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REINDEER RANGE APPRAISAL IN ALASKA

A

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REINDEER RANGE APPRAISAL IN ALASKA

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ABSTRACT

Several methods of evaluating reindeer ranges were tested on Nunivak Island and the Seward Peninsula, Alaska. Aerial photographs or an aerial-visual method similar to those used in Sweden can be used to ascertain the boundaries and per cent composition of the various vegetation types on reindeer ranges. Weight estimate or double-sampling weight methods can be used to determine the forage production of each vegetative type. The line point and 3/4 inch loop are not reliable for evaluating trend on tundra vegetation because the displacement of the line 1/4 inch or more often causes a different species to be recorded at the same sampling point. Exclosures and permanent sample plots in which estimates of weight are recorded, supplemented with photographs, are recommended for range condition and trend studies. The average annual linear growth of Cladonia alpestris, C. rangiferina, and C. sylvatica on the Seward Peninsula was found to be 5.0, 5.3, and 5.4 mm respectively. Although there is no apparent selection of particular species of lichens during the winter by reindeer, in the spring and summer the lighter-colored, fruticose Cladonia and Cetraria types are preferred. On summer ranges, where lichens comprise 30% of the available forage, at least 15% of the lichens should be considered unavailable because of trampling. By grazing only the top 1/3 of the lichen podetia in the dwarf shrub-lichen stands near Nome, it is calculated that 1,020 reindeer can be wintered per 100 acres during a 30 to 50 year period, compared to 192 if the lichens are completely grazed the first time.

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INTRODUCTION

Approximately 21,000 square miles of rangelands in Alaska are grazed by 18 herds, totaling approximately 36,000 reindeer (*Rangifer tarandus*), as of December 31, 1966 (Fig. 1). The number of reindeer has fluctuated widely in the past (641,000 in 1932 to 25,000 in 1950), and according to Leopold and Darling (1953) this was largely due to poor range management practices.

The Bureau of Land Management, which is responsible for the management of 17,616 square miles of this range, and nearly all areas that are being considered for possible expansion of the reindeer industry, issued a contract to the Alaska Cooperative Wildlife Research Unit to develop and appraise reindeer range evaluation techniques. These would enable initial range inventory surveys to be made to classify range areas as to their suitability for reindeer, potential stocking levels, and desired rotation. In addition, techniques were desired to assist in evaluating condition and trend of range vegetation on stocked ranges.

The reindeer industry is an important component of the economy of several northern countries. Consequently, there has been more interest in fully developing the industry in these countries than there has been in Alaska in the past. Range studies have been extensively conducted in the USSR (Andreev 1952 and 1954, Makhaeva 1961, Kuvaev 1964, Igoshina and Florovskaya 1939, Vasil'ev 1936, and Vakhtina 1964), Labrador (Hustich 1951), Finland (Ahti 1961), and Sweden (Skuncke 1967). Caribou range studies in Alaska by Skoog (1956) and in Canada by Scotter (1962, 1963a, 1963b, and 1964),

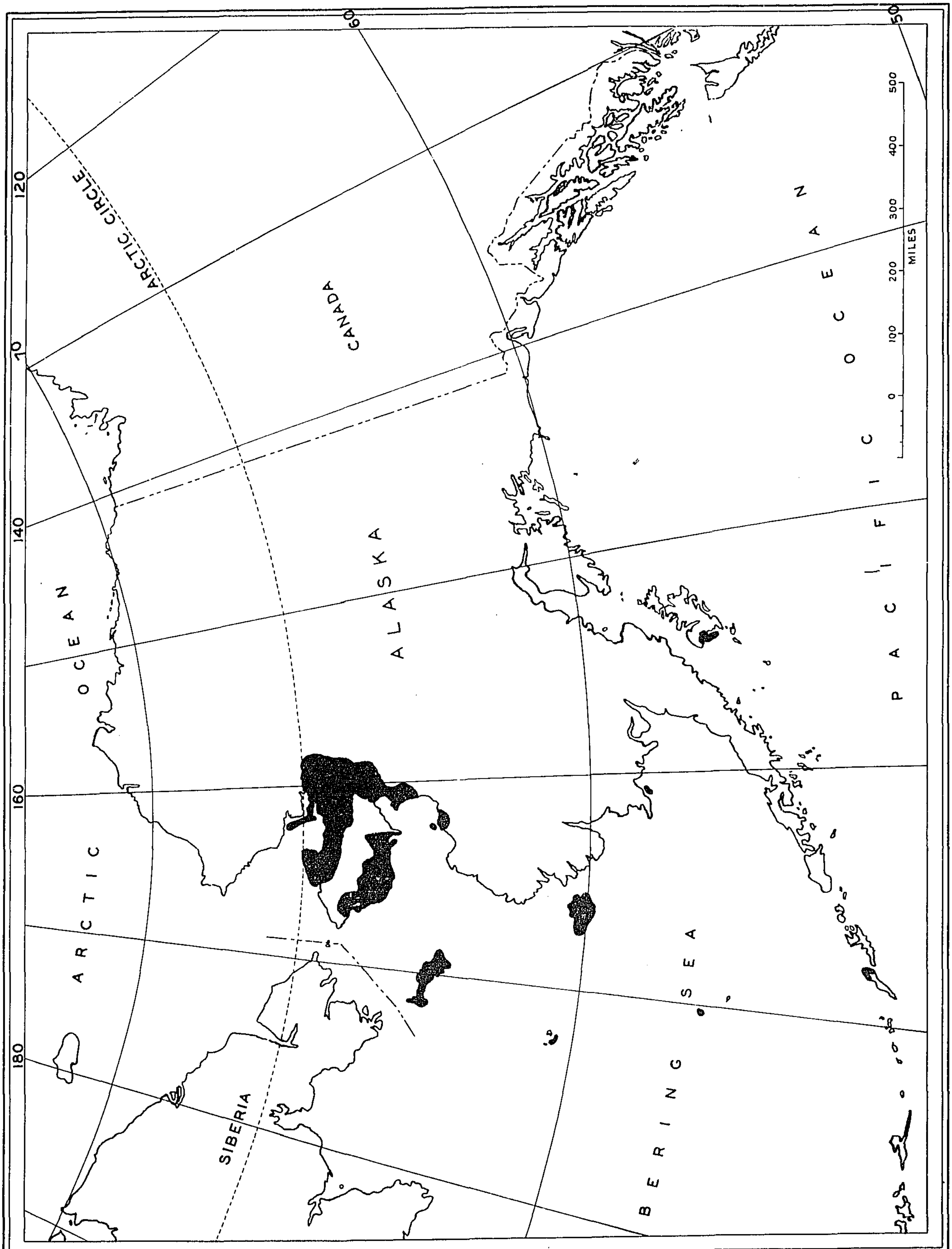


Figure 1. Current distribution of reindeer herds in Alaska.

Banfield (1954), Kelsall (1957 and 1960), Ahti (1959), and Cringan (1957) are the most prominent studies. Many reindeer and caribou range investigations were reviewed by Courtright (1959), and additional studies are abstracted in Arctic Bibliography (1953-1965).

Palmer (1926, 1934, 1945, and several unpublished reports in the files of the Alaska Cooperative Wildlife Research Unit, College, Alaska), Palmer and Rouse (1945), Hanson (1953), and Klein (1959, 1964, 1966, and 1967) have conducted the most extensive reindeer range studies in Alaska. Palmer's and Hanson's estimates of total carrying capacity and potential range in Alaska vary from 4 million reindeer on 200,000 square miles (Palmer 1934) to 320,000 reindeer on 50,000 square miles (Hanson 1952).

In the past, reindeer have occupied coastal regions from the Arctic Coastal Plain to the Alaska Peninsula with a few scattered herds in the interior (Fig. 2). Currently the largest concentration of reindeer is on, or adjacent to, the Seward Peninsula, with a few herds scattered on various off-shore islands (Fig. 1). Most of my work was centered on the Seward Peninsula, on Nunivak Island, and near Unalakleet.

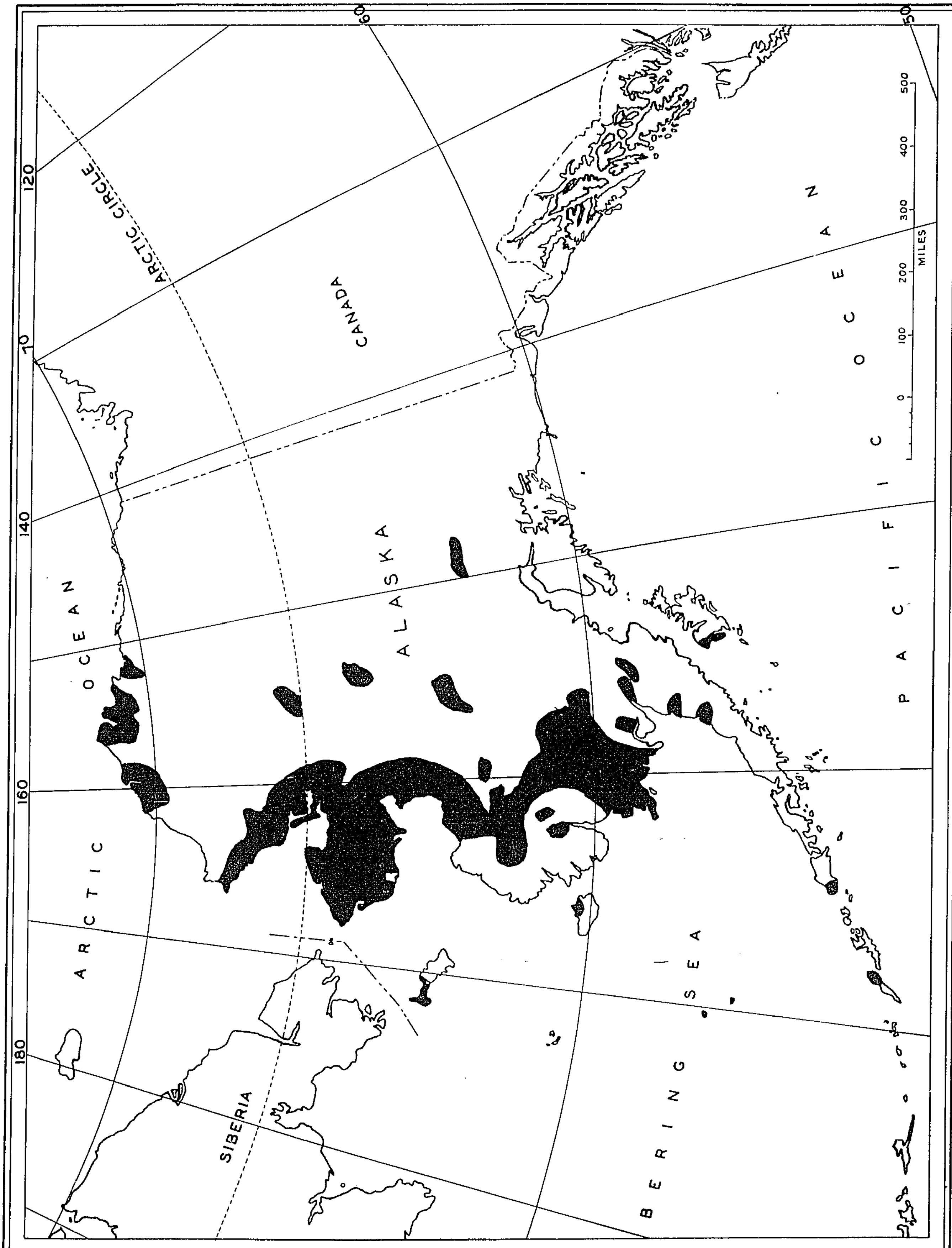


Figure 2. Distribution of reindeer herds in Alaska in 1926 (Palmer 1926).

VEGETATION

Arctic Vegetation in General

The area occupied by reindeer in Alaska is included in the arctic zone by Porsild (1951), but Polunin (1955) includes only the extreme western portion of the Seward Peninsula and all of Saint Lawrence Island in the arctic zone, the rest being considered subarctic. Most of the studies of arctic vegetation in Alaska have been conducted on the Arctic Slope (Britton 1957, Spetzman 1959, and Wiggins and Thomas 1962). Johnson et al. (1966) conducted one of the most thorough studies along the coast of the Chukchi Sea. The works of Hanson (1951 and 1953), Palmer (1945), and Palmer and Rouse (1945) are the most pertinent on the areas currently occupied by reindeer in Alaska.

Vegetation studies in other countries show the similarity of arctic and subarctic vegetation throughout the circumpolar region (Ahti 1959, Hustich 1951 and 1957, Polunin 1955, Porsild 1951, and Scotter 1963b and 1964 in Canada; Gelting 1955 in Greenland; Coombe and White 1951, Nordhagen 1955, and Skuncke 1967 in Scandinavia; and Aleksandrova 1960, Andreev 1954, Kuvaev 1964, Derviz-Sokolova 1965, and Tikhomirov 1960 in the USSR). Tikhomirov (1960) has prepared an extensive translated bibliography.

Studies have been made of the correspondence of physical features and the arctic vegetation. Bliss (1956) and Churchill (1955) discuss the importance of microenvironments on plant development in the Arctic.

Some of the factors that influence vegetational patterns under arctic conditions are: soil and air temperatures (Bliss 1956), micro-relief (Hanson 1951), solifluction (Wilson 1952, Hanson 1950, Aleksandrova 1960, and Metcalfe 1950), frost action (Hopkins and Sigafoos 1951 and 1954, and Sigafoos 1952), stone stripes (Taylor 1955), and pingo mounds (Polunin 1948, Russell and Wellington 1940, and Burns 1964). With the interaction of two or more of these fluctuating environmental features, highly complex arrangements of communities result (Steere 1954, Whittaker 1953).

Vegetation Types on Reindeer Ranges in Alaska

Hanson (1953), Palmer (1945), and Palmer and Rouse (1945) have classified the vegetation on reindeer ranges in Alaska. I have attempted to consolidate these, and use descriptive names that indicate the dominant plants or environmental conditions. The names of two types and one slightly modified type were taken from Johnson et al. (1966). The rest closely follow those of Hanson (1953) insofar as they can be identified from aircraft during favorable conditions. The principal species and locations are discussed under each type. For a more complete list of species that occur in each type, see appendix A. Bos (1967) has completed a vegetation type map for Nunivak Island, and his types are probably characteristic of all the islands occupied by reindeer. Hanson (1953) compared some of the following Alaskan types with types that have been described in Scandinavia.

Vascular plant nomenclature is that of Anderson (1959) unless otherwise indicated. Lichen nomenclature is that provided by the identifier and is listed in appendix A.

Forest types

White Spruce-Tall Shrub

The white spruce (*Picea glauca*) forest extends into the southeastern portion of the Seward Peninsula as far as the town of Council. It is most important on the ranges from Golovin eastward. There are two important sub-types within the white spruce forest.

