded to the high quality and quantity of the forage on the island by increasing rapidly due to a high birth rate and low mortality. By 1963, the density of the reindeer on the island had reached 47 per square mile and ratios of fawns and yearlings to adult cows had dropped from 75 and 45% respectively, in 1957 to 60 and 26% in 1963. Lichens had been completely eliminated as a significant component of the winter diet. Sedges and grasses were expanding into sites previously occupied by lichens. In the late winter of 1963–64, in association with extreme snow accumulation, virtually the entire population of 6,000 reindeer died of starvation. Apparently the population had increased to a level far in excess of the long term carrying capacity of the range, and the heavy grazing pressure resulted in the elimination of the lichens in a span of only a few years. Other forage species were not adequate to carry the population through the extreme winter conditions that prevailed, and without the opportunity to migrate to more favorable range, wholesale starvation was the only alternative.

A similar pattern of population growth and crash of reindeer occurred on the Pribilof Islands in the 1940's (Scheffer, 1951) and large population reductions from winter starvation have occurred among free-ranging, but partially managed herds, on Nunivak and St. Lawrence Islands.

### Discussion and Conclusions

It is apparent from the foregoing discussion that tundra rangelands are different in many respects from more southern rangelands. Occupying vast areas of the northern fringe of the continent these lands, however, produce a small biomass of grazing animals per unit area, even though individual herds may be large. Because of the long winters, quality and quantity of the winter forage determine the population levels that can be supported on the range. Lichens form a major portion of the winter forage for caribou and reindeer and have characteristics quite unlike more conventional forage species. They are of high energy value and the native grazers are specially adapted physiologically to use them. But lichens are also extremely slow-growing, fragile, subject to damage from trampling and readily destroyed by fire.

The very short arctic summers have resulted in the evolution of rapidly growing plants which yield high quality summer forage for grazing animals. Topographic variation and long day length affect initiation and rate of plant growth which also influence the availability of high quality forage. The native large grazers have also evolved growth patterns consistent with the seasonal variations in food quality and quantity and during summer they exhibit high rates of growth not normally encountered among ruminants. Characteristics of their feeding behavior enable them to select the highest quality forage available on the range. Low population density and opportunity to range over a large feeding area are essential for the well-being of these northern species.

The increasing pace of development in the North associated with the exploration and extraction of oil and other resources as well as the expanding population of Eskimos and Indians make any contribution to the food and economy of the local people that derives directly from the land of great importance. Domestic stock from temperate regions do not thrive well on the arctic tundra because they are neither morphologically adapted to survive the rigorous winter climate and the difficult winter foraging and terrain conditions nor physiologically adapted to make efficient use of the forage types, particularly the lichens. Herding of domestic reindeer and possibly muskoxen may prove successful in some local cases, contributing to both the subsistence and cash economies. However, the social and economic problems facing the development of animal husbandry in the North are of such magnitude that large scale development seems

unlikely. Wild populations of caribou and muskoxen probably offer the best potential for conversion of tundra vegetation into commodities utilizable by man. These species are by nature well adapted to the environment and over extended priods of time both the animals and the range vegetation fare relatively well. This has often not been the case with herding of semidomestic reindeer in North America. Wild game provides meat and other subsistence commodities to indigenous people without the constant attention and specialized skills required to raise domestic animals. Game can also bring cash into the economy of the North through services to, and fees from, non-resident sport hunters. Experiences in other parts of the world as well as in the North indicate that native ruminants often make more efficient use of natural forage than introduced domestic breeds.

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