White spruce-tall shrub.--The understory is composed primarily of willows, alders, and birches from 4 to 8 ft high. This type is often of little value to reindeer as the understory is so dense that they avoid the areas.

White spruce-lichen.--The understory is composed of small shrubs, bog blueberry (*Vaccinium uliginosum*), dwarf alpine birch (*Betula nana exilis*), narrow-leaved Labrador tea (*Ledum decumbens*), and crowberry (*Empetrum nigrum*) with large expanses of lichens (*Cladonia alpestris*, *C. rangiferina*, *C. sylvatica*, and *Cetraria islandica*). Arboreal lichens (*Evernia mesmorpha* and *Alectoria americana*) are often abundant on the branches of white spruce. Scotter (1962) and Edwards et al. (1960) consider arboreal lichens to be an important source of winter feed for caribou. This is the most important winter range type on the eastern portion of the Seward Peninsula and adjacent ranges, because of the large amount of lichens that occur in this sub-type.

These two sub-types are found throughout the white spruce forest of interest. The lichen sub-type predominates on the higher areas and often on north-facing slopes.

White Spruce-Alaska Birch-Shrub

This is a restricted type that is formed in the ecotone between the white spruce and Alaska birch (Betula resinifera) forest. It is best developed along the Unalakleet, Kobuk, and Noatak rivers. The shrubs are of the same species as in the white spruce-tall shrub subtype.

Alaska Birch-Shrub

The Alaska birch-shrub type is best developed in the vicinity of Unalakleet. Usually either the trees or the understory shrubs (willows, alders, and birches) grow in dense stands. There are occasional openings in which dwarf shrubs (dwarf alpine birch, glandular scrub birch (Betula glandulosa), and heaths) and lichens are abundant.

Tall shrub-herb types
(shrubs 2.5 or more ft high)

Willow-Herb

The willow-herb type has two sub-types based on the species of willow present.

Feltleaf willow.--Feltleaf willow (Salix alaxensis) can be recognized by the grayish green color of the leaves. It is usually restricted to streamsides or to severely disturbed areas such as those of old mining activity. Herbs (Equisetum spp., fireweed [Epilobium angustifolium], Artemisia arctica, Iris setosa, Aconitum delphinifolium, Achillea borealis, Valerinana capitata, and Polemonium caeruleum L.) often form a profuse understory. Lichens are usually absent except on the disturbed sites on which Stereocaulon spp. often is abundant.

Greenleaf willow.--The willow in this sub-type is one or more of such species as *Salix glauca*, *S. pulchra*, and *S. richardsonii*. It is found throughout the area along streams, on the edge of solifluction lobes, on steep banks, and on slopes where there is usually some running water. The areas occupied are usually quite disjunct, but as an aggregate, this type comprises a large portion of the reindeer ranges. *S. glauca*, and occasionally *S. alaxensis*, generally occur on the edges of these willow patches. This type is especially important in the early summer as the emerging willow leaves are one of the first and largest sources of green forage. It is utilized by reindeer throughout the summer and to a lesser extent in the fall.

Alder-Herb

Alders (*Alnus crispa* and *A. fruticosa*) form large, dense thickets on well-drained slopes and bluffs throughout the areas occupied by reindeer. Reindeer do not normally browse alders, and since the alders form dense thickets, the reindeer cannot utilize the understory herbs.

The "Willow-alder-balsam poplar type" of Hanson is not separated from the alder type because they have similar forage values, and the former has a restricted range.

Birch Type

Birches (dwarf alpine birch, glandular scrub birch, and birch hybrids) form large stands on some moderate slopes throughout the Seward Peninsula. Often these stands are somewhat open; and in these openings dwarf shrubs (bog blueberry, narrow-leaved Labrador tea, and crowberry) and lichens (*Cladonia rangiferina*, *C. sylvatica*, *C.*

gracilis, *Cetraria cucullata*, and *C. islandica*) are abundant. This type is used by reindeer during the summer, and the lichens can be grazed in early winter before the snow becomes too deep.

Birch-Willow Type

This type occurs mainly in the vicinity of Council at the edge of the white spruce forest. It contains the same species of birches as the Birch type as well as several of the greenleaf willows and alders. Dwarf shrubs, grasses, forbs, and lichens are common, and include crowberry, bog blueberry, narrow-leaved Labrador tea, bluejoint (*Calamagrostis canadensis*), Alaska bunchgrass (*Arctagrostis latifolia*), rough fescue (*Festuca altaica*), *Cardamine pratensis*, *Sedum roseum*, *Mertensia paniculata*, *Cladonia rangiferina*, *C. sylvatica*, *C. gonecha*, *C. cornuta*, and *Stereocaulon tomentosum*.

Dwarf shrubs
(less than 2.5 ft high)

Dwarf Shrub-Lichen Type

This is a consolidation of Hanson's "dwarf birch-heath-lichen" and "blueberry-heath-lichen" types. I have chosen to combine these two types because of the difficulty in distinguishing between them from the air, and because there seems to be a continuum from stands in which dwarf alpine birch dominates to those in which bog blueberry dominates. This type is found throughout the reindeer ranges in Alaska, especially on the slopes of foothills. It also occurs on mounds in the *Eriophorum*-*Carex*-dwarf shrub meadow type.

Dwarf shrubs are abundant, and include bog blueberry, dwarf alpine birch, narrow leaved Labrador tea, crowberry, alpine azalea

(Loiseluria procumbens), mountain cranberry (Vaccinium vitis-idaea), alpine bearberry (Arctostaphylos alpina), Salix glauca, S. pulchra, and S. richardsonii, which are interspersed with large growths of lichens (Cladonia rangiferina, C. sylvatica, C. amaurocraea, C. uncialis, C. gracilis, Cetraria cucullata, and C. islandica. Sedges, grasses, and forbs are scattered throughout. The dominant species include Carex montanensis, C. bigelowii, Alaska bunchgrass, rough fescue, red fescue (Festuca rubra), Hierochloe alpina, Poa arctica, Agrostis borealis, Alopecurus alpinus, Pedicularis labradorica, Luzula multiflora, Polygonum bistorta, and arctic coltsfoot (Petasites frigidus). The entire area is usually underlain by a moss mat, mostly Sphagnum spp. and Polytrichum spp.

This is the most important reindeer range type on the western portion of the Seward Peninsula and the coastal islands.

Four-Angled Heather-Mosses

This type is found in areas on which the snow remains the longest before melting. The substratum is often poorly developed, and well drained. Other dwarf shrubs, herbs, and mosses may be present, but often four-angled heather (Cassiope tetragona) forms a solid mat. Lichens, if present, are poorly developed. This type has little forage value for reindeer, but is a good indicator of areas where snow accumulates or remains into the summer.

Alpine Bearberry-Rhododendron Type

This is a modification of Hanson's "alpine bearberry-mountain cranberry" type. I have included Kamchatka rhododendron (Rhododendron kamtschaticum) with alpine bearberry because they are very similar from the air, and both are best developed on rocky soils, and usually on moderate slopes. The type does not become very extensive but is readily distinguishable from the air, especially during the autumn. The vegetation in this type is usually poorly developed. Lichens seldom obtain a length over 2 inches. It is of little importance in reindeer management because of the limited available forage, the rocky substratum and its limited range.

Dryas Fell-Fields

This is the same as Hanson's "alpine *Dryas*" type. It occupies the upper slopes and summits of hills and mountains throughout the entire region. *Dryas octopetala* forms complete mats in some areas and in others the mat is interrupted by large, rocky terraces or strips. Other common shrubs or subshrubs are *Salix phlebophylla*, crowberry, narrow-leaved Labrador tea, alpine bearberry, alpine azalea, and diapensia (*Diapensia lapponica*). Grasses (*Agrostis borealis*, and *Hierochloe alpina*) and forbs (*Luzula nivalis*, *Tofieldia pusilla*, *Campanula lasiocarpa*, *Oxtropis nigrescens*, *Pedicularis lanata*, and *Antennaria alaskana*) occur scattered throughout. The more important lichens include *Alectoria nigricans*, *A. ochroleuca*, *Cornicularia divergens*, *Sphaerophorus globosus*, *Cetraria nivalis*, *C. alaskana*, *Cladonia rangiferina*, *C. amaurocraea*, and *Thamnolia vermicularis*.

This is an important reindeer range type because the vegetation is usually available throughout much of the winter, and some of the lichens are preferred by reindeer; these include *Alectoria nigricans*, *A. ochroleuca* and *Cornicularia divergens*. This type requires a long time to recover from overuse (see p. 89). and should be carefully managed to prevent overgrazing.

Grassland-forb

Beach-Elymus

This type occurs as a narrow strip along the beach, and is best developed on the coastal islands. The soil is sandy; sand dunes often form. There are several grasses and forbs, the principal species being beach rye-grass (*Elymus mollis*), Alaska bunchgrass, fireweed, arctic coltsfoot, *Angelica lucida*, *Lathyrus japonica* Willd., *Arenaria peploides*, and *Equisetum* spp.

It is occasionally utilized by reindeer during the summer when they are on the beach attempting to avoid the insects or cooling off.

Grass Tussock

This type is best developed on the coastal islands, particularly Nunivak Island. It is composed of large, rough fescue or bluejoint tussocks. Several forbs (*Achillea borealis*, *Artemisia arctica*, *Polemonium caeruleum*, *Equisetum* spp., and fireweed) and grasses (*Poa* spp. and Alaska bunchgrass) are found on the edges and interspaces. Lichens are poorly developed and include *Cladonia gracilis*, *C. crispata*, and *Cetraria islandica*. It is of limited value to reindeer.

Calamagrostis-Arctagrostis Grassland

This type is scattered throughout the reindeer range. Usually it does not cover large areas and is best developed in the *Eriophorum-Carex*-dwarf shrub meadow and on disturbed areas near reindeer corral sites. This and the preceding two types were all included by Hanson in his "grasslands" type.

Ruderal

This type occurs on disturbed areas, particularly around mining camps. Forbs (fireweed, *Equisetum*, *Solidago multiradiata*, and *Artemesia tilesii*) predominate. Grasses (bluejoint, Alaska bunchgrass, and *Agrostis borealis*) are present to a lesser extent.

Sedge marsh

Eriophorum Tussock

Eriophorum vaginatum covers large areas in the lower elevations throughout the region. Other plant species include bog blueberry, dwarf alpine birch, and narrow-leaved Labrador tea. Occasionally some lichens (*Cladonia rangiferina*, *C. sylvatica*, and *C. amaurocraea*) will grow in the interspaces between the tussocks. This type is especially important in early summer as the young, green leaves and culms are avidly sought by the reindeer.

Eriophorum-Carex-Dwarf Shrub Meadow

This is the same as the "*Eriophorum*-*Carex* wet meadow" of Johnson et al. (1966) and the "cottongrass-sedge-dwarf heath shrub complex" of Hanson, which also includes the preceding type. This type is usually adjacent to the preceding type and is widespread in the entire region.

I have divided this into two sub-types.

Wet.--This sub-type occurs along the ponds and streams. *Carex aquatilis*, *C. kelloggii*, *Eriophorum angustifolium*, and *E. scheuchzeri* dominate, and during the summer they are very robust and bright green. *Chrysanthemum arcticum*, *Andromeda polifolia*, *Salix arbutifolia*, and *Potentilla palustris* are interspersed throughout this type. *Hippuris* vulgaris is emergent from the shallow portions of the ponds.

Dry.--This sub-type occurs away from the edges of the ponds and streams, and the plants are not as robust or green as in the wet sub-type. There are relatively more shrubs and herbs in the dry sub-type than in the wet sub-type. Both sub-types are underlain by a dense moss (Sphagnum spp.) layer. Lichens occur on the drier sites throughout this type, but they are often destroyed by trampling after a few years use by reindeer. This is the principal summer reindeer range.

Sedge-Sphagnum-Moss

This type is widespread but more common within or near spruce forest. The Sphagnum spp. mat is usually several inches thick and is often in low, boggy areas. Sedges (Carex spp. and Eriophorum spp.) and dwarf shrubs (narrow-leaved Labrador tea, dwarf alpine birch, mountain cranberry, crowberry, Oxycoccus microcarpus, and cloudberry [Rubus chamaemorus] occur sparingly throughout.

Rock desert

Rock-Foliose Lichens

This is comparable to Hanson's "lichen-moss barrens". The foliose lichen (Umbilicaria hyperborea) is widespread on the rocks. There are some fruticose species (Cladonia uncialis, C. alpestris, C. amaurocraea, and Sphaerophorus globosus) growing between the rocks. It is found chiefly on the mountain summits and adjacent to Dryas fell-fields. This type can provide emergency winter forage.

VEGETATION SAMPLING METHODS USED IN OTHER COUNTRIES

Canada

On reindeer ranges

A reindeer herd is located in the Mackenzie Reindeer Preserve, Northwest Territories, Canada. A forage survey has recently been conducted by the Canadian Wildlife Service on the Preserve, but the results are not yet published.

Hustich (1951) made a study of the lichen stands in Labrador to determine the area's potential for reindeer. He conducted a general survey of the area by establishing sample plots 1/40 acre in area in different vegetation types. An analysis of the ground vegetation by ocular estimation was made on a typical part of the sample plot, usually 6 by 6 ft. The vegetation was listed by a frequency scale with four classes: dominant, common, scattered, and occasional individuals of a species. He determined the total amount of pastures in Labrador, and then used figures from Soviet experiments to determine carrying capacity (Hustich 1951, p. 41).

On caribou ranges

Ahti (1959) estimated the cover by the individual species in one m^2 quadrats in Newfoundland. The average heights of lichens and dwarf shrubs were also measured in each quadrat. He used these figures to determine the composition, distribution, and succession of the different lichen stands and the effects of fire and grazing.

The Canadian Wildlife Service has conducted extensive studies on caribou ranges in Canada. Banfield (1954) used Raunkiaer's circle method to record species and approximate coverage of their leaves and stems. He also recorded the spacing of individual plants of each species by a modification of the Braun-Blanquet scale. The cover was tabulated as "total coverage of each species, expressed as a decimal fraction of the total area surveyed." A frequency index was computed as "the number of times each species occurred, expressed as a decimal fraction of the total number of samples."

He clipped all of the new seasonal growth (leaves, berries, and twigs) one inch from the ground in one $yard^2$ quadrats. He states, "The ground lichens were also collected." It is not certain whether he removed the decaying portion. The vegetation was separated by species, air dried, and weighed to determine production of the various communities.

Kelsall (1957:62) in continuing these studies states:

> The prime objective was to assess the influence of forest fires. Secondary objectives were (1) to enumerate the plant species, particularly lichens and to determine their relative densities and proportions; and (2) to determine the forest types and their proportionate utilization by caribou.

He decided against using Raunkiaer's circle and random plot techniques as he felt they depended too much on the judgment of the investigator. He wanted a method that could be used by various workers continuing the study. On page 62 he explains why he chose the line-point method.

> The line-point transect technique was decided upon for sampling the range vegetation. This is possibly the simplest of the range survey techniques, and it also appears to be the fastest in operation. The only articles of equipment needed - and used during the present investigation - are a compass, a 100 ft tape, and a notebook and pencil. The point-sample technique appears to be fully as useful, and was discarded only because it depends to a considerable extent on equipment.

The vegetation on the left hand side of the tape directly below each foot marker was recorded. The transect lines followed a compass bearing from the starting point. One end of the tape was held, and another man laid out the rest of the tape along the proper bearing by dropping the tape to the ground from a height of two and one-half ft. He states, "Vegetation above this height did not need to be sampled since caribou do little browsing." This is perhaps an oversimplification because reindeer avidly strip the leaves from willows during the spring and summer, and it is likely that caribou browse willows as well.

A transect line consists of 10 readings of 100 ft segments with each segment being separated by 300 ft for a total of 1,000 points.

> This number was decided upon because it was thought to provide sufficient samples for significance and also gave at a glance the percentage composition of the range by species. It was found that all important species of plants on a given range were present in 1,000 points and, as nearly as could be ascertained, the majority of the less important ones were also present.

This phase of the range studies was not continued, but a contract was issued for a study of caribou ranges through air photo interpretation (Kelsall 1960).

Scotter (1964) used the weight-estimate method (Pechanec and Pickford 1937, Campbell and Cassady 1955) to determine forage production in his study of the effects of forest fires on the winter range of caribou in Canada. This is the method I believe to be the most suitable for use on reindeer range in Alaska. The following is taken directly from his publication of the completed project (Scotter 1964: p. 45-46).

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

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

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

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

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

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

Scotter (1962, 1964) sampled arboreal lichen production by felling selected trees, and removing and weighing all the lichens from the trees. Then he estimated the number of trees per acre by taking "wedge prism readings and measuring the diameter of all trees viewed in each 360° horizontal sweep." Edwards et al. (1960) also weighed the lichens from some trees, and Cringan (1957) estimated arboreal lichen production.

On musk ox ranges

Tener (1954, 1965), studying musk ox range in the Northwest Territories, used the Clarke point-sample method (Clarke et al. 1942), and large quadrats that were charted to determine the composition, frequency of occurrence, and density of the vegetation. The vegetation was sparse, and these methods seem to work well in that type of situation. He clipped and weighed the current annual growth to determine the production of the ranges.

Sweden

A collection of publications by Folke Skuncke on reindeer ecology and management in Sweden has been summarized and translated into English and is currently being prepared for publication by the

Alaska Cooperative Wildlife Research Unit (Skuncke 1967). This publication covers several aspects of reindeer range management in Sweden.

Only the portions concerning vegetation analysis are reviewed here.

Grading and quality

Detailed descriptions of the different seasonal ranges and their productivity are discussed by Skuncke. A person needs a good basic knowledge of the community principles to effectively evaluate vegetation types by the aerial visual method that he proposes for range surveying.

The first step is to grade or determine the degree of quality of each vegetation type. Selected plots (the translation does not indicate the size of the plots) within typical portions of a community or "norm communities" were carefully described. All parts of plants that are used by, and accessible to, reindeer were clipped, sorted by species, and weighed. Several of the clippings were chemically analyzed. From these data a five grade scale of quality was determined. This quality scale provided a basis for determining the annual production of plants. Grading a "samesita" or range allotment is very similar to methods used in the United States to determine range condition. Skuncke states, "The grader must look both backwards and forwards in time to be able to assess both normal pasture production and what constitutes and causes shortsighted deviations from it." A range's potential value is "the capacity of the range to give a certain standard production or standard yield of pasture plant every year..." under normal conditions.

In discussing the relationship of one range to another, he remarks:

> In the five-graded scale of quality, quality 3, for example, was calculated to be able to produce per year 3 times as large an amount of reindeer pasture plants as a range of quality 1 with all quantities in kg dry weight per hectare.

The quality ratings also reflect the accessibility of the forage for reindeer. A range site producing a large amount of annual growth, but that is covered by snow too deep for reindeer to paw through during the winter, would receive a poor quality rating.

Exclosures

He established sample plots to "study the effects of reindeer grazing on the lichens and on forest regeneration, and the influence of forestry measures both on the annual growth and regeneration of the lichens, and also on the technique and economy of reindeer husbandry." Paired sample plots were employed with one plot of each pair being protected from grazing. Each plot was subdivided into 10 to 30 sections, each section being 16 by 1 m (52.5 by 3.28 ft) in size. David R. Klein (Leader of the Alaska Cooperative Wildlife Research Unit) viewed some of these plots in 1965 while in Sweden. He stated (viva-voce) that the individual sections were laid out next to each other with a buffer zone between each section of approximately the same size to allow access without disturbance to the study sections. There was a buffer zone, as well, between the fence and sections. The exclosures were of various sizes, often being an acre or larger. Skuncke states that his later plots are much larger than the early ones.

Aerial surveying

The boundaries of the different seasonal ranges must be determined and outlined on a map before determining the quality and quantity of the various ranges. He suggests using maps with a scale of at least 1:20,000.

The evaluator must be able to differentiate the various communities from 150 to 200 m (492 to 656 ft) above the ground. He is supplied with form sheets listing the different vegetation types and nonproductive areas, i.e. water, rock outcroppings, highways, etc.

The estimated percentage that each type of community occupies is recorded during the actual survey and is rounded off to the nearest 10%. His method of surveying the plots is quoted in its entirety:

> The survey lines must as far as possible give an objective expression of the distribution of the vegetation. The survey percentages have to be decided according to the degree of accuracy required. The homogeneity of the pasture types, the experience of the observer and finally the costs.
>
> If one flies over a relatively flat piece of ground at a constant speed, it is easy to measure the distance between the sample plots through timing in relation to the speed of the plane. It is necessary to make a preliminary flight to set up the size and the form of the sample plots. The author did this by marking out areas on the ground and then adjusting the flying height so that the sides of the plot coincided with the lines of sight along the window frames and/or wing struts. It was found to be advisable at 150 to 200 m [492 to 656 ft] altitude to observe square areas of about 1,000 x 1,000 m [3,280 x 3,280 ft]. It is not of great concern if the sample plots become 10 to 15% too large or too small during the actual survey, since the estimation aims at relative information about the areas of impediment or types of community.
>
> It is best to start with a time interval of 60 seconds between the sample plots. With some practice this can be cut in half.....
>
> The valuer sits beside the pilot and calls out the number of every sample plot. The pilot has to follow the survey lines that the valuer has drawn on the map in advance as a guide, and he must keep the recommended speed and height and draw in the exact

place and number of every whole or half-minute area on the map [see Fig. 3].

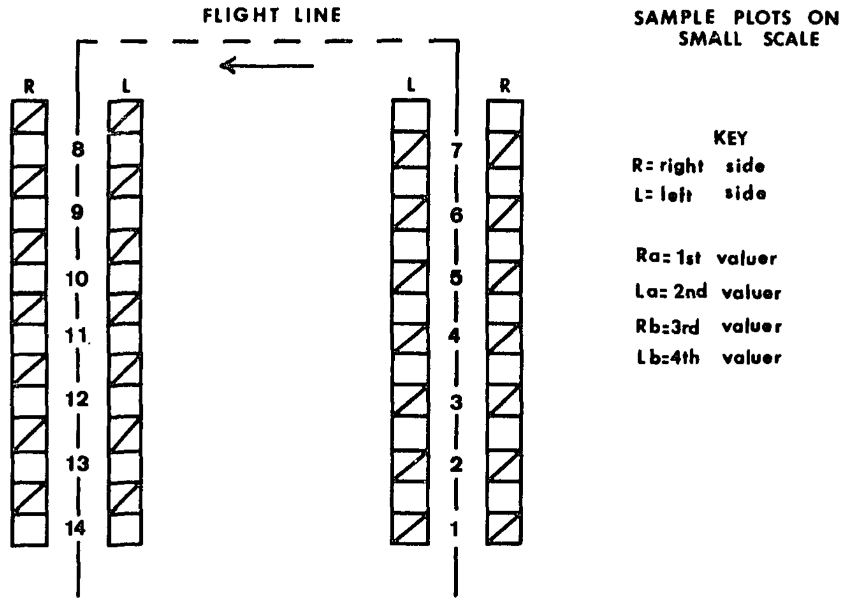
For the type of Cessna aircraft we used, the flying costs did not change at a flying height of up to 500 m [1640 ft] and with up to 5 passengers. Therefore 3 extra valuers and 1 timekeeper could be employed. All 4 valuers had a side window observation post. As soon as all four had passed a check flight the tasks were distributed so that the leader and the first assistant valuer each got a whole 60 second area, one to the right and the other to the left, while the second and third assistant valuers each received a half-minute area, also to the right and left. As the Cessna flew at the lowest advisable speed, 120 kph = 1 km/ 1/2 min [approximately 75 mph = 1.25 miles/min], it was possible to survey the whole length of the survey lines on both sides of the aircraft, that is to say 100% of a survey belt of 2 km [1.25 miles] width. This very large survey percentage allowed a relatively large distance between the survey lines. The distance varied between 20 and 30 km [12.4 and 18.6 miles], according to the homogeneity of the pasture ranges. The method gives a comprehensive view of the terrain which is also valuable in determining migration routes of reindeer herds and in appraising wear and tear of lichen pastures along reindeer fences; especially in transverse ones.

The average costs for the flying time and extra employees was $61.29 per hour, and the complete costs of the survey per km^2 surveyed is $.25 (approximately $.65 per mile^2). They were able to survey and grade the quality on the entire winter range of 4 samesitas (approximately 567 miles^2) during the 6 hours of flying time.

As the crew becomes more experienced the cost can be reduced to $.11 a km^2 (approximately $.29 per mile^2). Skuncke states:

> As soon as the experience of the crew makes it possible to identify plant communities from 250 m [820 ft] instead of 150 m [492 ft] height (this is most feasible in sunlight and when there are autumn colors), the speed of flight and periphery of sample plots can be increased by 50% that is to 180 kph [112 mph] and 1,500 x 1,500 m = 2.25 km^2 [4,920 x 4,920 ft^2] respectively, an increase that does not mean greater haste in working.

These surveys can be supplemented by color photography from the air on a certain percentage of survey lines, but Skuncke felt that in



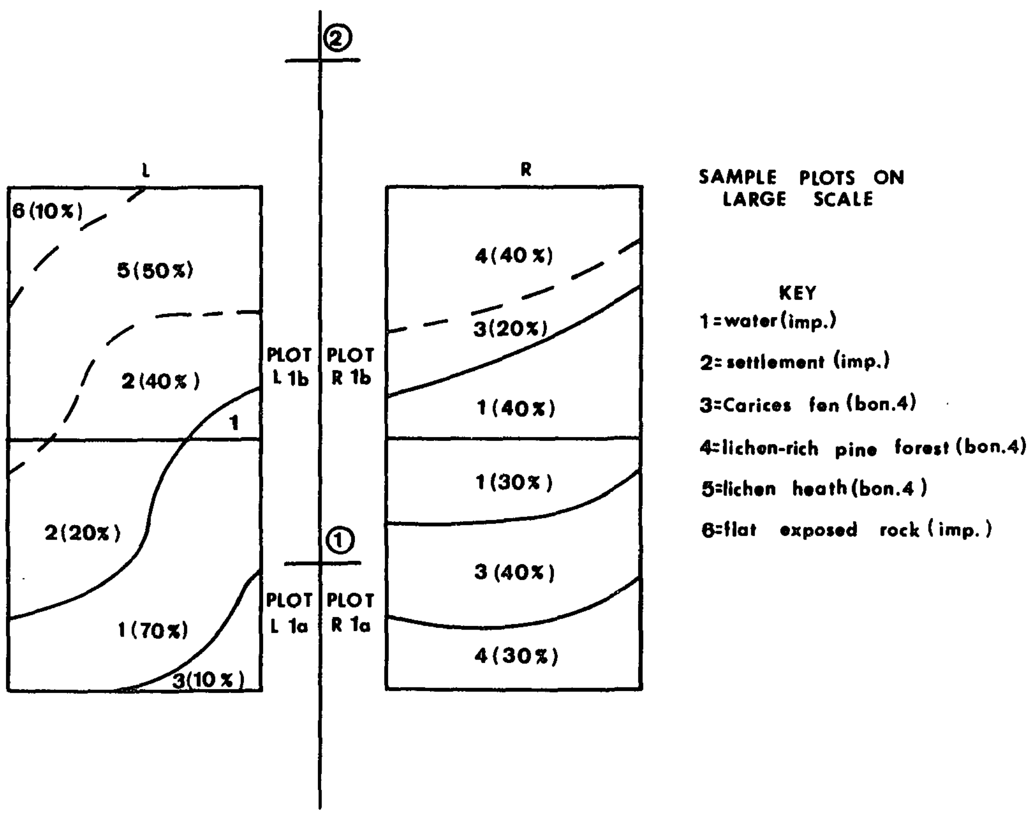


Figure 3. Flight lines and sample plots used in aerial surveying of reindeer ranges in Sweden (Skuncke 1967, Fig. 5).

normal cases it was unnecessary and always increased the cost of the survey.

USSR

Soviet investigators have studied reindeer ranges extensively. In reporting their data they are not usually very explicit concerning the methods employed to measure the different vegetation characteristics. Commenting on this, Kuvaev (1964) writes, "the methods of taking inventory of reindeer pastures, not to mention specific characteristics of the separate reindeer breeding areas, are far from uniform, possibly owing to a lack of information." He then proceeds to describe the seasonal ranges in which he includes the cover per cent and yields of the various species, without stating what methods he used to measure these attributes.

Composition and forage production

Species composition and forage production are the two principal attributes of the vegetation studied by most Soviet workers. Igoshina and Florovskaya (1939) used paired plots to determine the utilization of various plants by reindeer on the winter range. They clipped and weighed one plot from a feeding crater and another one from an ungrazed plot. The per cent utilization was calculated as the difference between the weight of the paired plots. They also measured the time reindeer grazed in various plots on different plant species. Ustinov et al. (1954) measured the stubble height of plants in feeding craters and compared these to adjacent ungrazed plants to determine the utilization of vegetation. Vasil'ev (1936) used 1 m^2 plots and estimated the cover and weight in each. Vikhereva-Vasil'kova et al. (1965) clipped and weighed the forage from plots .25 m^2 and in conjunction charted the vegetation on 1 m^2 plots.

Major emphasis has been placed on lichen production, recovery, and growth on most Soviet reindeer studies, particularly since Andreev's (1954) work. He indicated that lichens constitute 85 to 100% of the feed consumed during the winter and amount to 2/3 of the total reindeer forage for the whole year. His studies show that the fastest recovery of lichens occurs when up to 1/3 of the living portion is cropped. Recovery was usually complete after 3 to 5 years with this level of grazing. Aksenova (1937) reported that the highest concentration of carbohydrates, proteins, and fats occurs in the upper portions of the lichens. It is interesting to note that while some observers stress the importance of lichens, others (Ustinov et al. 1954, and Sdobnikov 1961) refer to reindeer herds that are apparently maintaining a satisfactory condition on a lichen-poor diet.

Makhaeva (1961, 1963) measured the area utilized by reindeer per day. He used a quadrat 10 by 10 m and plotted the outline and determined the area that was pawed clear of snow. He determined the per cent utilization of the plants by clipping and weighing paired plots 625 cm^2, one being over a feeding crater. He measured snow depth and density to determine the accessibility of different plants. That weight of forage production is considered to be one of the most important components of the vegetation to be studied is exemplified by Andreev's (1954) statement, "The supply of mature lichens is determined by the universally adopted methods of estimating the amount of forage on reindeer ranges."

Aerial methods

Andreev (1961) listed several uses for aerial photography and aerial-visual estimating on reindeer pastures. He states that the use of aeromethods in the last 15 years has enabled Soviet workers to cover map over 4 million km^2. Most aerial photographs are transferred to maps with a scale of 1:100,000. By improving the quality of the photographs and by using color and with the aid of helicopters for rapid ground checks, detail can be drawn onto maps with a scale of 1:10,000. He also states that with shrubs and certain lichens they are able to estimate the weight on pastures within 10 to 20%.

VEGETATION SAMPLING METHODS TESTED

Botanical Composition and Cover

An initial stage in a range survey should include a measure of the species contribution to the ground cover. Several of the vegetation sampling methods in current use can measure this attribute.

Point method

The point method was developed in New Zealand (Levy and Madden 1933) and has been widely used on pastures (Drew 1944, Tinney, Aamodt and Ahlgren 1937, Leasure 1949, Sprague and Myers 1945, Radcliffe and Mountier 1964a and 1964b) and on rangelands (Hanson 1934, Whitman and Siggeirsson 1954, Cook and Box 1961, Evans and Love 1957, Crocker and Tiver 1948, and Dasmann 1951).

Hanson (1950b), Brown (1954), Tothill and Peterson (1962), and Hutchings and Pase (1963) critically review point sampling, and several of the advantages and disadvantages are discussed. They felt that the point method is one of the most reliable methods of vegetation analysis.

Hanson (1950a, 1951), Kelsall (1957), Skoog (1957), Klein (1959), and Tener (1965) have used the point method on tundra vegetation in Alaska or Canada.

The point method appears to be particularly well suited to sampling tundra vegetation because the pin point makes possible the distinction of plant units in the sample. It is relatively rapid, ample replications can be obtained, and the necessary equipment is light and compact. The vegetation is not disturbed or damaged, and the technique itself does not induce changes in the botanical composition.

Methods

In the summer of 1965, both the line-point and point-frame methods were used. During the summer of 1966, only the line-point method was tested as it has been more widely used to measure trend (Kelsall 1957, Skoog 1957, Webb 1957, and Klein 1959).

A 100-ft steel tape was stretched tautly between two metal stakes driven into the ground. The tape was laid as close to the ground as possible without deflecting any vegetation along its length. A metal spring was attached from one end of the tape to a stake, and the opposite end of the tape was attached to the other stake by a turnbuckle to facilitate stretching the tape with a similar amount of pressure each time.

At each foot interval a tapered pin was lowered to the ground level. The vegetation touched by a descending pin was recorded in three categories: the first species hit; all hits on vegetation regardless of whether the same plant or different plants were hit more than once by the pin; and each species hit. The three methods of recording have often been used by different investigators to measure species composition of the coverage.

With the first hit method only the first species hit is recorded. Species composition is computed directly in per cent if 100 readings per line are read. The total usable forage is all vegetation other than moss. Bare ground, rock, litter, and moss were only recorded when they were the only objects hit by a descending pin.

In the all hits method, species composition of the coverage is equal to the total hits for that species divided by the total hits on all usable forage multiplied by 100 minus nonusable portion hits. The formula is as follows:

$$\frac{\text{Total hits for a species}}{\text{Total hits all usable forage}} \times \text{100 minus nonusable hits portion} \qquad (1)$$

Species composition with the each species hit method is calculated with the same formula used in the all hits method.

Discussion

Recording first hits only is the easiest and most rapid method, but as seen in Tables 1 and B-1, appendix B, it tends to favor the taller species, and the results are generally more variable. The all hits method is the slowest and most difficult to read, but it does measure the degree of cover. The main disadvantage of this method is counting the number of hits as the pin descends through a compact clump of lichens, especially when they are dry. Since in the each species hit and first hit methods a particular species is only recorded once on each pin regardless of the number of plant parts of that species the pin hits, they do not give a measure of the degree of cover. The degree of cover is particularly important where the point method is used to record changes or trend in the cover or composition.

Hanson (1950a, 1951) used the each species hit method to record the frequency of each species or dispersion of the individuals of a species in a vegetation type.

When different methods of recording point method transects have been compared, usually the area is clipped and weighed, and dry weight is used as the basis for determining which method gives the most reliable results (Drew 1944, Cook 1960, Arny and Schmid 1942, and Van Keuren and Ahlgren 1957). Correction factors had to be developed for certain species. On tundra vegetation the point method, which measures area, is best suited for measuring composition and cover, and efforts to try to correlate hits with weight should be avoided as there are better methods for determining weight that are described in the forage production section.

The average differences in composition and _t_ values of the differences of the most important species and groups by the three methods of recording on forty 100-ft line-point transects (4,000 points) are summarized in Table 1. The paired observation _t_ test described by Goldstein (1964) was used to determine if one method would give significantly higher or lower composition values. In the first group the each species hit readings were subtracted from the first hit readings with the readings from a transect being paired. In the second group the each species hit readings were subtracted from the all hit readings. A negative sign in the average difference column indicates that the each species hit method gave a higher composition value.

As seen in Table 1 the average difference between the first hit and each species hit methods is more than between the all hits and each species hit methods except for crowberry, which are almost the same, and _Cetraria islandica_. The _t_ values are usually lower on the all hits and each species hit methods.

The all hits readings were not compared to the first hit method,

TABLE 1. Average differences and computed t value of paired observations from the same line point transect using three different methods of recording composition.

		Method of Recording			
		First hit - each species hit		All hits - each species hit	
Species or Group	d.f.	Average difference	t[a]	Average difference	t[a]
Shrubs	38	3.38	4.84**	.29	.79 NS
Vaccinium uliginosum	32	.70	1.44 NS	.03	.17 NS
Empetrum nigrum	31	- .11	.33 NS	-.12	.78 NS
Betula nana exilis	28	3.19	3.53**	.23	.98 NS
Vaccinium vitis-idaea	27	-1.10	3.40**	-.17	2.18*
Ledum decumbens	24	- .23	.79 NS	-.16	1.32 NS
Salix pulchra	18	1.17	3.35**	.83	1.65 NS
Lichens	31	-3.94	6.41**	.65	2.49*
Cladonia rangiferina[b]	28	-1.32	3.70**	.78	2.26*
Cetraria islandica	27	- .45	1.76 NS	.69	3.57**
Cladonia gracilis	23	-1.19	4.07**	-.34	2.16*
Cetraria cucullata	18	- .74	2.54*	-.16	.35 NS
Sedges	36	1.40	3.68**	.54	1.53 NS
Carex spp.[c]	35	1.07	3.11**	.28	1.27 NS
Grasses	24	1.05	1.76 NS	-.48	2.54*
Calamagrostis canadensis[d]	18	-1.55	2.05 NS	-.59	2.11*
Forbs	33	-1.59	2.55*	-.56	2.41*

[a] **Significant at the 1% level; *Significant at the 5% level
NS = Not significant
[b] Includes *Cladonia sylvatica* and *C. mitis*
[c] Primarily *C. bigelowii*
[d] Includes *Arctagrostis latifolia*

but by comparing the sign of the difference and t values it can be seen that the difference between all hits and first hits is greater, with a few exceptions, than between the first hit and each species hit methods.

The mean number of hits on each species and the coefficient of variation of each in the two principal vegetation types, dwarf shrub-lichen and Eriophorum-Carex-dwarf shrub meadow, are listed in Table B-1. In the dwarf shrub-lichen type, the hits on ten 100-ft line-point transects are tabulated and 16 transects were used in the Eriophorum-Carex-dwarf shrub meadow type. The coefficients of variation are usually similar in the all hits and each species hit methods, and these generally are less than those of the first hit method.

It appears that the first hit method of recording species composition on tundra vegetation should be avoided since the results are the most variable of the three methods and it tends to overemphasize the taller species. The all hits and each species hit methods give similar results, but since the all hit method does measure the degree of cover, it should be used. The difficulty of counting the total number of hits by a pin descending through a clump of lichens can be reduced by continued use and becoming familiar with the method.

Goodall (1952) and Greig-Smith (1964) report that with point sampling methods the angle, size, distribution, and number of pins; angle, width, and length of the leaves; life-form and growth-form of the plants, affect the accuracy of the estimate. The line-point is not a reliable method of measuring changes in the cover or species composition (see Range condition and trend section). Therefore, point methods are not recommended for use on tundra vegetation.

Line intercept

The line intercept method was developed by Canfield (1941, 1944) in semi-arid type vegetation. He developed it to measure species composition of cover and utilization. Parker and Savage (1944) modified the line intercept method by increasing the width of the transect into a narrow belt.

Brown (1954) and Hanson (1950b) review several modifications of the line intercept method and concluded that it is best adapted to sparse vegetation where the plant units can be readily visualized and measured. The line intercept method has not been widely used on tundra vegetation in Alaska although Johnson et al. (1966) used it in their vegetation study of the Cape Thompson-Ogotoruk creek area in northwestern Alaska.

During the summer of 1965, I tested the line intercept method of Canfield (1941) in the dwarf shrub-lichen type near Nome. It was difficult to accurately delineate the different plants. This was especially true where a clump of lichens, often three to five species, would be interspersed by one or two prostrate shrubs, frequently crowberry, mountain cranberry, or alpine azalea. The same lines were reexamined, and the results were so variable that the method was discontinued. It does not appear to be suited to dense tundra vegetation because as the vegetation becomes more dense and complex, the outline of the plants intercepted becomes more arbitrary.

The U.S. Fish and Wildlife Service (Skoog 1959) and the Alaska

Department of Fish and Game (Skoog and Keough 1960) used the line intercept to measure utilization and destruction of lichens on caribou ranges. I used the line intercept method in the Eriophorum-Carex dwarf shrub meadow type, but it was discontinued after it was noted that when reindeer graze moist lichens they often remove entire clumps and do not leave any evidence that lichens ever existed in that particular spot, much less what amount of the lichens were utilized. This also occurs to a lesser degree with sedges and grasses as reindeer do not bite off their vegetation, but pull up on it; consequently, either the leaves, culms, or the entire plant are removed completely.

Cover estimates

Several methods of estimating cover are discussed by Brown (1954), Greig-Smith (1964), Oosting (1956), Holscher (1959), and Hanson (1950b). Cover estimate methods have been widely used on reindeer and caribou ranges in Alaska and Canada either alone (Hanson 1953 and 1958, Palmer 1926, and Hustich 1951), or in conjunction with other sampling methods (Palmer and Rouse 1945, Cringan 1957, Banfield 1954, and Skoog 1957 and 1959).

The estimates are taken within a quadrat, usually one m^2. Total cover is estimated directly, but species composition is frequently estimated according to the Braun-Blanquet or Hult-Sernander scales. Hanson (1953 and 1958) modified the scale to include six degrees rather than the usual five. He employed this method plus other characteristics of the vegetation to describe stands and general features of the vegetation types.

The principal advantage of this method is that it is rapid and provides direct comparison with similar vegetation types in other localities as Scandinavian workers widely use the Braun-Blanquet or Hult-Sernander scales to describe vegetation stands.

These scales should not be used on permanent quadrats to study the effects of grazing or trampling because the range is too large in the top three categories. Cover estimates on permanent plots should be the total that each individual species contributes.

This method was used on the dwarf shrub-lichen type near Nome. It was not tested extensively because I did not have an accurate measurement of the actual cover to compare with the estimate. It was rapid and comparatively easy to read. The sample size was large enough so that exact relocation of permanent plots was not as critical as in the point method.

Square quadrats were easier to sub-divide than circles, which aided in estimating. Caution should be exercised when estimating on tundra because plants like mountain cranberry, Cetraria islandica and Cladonia gracilis, which were often abundant, were easily overlooked unless careful examination of the plot was made.

Forage Production

Grazing capacity is dependent on the amount of forage a given area produces. Weight is a direct measure of forage production. When some other attribute of the vegetation is measured, i.e. cover, density, frequency, etc., the relation to weight is usually considered in determining grazing capacity.

Brown (1954), Reppert et al. (1963), and Hanson (1950b) discuss several methods of sampling weight. Scotter (1963a and 1964), Banfield (1954), Tener (1965), Skuncke (1967), Andreev (1954), Makhaeva (1961 and 1963), and Vasil'ev (1936) have all used a method of measuring weight of forage in their caribou or reindeer range studies.

Weight-estimate method

The weight-estimate method was developed by Pechanec and Pickford (1937) on rangelands in Utah after it was observed that the grazing capacity derived by measuring cover varied from the actual grazing trials. It has the favorable features that it is rapid and can be used on permanent plots. The weight-estimate method has been widely adopted in the western United States for range reconnaissance studies.

Hughes (1959) reviewed the application of the method and suggested possible uses of the weight-estimate method on southern ranges.

Method

The weight-estimate method was tested on the dwarf shrub-lichen type near Nome, and in the white spruce-lichen sub-type near Koyuk and Golovin. These are the principal winter range types and are the most complex communities, so if the method works under these conditions it should be applicable on the other vegetation types.

The procedure used was similar to that recommended by Pechanec and Pickford (1937), the major difference being that I tried to estimate both green and dry weights on some plots. Estimating dry weight eliminates the conversion of green to dry weights. This is particularly useful with lichens, whose green weights vary widely according to the weather conditions due to their hygroscopic nature. In addition, if dry weights are estimated directly, the clipping of samples of each species each day to use to convert the green to dry weights is not necessary. It has the disadvantage, however, that an estimate cannot be readily checked as the material must first be air dried.

The plots to be estimated were located by first selecting an initial point at random within a vegetation type. From this point, a sample plot was estimated at 100 ft intervals along a compass bearing until the line started getting out of the type, at which time a new initial point would be located and the procedure continued. Circular plots of three sizes, .96 ft^2, 2.4 ft^2, and 9.6 ft^2, were used. The method of locating the plots was the same for all sizes. A center pin was placed at the 100 ft mark of a tape, and the circular frame was laid down using the pin as the center of the plot.

In each plot the weight of the individual species was estimated to the nearest gram except in the .96 ft^2 plots, which were estimated to the .5 g. Some lichens, grasses, and sedges (Table B-2) were grouped and estimated as a group due to my uncertainty of identification.

The portions of the plants estimated were: the current growth of grasses, sedges, and forbs; current twig growth of deciduous shrubs; the green leaves of nondeciduous shrubs; the living portion of the lichen podetia.

A training period, as suggested by Pechanec and Pickford (1937), was conducted prior to testing the method to check the estimates with the actual weight.

The results of this method are discussed in the double-sampling method since one of the steps involved is the estimation of several plots.

Double-sampling method

Reppert et al. (1963), Hilmon (1959), and Brown (1954) review the application of double-sampling methods.

Wilm et al. (1944) described two methods of determining forage production by double-sampling. Of these two methods, the one using estimates on a large number of plots with a small portion of these being clipped and weighed was tried in the dwarf shrub-lichen type. A linear regression of the plots that were both estimated, and clipped and weighed, was used to adjust the data from the large number of plots on which only estimates were made.

Campbell and Cassady (1949), Frischknecht and Plummer (1949), and Scotter (1963a and 1964) have used this method or a slightly modified form.

The use of line-intercept transects combined with clipped plots described by Wilm et al. (1944) was not tested on the tundra vegetation. As noted in the line-intercept section, it is not very applicable on tundra; and the correlation of weight and cover in vegetation with several growth forms often is not accurate.

Method

The plots were located in the same manner as described in the weight-estimate section.

Three out of every 10 estimated plots were randomly selected to be clipped and weighed. The plots to be clipped were not selected until the group of 10 plots had been estimated. This prevents the estimator from being more conscientious while estimating the plot to be clipped, but it involves more walking and time as the rods must be retrieved. A long rod with flagging tape attached was used as the center pin in each plot to facilitate relocation of the plots to be clipped.

The necessary field equipment includes a small spring balance with a 250 to 500 g capacity, sacks, a pair of scissors, plot frame, compass, tape, center pins, and recording material.

Wilm et al. (1944) wanted a short cut method that could be used with accuracy comparable to clipping and weighing all plots. My objective was to see if by clipping a few plots the accuracy of the estimate could be improved over estimates alone, and whether this gain in accuracy was worth the extra time required to clip, sort, and weigh the various species.

<u>Discussion</u>

Frischknecht and Plummer (1949) stated that plots .96 ft^2 could be used in areas of high uniform productivity. After using .96 ft^2 plots on the dwarf shrub-lichen type near Nome, it was discontinued because the natural variability of species in this type is large (Table 2).

Ten plots 9.6 ft^2 in area were estimated and then clipped. It was soon apparent that to separate the species was going to take a

TABLE 2. Mean weight, standard error, coefficient of variation of clipped and estimated plots and corrected means. Optimum ratio of clipped to the estimated plots for the most important species and groups that were double-sampled.

Species or group	mean weight (clipped) per 2.4 ft^2 grams	Standard error grams	coefficient of variation %	mean weight (estimated) per 2.4 ft^2 grams	Standard error grams	coefficient of variation %	mean weight (corrected) per 2.4 ft^2 grams	Optimum ratio clipped to estimated plots (see formula 2)
Total forage	128.40	17.88	76	146.53	8.05	55	143.19	1:35
Shrubs	39.10	4.56	64	47.41	2.29	48	44.88	1:11
Empetrum nigrum	9.83	1.71	95	13.40	1.19	89	12.20	1:6
Betula nana	7.85	2.29	160	7.46	1.03	138	7.04	1:5
Vaccinium uliginosum	6.12	1.22	109	6.72	.60	90	6.33	1:20
Ledum decumbens	5.33	.83	85	5.95	.46	78	5.97	1:12
Vaccinium vitis-idaea	1.98	.45	125	1.91	.23	119	1.91	1:11
Lichens	83.25	14.33	94	90.58	6.54	72	90.55	1:40
Cladonia rangiferina[a]	45.90	9.98	119	48.31	4.59	95	47.79	1:25
Cladonia amaurocraea[b]	7.76	2.48	175	7.84	1.03	131	8.16	1:11
Cladonia uncialis	6.89	1.92	153	8.19	1.04	127	7.97	1:5
Cladonia gracilis	6.89	1.77	141	7.13	.80	112	6.68	1:4
Cetraria islandica	7.35	1.38	103	7.22	1.00	138	6.74	1:26
Grass-like plants[d]	6.16	1.10	98	7.84	.60	77	7.81	1:12

[a] Includes *Cladonia sylvatica* and *C. mitis*
[b] Includes *Cladonia crispata* and *C. subfurcata*
[c] Includes *Cladonia boryi*
[d] Includes all *Poacaea*, *Cyperaceae* and *Juncaceae* present in plots

considerable time so the forage was placed in bags and then sorted by species in the laboratory. The estimates were usually within 7-10% of the actual weight, but as the total weight in a 9.6 ft^2 plot averaged 768 g and often exceeded 1,000 g, this amount of vegetation can unnerve the estimator.

The average time required to estimate a 9.6 ft^2 plot was 18 minutes compared to 7 hours and 30 minutes to clip, sort, and weigh the various species from the same plot. The following equation from Schumacher and Chapman (1948) was used to determine the optimum ratio of estimated plots to clipped plots:

$$\frac{m}{n} = \sqrt{\frac{Cn}{Cm}} \left\{ \frac{(b)(sx)}{sy.x} \right\} \qquad (2)$$

where m = estimated plots

n = clipped plots

Cn = time required to clip a plot

Cm = time required to estimate a plot

b = regression coefficient

sx = standard deviation of the estimated values

sy.x = standard deviation from regression.

Using this equation, the optimum ratio was approximately one clipped plot per 40 estimated plots. One clipped plot requires almost an entire working day to clip, sort the species, and weigh. In addition, the forage is bulky and must be brought into the laboratory to be air dried. Approximately 25 plots can be estimated in the time required to clip one plot.

The mean weight, standard error, and coefficient of variation for some of the more important species and groups from 100 estimated and

30 clipped 2.4 ft^2 plots are presented in Table 2. The following linear regression equation was used to correct the mean weight of the estimated values:

$$Y = \bar{y} + b(\bar{x}_1 - \bar{x}_2) \quad (3)$$

where Y = the actual weight considering the regression of clipped on estimate

$\bar{y}$ = the mean of the actual weight of clipped plots

b = the regression coefficient

$\bar{x}_1$ = the mean of the estimates on all estimated plots

$\bar{x}_2$ = the mean of the estimates only on the plots that were clipped.

The coefficients of variation are rather large, and this is caused mainly by the natural variability of the tundra vegetation. The coefficient of variation can be reduced to some extent by increasing the number of plots as seen when the coefficients of variation of the 30 clipped plots are compared to the 100 estimated plots. This can also be reduced by increasing the size of the plot.

The weight in grams of vegetation from 40 plots 2.4 ft^2 is equal to the weight in lb. per acre. The corrected and estimated weights of all species occurring on the 2.4 ft^2 plots converted to lb. per acre are presented in Table B-2.

The 2.4 ft^2 size plot was comparatively easy to estimate, and the accuracy of the estimate was usually within 10% of the actual weight, and when a group of estimates are summarized the accuracy is usually within 5 to 7%. When the actual weight means are corrected by the regression equation, the estimated means are very similar, usually within 2%.

The average time required to clip, sort, and weigh the forage from a 2.4 ft^2 plot is 1 hr 30 min. To estimate a plot it takes about 12 min. The optimum ratios of clipped to estimated plots are listed in Table 2. They vary considerably according to the species and its abundance.

For general range reconnaissance studies, the weight-estimate method could be used and the data would be reliable if the estimators are conscientious. Considerable time can be saved by not having to clip, sort, and weigh the various species, and this time can be used to estimate more plots. Possibly plots 4.8 ft^2, which multiplied by 20 gives lb. per acre, could be used to increase the precision of the estimates. The time required to estimate the larger plot would probably be less than the time to locate more smaller plots to get the same precision of the estimates.

Double-sampling does provide a method of checking and correcting the estimates. The means and variances of the estimates can be corrected if some of the plots are clipped. Double-sampling would be useful for intensive studies.

Lichen growth rates

It is widely held that lichens are the principal component of the diet of reindeer and caribou. They may constitute two-thirds of the total food eaten by reindeer (Andreev 1954) and are especially important during the winter. Range management practices for reindeer and caribou must be based on principles that incorporate lichen biology.

Certain fruticose species of *Cladonia* are the principal lichens in reindeer and caribou management either due to their abundant occurrence or to their palatability or both. Three species, *Cladonia alpestris*, *C. rangiferina*, and *C. sylvatica* may comprise from 75-90% of all lichens eaten by reindeer (Andreev 1954). Knowledge of the growth rates of these species is essential to determine carrying capacity, rate of recovery, and patterns for rotational grazing of reindeer and caribou rangelands.

In North America, only a limited number of range studies have included growth rate data. Scotter (1963b and 1964) in the Northwest Territories and Northern Saskatchewan, respectively, and Ahti (1959) in Newfoundland, are the principal investigators of lichen growth rates. In Alaska, growth rate data are apparently completely lacking aside from a casual statement by Palmer (1926) that lichens grow from 1/8 to 1/4 inch per year. In the USSR, growth rate data have been extensively collected in conjunction with other studies concerning reindeer management. Andreev (1954) reviewed growth rate studies throughout the USSR, which included over 37,000 measurements taken under a myriad of vegetative, climatic, and edaphic conditions. He included many management recommendations based on the information gained in these studies.

The Soviet studies indicate that fruticose Cladonia lichens have three distinct growth periods. The first is the growth accumulation period during which the podetium increases in length for an average of 10-15 years. Igoshina (1939), Gorodkov (1936), Glinka (1939), and others marked several podetia of fruticose species of Cladonia, and they found that branching of the podetium generally occurred once each year. The new branch forms at the top of the podetium so that each node along the podetium represents one year's growth, with the oldest node at the base. Growth of the podetium consists of the apical and the intercalary growth.

The second period of growth is the podetium renewal period. The algal and fungal cells at the base of the podetium become moribund and eventually die. This decaying of the base occurs at approximately the same rate that the living portion of the podetium is growing. Thus the length of the living portion of the podetium remains fairly constant for several decades until the third stage, the podetium degeneration period, is reached. This occurs when the base decomposes faster than the new growth accumulates on the top. Eventually the podetium dies.

Methods

Since the podetium branches once each year, the average annual linear growth rate is obtained by dividing the length of the living portion of the podetium by the number of nodes on it. The living portion is distinguishable due to a color change in the region where the podetium is decaying. The formula, length of living podetium/ number of nodes on the living podetium = average annual linear growth rate of the podetium, was used to measure 100 podetia each of Cladonia alpestris, C. rangiferina, and C. sylvatica at three different localities on the Seward Peninsula, Alaska. Podetia with decay at their bases, which were in the podetium renewal period, were used for the measurements. They were measured while moist and fully expanded as dry podetia shrink and are very brittle. For comparative purposes, it is imperative that only moist podetia be measured.

Areas.--Site number one is in the foothills west of the Snake River, 6 miles northwest of Nome, Alaska. This is in the dwarf shrub-lichen type composed mainly of fruticose lichens, Cladonia rangiferina, C. sylvatica, C. amaurocraea, C. gracilis, Cetraria cucullata, and C. islandica, with interspersed small shrubs of bog blueberry, narrow-leaved Labrador tea, crowberry, and dwarf alpine birch. This type covers most of the foothills from the coast inland to the Kigluaik Mountains.

The second site is Dexter Creek, 7 miles north of Nome. It is similar to the Snake River site except the lichens are more abundant, especially Cladonia alpestris.

The third site is in a white spruce-lichen sub-type near Koyuk, Alaska. The lichens are more abundant and robust than at the two sites near Nome. Cladonia alpestris occurs in large uniform stands in open areas in the forest, particularly on high knolls. Dwarf alpine birch, bog blueberry, crowberry, and narrow-leaved Labrador tea are present, but lichens compose a larger portion of the total flora.

Results and Discussion

As seen in Table 3, the average annual linear growth rates of *Cladonia rangiferina* and *C. sylvatica* are similar in the three localities. The growth of *Cladonia alpestris* was notably more in the white spruce-lichen sub-type, 5.8 mm as opposed to 4.6 mm, than in the dwarf shrub-lichen type. Andreev (1954) noted that lichens growing in uniform stands generally had greater growth rates than those in mixed stands. *Cladonia alpestris* seems to be the most susceptible to damage by grazing of the three species studied. Apparently it has not fully recovered from past reindeer use on the range near Nome.

Growth rates on the Seward Peninsula are greater, Table 4, than those of northern Saskatchewan (Scotter 1964) and the Taltson River region, Northwest Territories (Scotter 1963a). The Seward Peninsula, being adjacent to the Bering Sea, has proportionally more foggy, drizzly days in the summer which create more favorable growing conditions for the lichens than in interior Canada. The lichens are generally found growing on a moss substrate, principally *Sphagnum* spp. and *Polytrichum* spp., which retains a considerable amount of moisture even when the air is relatively dry. Ahti (1959), working in Newfoundland, reports that lichens usually grow more rapidly in maritime heaths.

The growth rates in the open forest of the Pechora North, USSR (Andreev 1954), are very similar to those at Koyuk, while those in the subarctic tundra are less than near Nome. The average length of the growth accumulation period on the Chukotsk Peninsula is 16 years, about 5 years longer than those found near Nome. The lichen recovery rate

TABLE 3. Average annual linear growth rate of Cladonia alpestris, C. rangiferina and C. sylvatica on the Seward Peninsula, Alaska.

Location	Average annual linear growth rate (mm)			Average length of growth accumulation period (years)		
	C. alp.	C. rang.	C. sylv.	C. alp.	C. rang.	C. sylv.
Snake River	4.3	5.3	5.2	11.1	6.6	10.0
Dexter Creek	4.9	5.0	5.5	11.3	5.6	11.7
Koyuk	5.8	5.6	5.5	10.8	5.5	10.3

TABLE 4. Average annual linear growth rate of Cladonia alpestris and C. rangiferina in different regions.

Location	Average annual linear growth rate (mm)		Source
	C. alp.	C. rang.	
Talston River, N.W.T.	3.4	4.1	Scotter 1963b
N. Saskatchewan	4.1	4.9	Scotter 1964
Chutotsk Peninsula, USSR	3.3	2.7	Andreev 1954
Tundra) Pechora North,	3.3	3.9	Andreev 1954
Open Forest) USSR	5.0	5.5	Andreev 1954
Tundra) Seward Peninsula,	4.6	5.1	Table 3
Forest) Alaska	5.8	5.6	Table 3

should be more rapid on reindeer ranges on the Seward Peninsula than on the Chukotsk Peninsula.

Cladonia rangiferina reached the period of podetium renewal almost twice as fast as either C. alpestris or C. sylvatica; averages were 5.9, 11.1 and 10.7 years respectively. Since Cladonia rangiferina matures earlier than the other two species (Scotter 1963b, Andreev 1954, and Table 3) grazing on ranges in which it predominates should be rotated more often to obtain maximum utilization. If a range land with mature lichens is not grazed, the production of lichens will accumulate as peat, and its potential use as forage for reindeer will be lost.

Efforts to increase the lichen growth rates by chemical stimulants have mostly been unsuccessful (Andreev 1954), although Barashkova (1964) reported increases ranging from 137 to 164% with the use of 2,4-D, Thiamine, or ammonium sulphate. Andreev (1954) recommended proper grazing of lichen pastures to get the maximum growths rather than use of chemical stimulants. He suggests rotating pastures so that reindeer only graze the top 1/3 of the lichens as complete restoration of the lichen crop under these conditions occurs within 3 to 5 years.

Range Condition and Trend

Range condition is the state of health of the range and is expressed in the amount of forage an area will produce under the best practical management. Normally a rangeland is classified as being in one of four or five classes: excellent, good, fair, poor, and sometimes very poor. The classes other than excellent represent the degree of departure from the potential of the site. Soil condition, cover, species composition, forage production, vigor, and use are all considered in determining the range condition.

Trend refers to the direction toward which the condition of a particular range is progressing. A range in poor condition that is deteriorating requires that the current grazing plan be altered, but a range in poor condition that is improving indicates that the plan is allowing for recovery of the range. There are many different guides or score cards that have been developed to aid in classifying ranges into the different range condition classes as well as to record trend. Several are presented in Sampson (1952) and Stoddard and Smith (1955). A useful tool for measuring trend is permanent transects or quadrats that can be reexamined periodically.

Line-point
(modified 3-Step method)

The 3-Step method (Parker 1954) is used widely in the western United States to evaluate range conditions and trend. Normally step one involves dropping a 3/4 inch loop at foot intervals along a tape stretched between permanent stakes to record botanical composition and cover. In testing this method on tundra vegetation, the 3/4 inch loop was found to be impractical because on several "drops" the loop would contain several species in varying amounts. This was especially true of lichens where one "drop" might contain up to five species in different relative amounts. Also the basal area of lichens and prostrate shrubs is difficult to delimit or identify.

The point-method, using a 2-ft long, 1/8 inch diameter rod with the end tapered to a fine point, substituted for the loop, was tested. Similar methods have been used by Kelsall (1957), Skoog (1957), Klein (1959), and Webb (1957) to evaluate ecological changes in tundra or alpine vegetation.

Method

Between August 22 and 25, 1965, 28 permanent line-point transects were established near Sunset Creek, 7 miles northwest of Nome, Alaska. Sixteen of these were in the dwarf shrub-lichen type, and 12 were in the *Eriophorum*-*Carex*-dwarf shrub meadow type. The transects were reexamined from August 19 to 23, 1966. The differences between two readings of any one transect should be due to either one year's growth or inherent in the method of reading the transects.

Twenty permanent line-point transects were established west of the Snake River, 6 miles northwest of Nome. These were located in dwarf shrub-lichen, *Dryas* fell-fields, greenleaf willow and *Eriophorum*-*Carex*-dwarf shrub meadow types. These transects were examined, and then re-examined within four days in early August, to determine if the mechanics of reading a transect varied the results. Any change in the readings could be attributed to the mechanics of reading the transects since growth, if any, this late in the season would be minimized. The reindeer herd in the area was kept over 2 miles from the transects so that the transects were not disturbed.

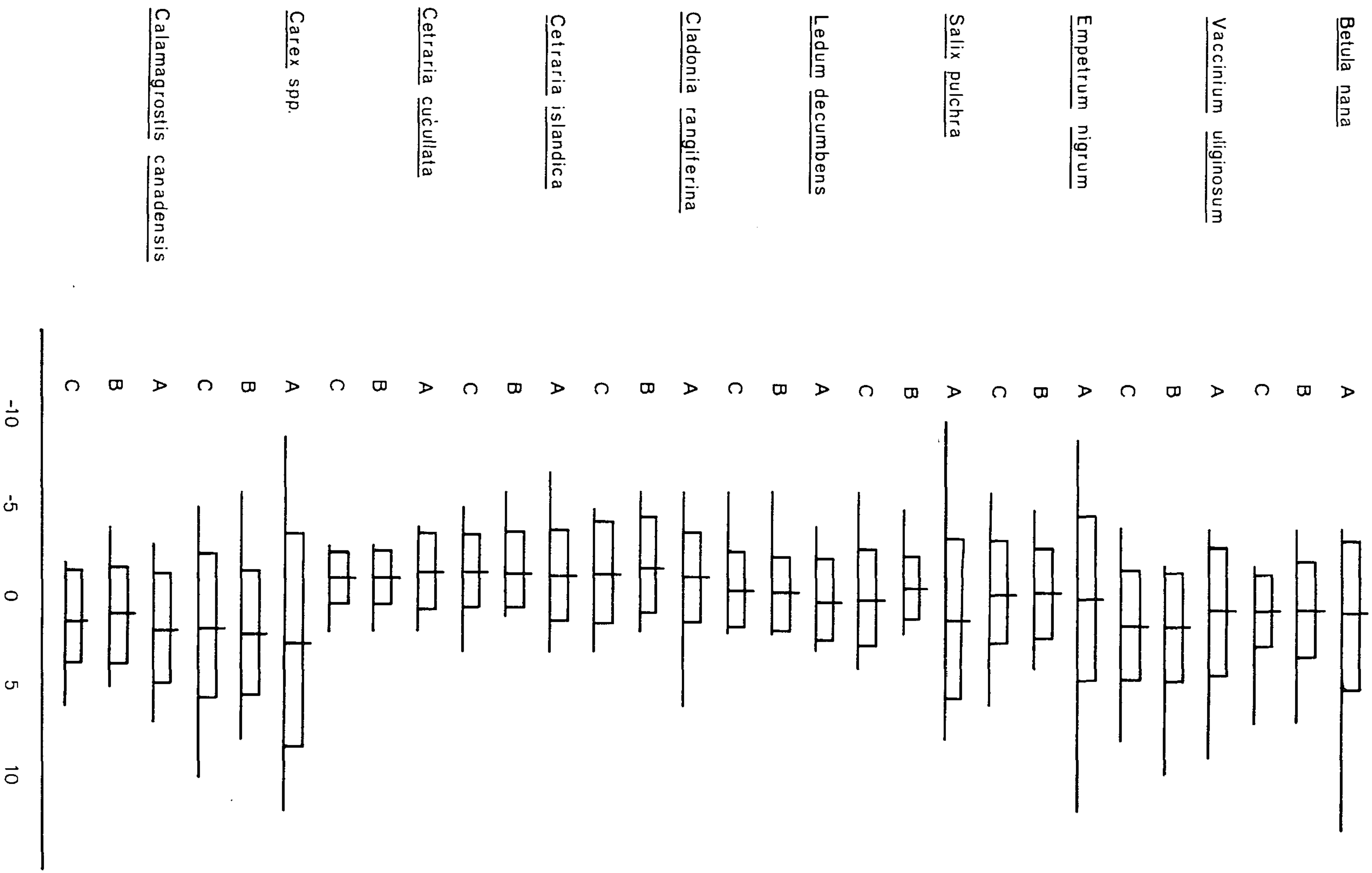
In both groups the transects were established in the same manner. A 100-ft steel tape was stretched tautly between two anchor points. Angle iron stakes were driven into the ground with the corners marking the 0, 40, and 100 ft points to facilitate locating the same points from one reading to the next. One end of the tape was attached to one of the anchor stakes by a metal spring, the other end was attached to the opposite stake by a turnbuckle so that the 0, 40, and 100 ft points of the tape could be directly aligned with the three angle iron markers. The tape was placed as close to the ground as possible, yet high enough so that no vegetation was displaced. The pin was lowered from each foot marker and vegetation touched by the pin as it descended was recorded.

On the group of transects established in 1965, only first hits and each species hit by the pin were recorded. The readings were taken at 1/2 ft intervals making a total of 200 readings per line. On the second group of transects, first hits, all hits, and each species hit were recorded at every foot on the tape.

The three methods of recording hits are described in the point-method section.

The concern is in the method itself. Could the transects be read and four days later be reexamined and the results be identical? Fig. 4 shows the mean, standard deviation, and range of the differences between first and second readings on the same transect of the most common species or types of ground cover from the Snake River transects.

Figure 4. Mean, standard deviation and range of the differences between first and second readings using three, A = first hit; B = all hits; C = each species hit, methods of recording species composition. The units are absolute values.



A more complete list as well as the per cent of second readings that were the same as the first readings are listed in appendix B, Table B-3.

The data from all twenty transects are combined. As can be seen, the per cent of second readings that are the same as the first reading is very low in almost all cases. The range of the differences between readings is the greatest in the species or types of ground cover that are the most abundant on the transects. The range and standard deviation of the differences between readings for most species and ground cover are so great that the use of a permanent line-point method for following ecological changes might be ineffective.

The standard deviation and ranges of the differences are similar for the all hits and each species hit methods, and both are usually less than by the first hit method.

The second reading of total usable forage differed from the first by -11 to +19% with a mean of 3.25%. The major portion of this difference results when a shrub, usually blueberry, dwarf alpine birch, crowberry, or Salix pulchra; or a Carex spp. is the only plant to be hit by a pin during one of the readings. On the next reading the tape might be displaced 1/4 inch, and the pin could descend through the same shrub or Carex without hitting a leaf or stem, but it would hit moss or litter. In the second instance, the nonusable portion would increase by one per cent, and the total usable forage would decrease by one per cent.

A pin point samples such a small area that in a very heterogeneous vegetation, such as tundra, the displacement of the pin's line of descent by 1/4 inch or more often causes a seeming change in the botanical composition. Several factors contribute to differences in the readings. The tundra, particularly where there is a large moss layer, is resilient, and when you step near a point the surrounding vegetation is pulled toward your foot. On windy days the determination of whether a plant was hit is subjective, in addition the tape sways even though it is tied to the 40 ft marker. It is difficult to count the exact number of times plant parts are hit if they are in clumps; this is particularly true of lichens and crowberry.

In Table B-4 the results of the 28 transects that were reexamined one year later are presented. On these transects the all hit method was not tested. The differences between the two readings are less than in the first group of transects. On these transects the vegetation under each 1/2 ft point was recorded for a total of 200 readings per 100 ft line. The more sampling points there are along the same length of line the more accurate is the sample.

The first and second readings of the same points on a transect are more variable than when the entire transect data is presented. Less than 35% of the first and second readings of the same points were identical. With the larger number of samples per line the readings tend to compensate one another.

On tundra vegetation where line replacement is so critical the use of a modified 3-Step (line-point) method as a means of recording ecological changes should be avoided if possible. If it must be used, the length of a line should be less than 40 ft and readings recorded at less that 1/2 ft intervals.

Charting

Charting is used primarily on permanent quadrats that are to be reexamined periodically. By comparing successive charts from the same quadrat, the individual plant's behavior can be followed. Charting requires experience and takes a considerable amount of time to complete. It becomes more difficult to accomplish as the vegetation becomes denser, more complex, and is composed of more layers. It is not practical for large scale surveys, but it has been used on intensive studies, especially in conjunction with range trend or succession studies.

Klein (1959) used charting and line-point transects to study the influence of an expanding, confined reindeer herd on its range. Palmer and Rouse (1945) used charting extensively on reindeer ranges in Alaska. They simulated different degrees of grazing or trampling on m^2 quadrats and followed the quadrat recovery by charting. The data obtained from these quadrats concerning plant succession and recovery from disturbance are presented in the report by Palmer and Rouse (1945).

During the summer of 1965, I attempted to relocate as many of these plots as possible. The quadrats in the exclosures were charted and compared to the charts that Palmer and Rouse made when they originally established the quadrats in the 1920's and the last ones they took before their report.

By 1965 the recovery of the vegetation was complete except on the most severely disturbed quadrats in the *Dryas* fell-fields. The lichens were dense, usually 3 to 5 inches in length, and frequently consisting of two to seven species with prostrate shrubs growing over and through the lichen mats. The m^2 quadrats were subdivided into 100 units by stretching string across the m^2 frame at decimeter intervals to aid in charting. The data from the quadrats are summarized and presented in the Reindeer and the Range section.

From the work of Palmer and Rouse, and my own, certain observations about charting on tundra vegetation can be made. Charting is useful in succession studies because it makes possible the study of the behavior of individual plants. This was very valuable in the reexamination of Palmer and Rouse's plots because by comparing the charts it could be seen that most of the reinvasion of a disturbed quadrat came from adjoining plants. $Meter^2$ plots were not large enough to accurately measure reestablishment and succession following disturbance in tundra vegetation. The charting method requires the most time to complete of any of the sampling methods tested. When the vegetation is very complex and multi-layered, it is difficult to accurately chart the vegetation. Charting is not suitable for general surveys, but it is useful on intensive studies such as succession.

Exclosures

Exclosures are a useful device used to aid in evaluating range condition and trend of a range site. Exclosures for this purpose are constructed to remove one of the biotic factors, i.e. grazing. Thus it is imperative that the exclosures be constructed so that they do not alter the other factors influencing the site. Costello and Turner (1941) list some of the factors that are often influenced by an improperly constructed exclosure and some of the misinterpretations that can arise from the data.

Palmer and Rouse (1945) and Klein (1959) have used exclosures to record trend on reindeer ranges in Alaska. Webb (1957) used them in Canada. The Alaska Department of Fish and Game has used them extensively in their caribou management studies (Skoog 1957 and Skoog and Keough 1960). These exclosures are all smaller than 0.1 acre as most of them have from 1 to 4 m^2 plots within the exclosure with the boundaries of the fence not more than 10 ft from the plots.

Stoddart and Smith (1955) state that the minimum size of an exclosure for any area should be at least 1/4 acre and preferably up to several acres. The use of small exclosures can easily lead to the misinterpretation of the actual effects of grazing. This is especially important on tundra vegetation which consists of complex arrangements of communities which are the result of several interacting environmental features. Comparison of the quadrat charts of Palmer and Rouse (1945) with the ones that I did of the same quadrat in 1965, showed that a m^2 quadrat does not accurately reflect the effects of grazing or trampling, because the quadrats were often reinvaded by plants that were already established around the periphery of the quadrats.

After assisting the Bureau of Land Management locate suitable areas for exclosures, it is recommended that exclosures contain at least 1/2 acre and preferably an even larger area. One-half acre seems to be the smallest size that will include a fairly uniform vegetation. A detailed description of the vegetation inside and outside the exclosure should be recorded when the exclosure is established so that future differences of the vegetation can be compared with any differences that were present when they were established.

Results from the exclosed areas must be interpreted with caution. An exclosure excludes grazing by reindeer, therefore, the area within the exclosure does not necessarily represent the state of the vegetation under proper management.

Since microclimate has such a large effect on tundra vegetation, a buffer zone between the fence of the exclosure and the study plots should be established as a temporary method of reducing this effect. An accurate determination of these factors can only be ascertained with the aid of instruments.

Photography

The use of photographs in conjunction with range condition and trend studies is widespread. Step three of the 3-Step method (Parker 1954) consists of taking photographs from photo points on permanent transects. Humphrey (1962) discusses several applications of photography.

Three-dimensional or stereoscopic photographs appear to be particularly suited for use on low growing tundra vegetation.

The value of good photographs to be used in determination of range conditions and trend cannot be over-emphasized, and their use should be employed on any range condition and trend studies undertaken on reindeer ranges.

METHODS RECOMMENDED FOR USE ON ALASKAN REINDEER RANGES

One of the first objectives concerning reindeer ranges in Alaska is ascertaining the grazing capacity of different range allotments. The most direct method is by determining the weight of the forage that is available for use by reindeer. Methods involving determinations of area, frequency, or numbers are all indirectly related to weight. Apparently there is not an easy, simple, and accurate method of determining these latter criteria of tundra vegetation; methods measuring weight are recommended. The weight of the forage is also a better indication of the potential energy available for reindeer than are cover, numbers, or frequency. Measurements of weight can be obtained simply and relatively easily by either weight estimates or double-sampling weight methods.

Cover

A measurement of cover is useful in succession studies. As the more objective methods, point method or line-intercept, do not appear to be useful on tundra vegetation, cover estimates in conjunction with photographs of permanent plots is recommended for use to evaluate the changes in cover. The advantage of the latter methods is that cover and weight can be estimated in the same plot giving a measurement of two attributes of the vegetation. The plot can also be photographed.

Plots that are artificially treated to simulate such factors as trampling, fires, different degrees of grazing, etc., should be larger than 1 m^2.

Forage Production

Forage inventories on each range must be conducted to determine grazing capacity. There is usually more summer range available than winter range, so preliminary grazing capacity determinations could be based on winter range capacity alone.

On those ranges where the amounts of summer and winter range are similar, grazing capacity can usually be determined on the basis of the winter range alone due to the more rapid recovery of summer ranges. Summer ranges should not be de-emphasized because, as reported by Palmer (1944 and 1945), reindeer do not maintain their weight while on a lichen diet; therefore, the quality of the summer range is particularly important in determining the condition of the reindeer at the time they shift to a winter diet. In addition, the fawns are undergoing their maximum growth rates while on a summer diet.

The approximate boundaries of the winter range should be drawn onto a map for each range allotment. The reindeer owners and herders can provide useful information as to where their reindeer normally winter; areas of deep snow accumulation, ice crusting, and barren areas should be outlined and subtracted from the total winter range. The next two major projects are the determination of the amount of each vegetation type in each winter range and measuring the average amount of forage production in each type. The order of doing these projects can be reversed, but a more efficient sample design can be utilized by determining the boundaries of each vegetation type first.

An estimate of the per cent composition by each vegetation type can be obtained by the aerial surveying method described by Skuncke

(1967). No attempt to assign quality ratings to the different stands should be made until after the forage production has been determined on the ground. Aerial estimating can best be conducted about the first week in September in the Nome area as at that time the vegetation types can be differentiated due to the different fall colors of the foliage. The most accurate and detailed map of the vegetation types can be obtained with the use of aerial photographs, especially with color photographs in the fall.

To get an estimate of the average forage production by each type, the weight estimate method or a modified double-sampling weight method is recommended. The double-sampling weight method involves considerable time to clip and sort the species, although it does give a method of correcting estimates of individual estimators. Double-sampling, using a method similar to that described by Campbell and Cassady (1955) on the clipped plots, where the total forage of each class of forage, shrubs, lichens, forbs, etc., is weighed and then the amount that each species contributes to this weight is estimated, can be used to reduce the time and expense of double-sampling and improve the accuracy of the estimate compared to weight estimates alone.

Estimating dry weight of lichens alleviates the neccessity of clipping and drying known weight samples each day. It requires more training, but it can be readily learned after a few days practice.

A biometrician should be consulted before the estimators go into the field to aid in designing the sample scheme to obtain the desired accuracy within practical limits of time, money, and effort. He can also help write a computer program to analyze the field data, particularly if linear regressions, as in double-sampling, are to be computed.

Two field crews consisting of two men in each crew can be transported to each range, and an estimate of the forage production in each type can be obtained. The grazing capacity on the most important winter ranges can be determined in one field season.

Range Condition and Trend

Transect lines

Permanent transect lines similar to those used in the line-point method described in the Range Condition and Trend section should be established throughout representative areas on the different seasonal ranges. Pin points and 3/4 inch loops are not suitable for permanent transects on tundra vegetation. Estimation of weights in 4.8 ft^2 plots along each line is recommended. Figure 5 shows the details of a transect line near a landmark or cluster stake to aid in relocating the cluster of transects.

Exclosures

Exclosures, preferably 1/2 acre or larger, should be constructed in key areas on all of the winter ranges as funds are available. The use of small exclosures should be avoided due to the distinct possibility of misinterpreting the changes that may occur. Extreme care should be exercised to avoid excess disturbance of the vegetation within the study plots while constructing, maintaining, and travelling to and from the exclosure and while establishing and reading the study plots. This is particularly important for the plots outside the exclosure; one is generally more careful and alert when working inside an exclosure.

The exclosures should be constructed on areas that are typical of the vegetation type being studied and where the desired use by reindeer will normally be obtained. They should be well away from villages, fishing or mining camps, and other areas where people can easily come into contact with them. The exclosures should be maintained regularly to keep them reindeer proof and so that people in the vicinity know that they are still in use. Wire and posts are often valuable commodities in remote areas.

The vegetation inside and outside the exclosure should be described in detail so that any suspected differences noted later can be checked by comparison of the vegetation with that originally described. Weight estimate or double-sampling, if the exclosure is large enough, are the methods recommended for evaluating trend. These should be supplemented with estimates of cover and photographs of permanent plots.

The study plots can be randomly located along permanent transect lines. This allows unobstructed grazing on the plots outside of the exclosure. Square or rectangular plot frames that can be placed next to the tape should be used rather than circles to help minimize the chance of stepping on a plot when relocating the tape. If a plot size of 4.8 ft^2 is used, three transect lines can be established between each buffer zone (Fig. 6).

A buffer zone approximately 12 ft wide between the fence and the transects inside the exclosure should be used to provide access to the different transect lines and to reduce the influence of the fencing on

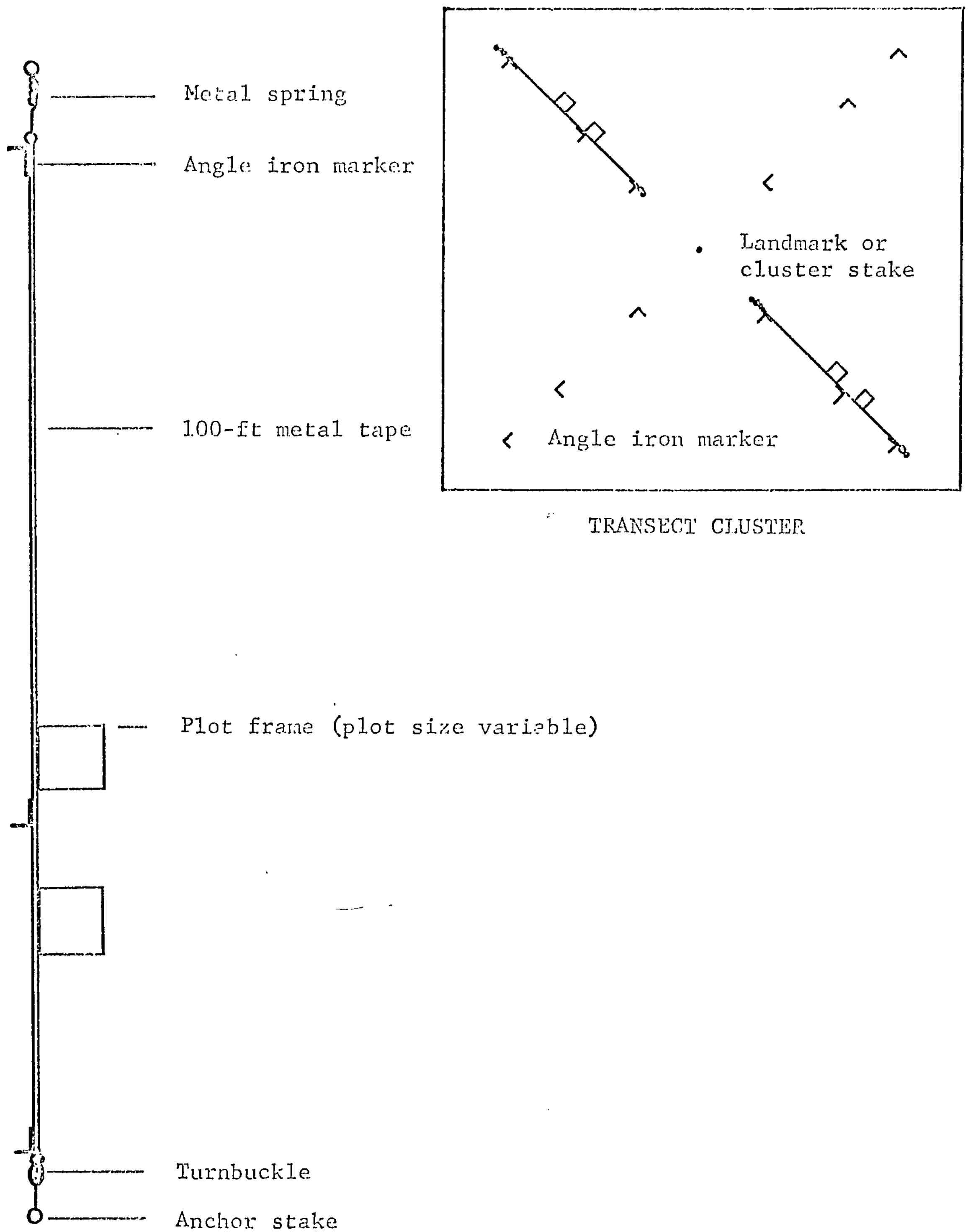


Figure 5. Cluster of transects with one transect enlarged.

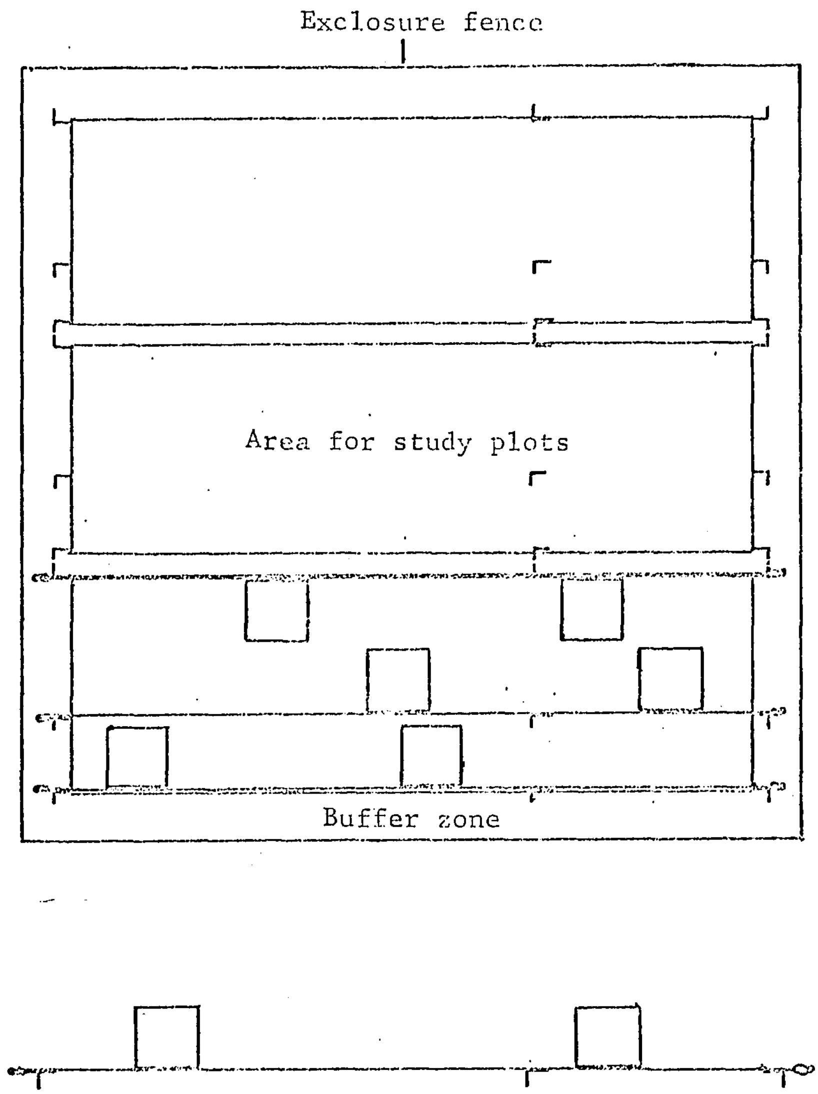


Figure 6. A generalized diagram of an exclosure with three transect lines in place within the exclosure and a transect line outside of the exclosure that can be used for exclosures with different dimensions.

the microenvironment on the study plots. Figure 6 shows the transect lines and buffer zones in a proposed exclosure that could be used for different sizes of exclosures.

REINDEER AND THE RANGE

Seasonal Forage Preferences

Most investigators working on reindeer or caribou ranges include their observations of the palatibility of the various plant species (Banfield 1954; Kelsall 1960; Ahti 1959; Edwards and Ritcey 1960; Scotter 1964, 1967; Skuncke 1967; Murie 1935; Hanson 1958; Palmer 1926, 1934, 1944, 1945, and Palmer and Rouse 1945; Klein 1959, 1967; Andreev 1954; Vakhtina 1964; and Kuvaev 1965). Courtright (1959, Table 10) summarizes statements made by several other investigators concerning the palatibility of numerous plants.

Winter

During the last two weeks of March 1966, the grazing patterns of reindeer in the model herd near Nome were observed. The snow cover was complete except for a few high windswept ridges. There were several large patches of ice that averaged 4 to 5 inches deep. Even under the snow, there was generally a layer of ice of about the same thickness. The reindeer utilized the slopes and ridges of the foothills in the area. They would generally paw through up to 18 inches of snow to graze. Also they would often paw through 2 to 3 inches of hard ice to get to vegetation.

There was no apparent pattern to their grazing habits. It appeared to be more of a random action, as one individual would be walking slowly, then suddenly start pawing. Once a crater was dug out there was a continual succession of individual reindeer using it. One would be grazing, then another would force the first out by butting, and the second individual would paw and graze until it was butted out or until the crater was large enough for two reindeer to use. Generally, a continual replacement of individuals occurred until the crater was large enough for up to 10 to 15 individuals to feed simultaneously.

When the reindeer pawed through the snow and ice, they seldom cleaned all the loose snow out; instead they would root through 1 or 2 inches of loose snow with their muzzles and graze in this manner. On several occasions as they raised their heads out of the crater, a large clump of lichen, the large *Cladonia* and *Cetraria* types, would drop from their mouths. The reindeer very seldom made an effort to retrieve these large clumps. I examined several of them; no single species was most abundant nor were the clumps always ones that had decaying portions. The reindeer did show a preference for bog blueberry and dwarf alpine birch stems and buds. The lichens were utilized heavily, and no single species seemed to be sought out.

Spring and summer

In early June, *Eriophorum vaginatum* tussocks were heavily grazed as they are the largest source of green vegetation present at this time. Late in the month, reindeer begin to utilize shrub, leaves, principally *Salix pulchra*, *S. glauca*, *S. alaxensis*, dwarf alpine birch, and bog blueberry, extensively. Lichens are still utilized by the reindeer during this period, especially *Cetraria cucullata*. They continue to make heavy use of willows through mid-July, at which time they start to graze the sedges and dwarf shrubs in the *Eriophorum*-*Carex*-dwarf shrub meadow type. Some of the herbs that occur in the willow-herb type that are moderately utilized include *Equisetum arvense*, *E. sylvaticum*, *Caltha palustris*, *Angelica lucida*, *Claytonia arctica*, *Sedum roseum*, and *Petasites frigidus*. The grazing pressure on willows is gradually decreased until by mid-August the reindeer only utilize them sporadically.

About the beginning of July the reindeer actively seek out the green growth along streams and ponds in the wet sub-type of the *Eriophorum*-*Carex*-dwarf shrub meadow type. On numerous occasions I observed a herd of reindeer that would be slowly moving through a large *Eriophorum*-*Carex*-dwarf shrub meadow flat, and as they approached within 100 to 150 ft of a stand of the wet sub-type, they would break into a run and when they reached the wet sub-type they would avidly graze sedges (*Carex aquatilis*, *C. kelloggii*, *Eriophorum angustifolium*, and *E. scheuchzeri*) and *Potentilla palustris* for about 10 to 15 minutes, then move slowly onto the dry sub-type.

During the entire summer, lichens, wherever available, were heavily utilized. I have rated several species of lichens according to their palatibility during the summer (Table 5). These are based on several observations made of reindeer grazing throughout the summer. I was fortunate in being able to use the Model Herd reindeer as they are accustomed to herders and are relatively tame. I was often able to come within 20 ft of grazing reindeer without apparently disturbing their grazing and to remain there until they moved out.

Reindeer are selective feeders as they continually graze the youngest stages of the vegetation. They do not normally graze an area extensively, but are continually milling about seeking their

TABLE 5. Palatability of certain lichens during the spring and summer near Nome.

	Most Preferred	
High	Medium	Low
Cetraria cucullata	*Cladonia alpestris*	*Cetraria islandica*
Cladonia uncialis	*Cladonia amaurocraea*	*Cetraria andrejevii*
Cladonia rangiferina		*Cladonia crispata*
Cladonia sylvatica		*Cladonia subfurcata*
Cladonia mitis		
	Moderately Preferred	
High	Medium	Low
Cornicularia divergens	*Cladonia gracilis*	*Umbilicaria hyperborea*
Alectoria nigricans	*Cladonia ecmocyma*	*Cetraria nivalis*
Alectoria ochroleuca		*Cetraria alaskana*
Stereocaulon paschale		
Stereocaulon alpinum		
	Least Preferred	
High	Medium	Low
Cladonia gonecha		*Nephroma arcticum*
Cladonia coccifera		*Lobaria linita*
		Peltigera spp.

preferred forage.

Lichens are only grazed when the lichens are moist. During the spring and summer, the lighter colored lichens seem to be more heavily grazed than the brown or dark green forms. Of the highly palatible lichens listed in Table 5, Cladonia uncialis and Cetraria cucullata are the most preferred during the summer, followed closely by Cladonia rangiferina, C. sylvatica, and C. mitis, while C. amaurocraea and C. alpestris are less preferred than those listed above.

Chemical Analysis of Important Reindeer Forage Plants

The forage quality must be considered as well as the palatibility to accurately determine the value of various species for reindeer.

Spencer and Krumboltz (1929), reported the analyses of certain lichens on reindeer ranges in Alaska, and these were also reported in Palmer (1934 and 1945). Unfortunately, they did not include the date of collection or the parts sampled. Klein (1967) reported the analysis of some vascular plants and rumen contents. Courtright (1959, Tables 1, 2, 3) summarizes chemical composition of plants collected on rein- deer or caribou ranges in various countries. Scotter (1965) and Tener (1965) have reported the analysis of forage plants on Canadian ranges.

Methods

As reindeer have definite seasonal ranges, plants collected for chemical analysis should be collected from the different seasonal ranges during the period that they are being utilized. Some important forage species were collected near Nome in March, June, and August 1966. The plants collected in March were in dwarf shrub-lichen stands on the foothills between the Snake and Nome rivers, north of Nome. Reindeer were allowed to start several feeding craters, and after they had begun to feed continually in a particular crater, they were chased away and plant samples were taken directly from the plants they had been grazing and from plants adjacent to the crater in the direction in which it was being expanded. Only the buds and current year's growth of the twigs were taken on the deciduous shrubs. The green leaves and attached twigs were taken from non-deciduous shrubs. The green leaves from sedges and the non-decaying portion of lichens were also collected.

The plants collected in June and August were from willow-herb and Eriophorum-Carex-dwarf shrub meadow types west of Nome. The plants were collected by following the reindeer and taking samples from the same plants they were grazing. Only the green leaves of the vascular plants were sampled. The March sample represents the reindeer winter diet; the June sample, the first transition to a green forage diet with supplemental lichens; and the August sample represents the shift from the willow-herb to almost exclusive use of Eriophorum-Carex-dwarf shrub meadows. These periods also coincide with dormancy (March); height of growing season (June); and maturity (August) of the vascular plants. The physiology of the lichens during these periods is not well known.

All the plants were analyzed by a commercial firm and the data are presented on a moisture free basis (Table 6).

TABLE 6. Chemical composition and caloric content of important reindeer forage plants near Nome.

Species	Month	Protein % (N x 6.25)	Fat % Ether Extract	Crude Fiber %	Ash %	Nitrogen free Extract	Kcal per 100 grams
Cladonia rangiferina	March	2.7	1.0	30.3	1.1	64.9	451
	June	2.9	0.4	27.7	2.3	66.7	466
	August	2.7	0.4	26.9	0.8	69.2	431
C. sylvatica[a]	March	2.5	1.4	21.9	1.1	73.1	426
	June	2.2	0.7	26.8	1.2	69.1	452
	August	2.0	0.6	22.2	0.9	74.3	426
C. uncialis	March	2.3	1.6	19.8	0.9	75.4	437
C. crispata	March	3.5	1.1	40.8	1.3	53.3	431
C. gracilis	March	2.8	1.0	29.8	1.1	65.3	471
	August	2.4	0.6	31.6	1.0	64.4	431
Cetraria cucullata	June	2.4	1.9	3.6	1.2	90.9	474
	August	2.2	2.6	7.0	1.2	87.0	463
Cetraria islandica	March	2.4	0.8	6.6	1.2	89.0	453
	June	2.6	0.3	3.7	1.1	92.3	426
	August	2.6	1.1	8.4	1.2	86.7	458
Betula nana	March	5.3	2.6	29.3	1.3	61.5	560
	June	26.0	2.2	13.2	4.6	54.0	542
	August	16.0	3.5	16.3	2.8	61.4	536
Vaccinium uliginosum	March	6.0	3.1	35.9	1.3	53.7	543
	June	23.4	2.2	11.0	4.0	59.4	523
	August	13.2	2.0	16.5	2.5	65.8	466
Vaccinium vitis-idaea	March	6.2	3.6	26.9	2.3	61.0	518
Ledum decumbens	March	7.4	6.2	25.9	1.8	58.7	555
Empetrum nigrum	March	5.4	10.2	23.8	1.8	58.8	573
Salix pulchra	June	25.2	1.6	8.6	4.9	59.7	504
	August	22.4	2.1	11.5	3.8	60.2	490
Potentilla palustris	August	18.8	3.1	17.5	5.1	55.5	463
Carex bigelowii	March	4.3	1.3	32.5	4.5	57.4	475
Carex bigelowii[b]	June	16.6	1.3	24.5	4.3	53.3	471
	August	12.9	1.8	28.5	4.0	52.8	479
Eriophorum angustifolium	June	16.1	1.3	21.5	5.6	55.5	477
	August	12.1	2.0	20.7	3.1	62.1	501

[a] Includes Cladonia mitis

[b] Includes a small portion of Carex aquatilis

Discussion

Stoddard and Smith (1955) state that the minimum protein requirement for cattle and sheep is 4.5 and 5.0% respectively. All the lichens sampled during the three dates are well below these minimums. The shrubs are above the minimum requirements. The deciduous shrub twigs are similar in protein content to the green leaves and twigs of the non-deciduous shrubs. The protein content increases markedly in June (leaves only) in the deciduous shrubs. By August, the protein content drops again in dwarf alpine birch and bog blueberry, but it remains high in Salix pulchra leaves.

Fats provide about 2.25 times as much energy per pound as carbohydrates (Morrison 1950) although not all of the fats are available for reindeer. Cetraria cucullata is the only lichen that has fat content similar to the shrubs. Crowberry is apparently a good source of fat, and the plant is available to reindeer during the winter, but it is seldom grazed. Skuncke (1967) considers it to be used only as a last resort. Credence to this and that not all fats are available to the animal is added by the fact that reindeer on Saint Matthew Island were utilizing crowberry almost exclusively at the time of a large die off there (Klein 1967).

Crude fiber content is markedly less in Cetraria cucullata and C. islandica than in other lichens or vascular plants.

Nitrogen-free extract is usually considered to represent digestible carbohydrates and therefore is more available than crude fiber, although reindeer appear to digest crude fiber better than domestic ruminants (Nordfeldt 1961, in Scotter 1965). The value of lichens as an energy source to reindeer probably is in their high carbohydrate content.

The caloric content of the lichens is generally less than that of the shrubs and similar to that of the sedges. The thick waxy layer on the leaves and stems of dwarf alpine birch and narrow-leaved Labrador tea probably contributes a significant portion of the energy measured in these species. It is uncertain how well reindeer utilize these waxes. Crowberry has the highest caloric content of the plants sampled, and this may be related to the relatively large surface area as the leaves are small and numerous.

Palmer (1944) indicated that reindeer lose weight on a pure lichen diet. The summer forage as a consequence is very important as the reindeer must be able to accumulate fat reserves to enable them to survive the winter. This is particularly true of pregnant cows as parturition occurs in late April or May, and there is little green forage available for the lactating cows.

Chemical composition and palatibility are not necessarily related as seen in Potentilla palustris which is a highly preferred forage item, yet it does not appear to be particularly nutritious.

Effect of Trampling and Grazing

That a considerable amount of damage to lichens is caused by reindeer and caribou either by trampling or through their grazing habits has been mentioned in passing by some investigators (Palmer 1926, 1934, Andreev 1954, Skuncke 1967, Skoog 1956, and Larin 1937). None of these have quantitatively measured this damage. In past determinations of carrying capacity on reindeer ranges, the damage to lichens by trampling has not been considered. During the summer of 1966, I made use of a reindeer herd in the Nome area to evaluate the extent of reindeer damage to lichens by trampling and grazing.

The herd I used, known as the Model Herd, was established in March 1966 by the Bureau of Indian Affairs for demonstration purposes. The herd remained in the foothills of the Kiguaik Mountains on the Seward Peninsula until early June when they were driven onto their summer range, a large Eriophorum-Carex-dwarf shrub flat lying west of Nome, between the Penny and Snake rivers, and between the coast of the Bering Sea and the Nome to Teller road. This encompasses approximately 17 miles^2. The area had not been occupied by reindeer for at least 26 years, although reindeer from the Teller herd have occasionally strayed within 7 miles of the sedge flats near Nome. Caribou have not been this far west on the Seward Peninsula since before the turn of the century.

The lichen flora, with the possible exception of Cladonia alpestris, has recovered from past use and is composed primarily of C. rangiferina, C. sylvatica, C. mitis, C. amaurocraea, C. gracilis, Cetraria cucullata, and C. islandica. The living portions of these lichens are generally from 1.5 to 4 inches (38 to 100 mm) long and are in well developed clumps. Except for the numerous small ponds and streams, the vegetative cover is 100% with lichens comprising approximately 30% of the total vegetation. In the moist areas, sedges (Carex spp. and Eriophorum spp.) predominate. On the drier sites there is a combination of sedges, lichens, and small shrubs including bog blueberry, crowberry, dwarf alpine birch, and narrow-leaved Labrador tea. During the summer, the greatest damage to lichens by reindeer occurs on these drier sites.

Reindeer are selective foragers as they seldom stop and completely graze an area, rather they continually move, seeking out preferred forage items. Instead of biting off their forage when grazing, reindeer pull up on it; consequently, large portions of plants are detached. Since the principal reindeer forage lichens are only loosely attached or completely unattached to the substratum, they are easily dislodged when moist. In the summer reindeer prefer to graze during cool or moist or windy days. They will move about seeking out the more succulent plant parts. Large quantities of moist lichens are either dropped or rejected from the mouth, and the reindeer make no apparent effort to retrieve these. These include all the major species of lichens both with and without decayed portions.

On warm, windless days the reindeer concentrate along the beach to cool off or to avoid insects, and they do very little grazing. On warm or dry, windy days the moisture content of lichens is reduced and they become dry and very brittle. Reindeer will not utilize them in this condition, but they shatter into small fragments if stepped on by reindeer.

Procedure

During a period of rainy and foggy days in July 1966, a herd of approximately 500 reindeer was herded in a loose front from 50 to 100 yards wide, across a previously non-utilized area in the sedge flat.

The reindeer were allowed to graze and move at their will except when they attempted to move onto used areas. A ft^2 frame was randomly thrown out 300 times on the area that the herd had traversed. The per cent of lichens that had been dislodged and the per cent that were shattered into segments 1/2 inch or smaller were estimated. The reindeer dislodged 15% of the lichens while crossing over the area once. Only 2% were shattered into segments 1/2 inch or smaller, and these were probably rejected or dropped from their mouths.

During a period of warm, dry days in July, the reindeer were again herded in a similar manner. It had not rained for over 24 hours, there were few clouds, and the wind had blown until the lichens were dry and brittle. The reindeer were bothered by insects and were constantly moving. They would take sporadic bites of forage as they traveled. Herding under these conditions is difficult as the reindeer are hard to control and can easily outdistance the herders. The ft^2 frame was thrown 300 times in the same manner as on the moist day. Twenty-seven per cent of the lichens was dislodged or broken into parts 1/2 inch or larger. Eight per cent of the lichens was shattered into portions 1/2 inch or smaller by the herd passing over the area once. Almost all of the shattering of dry lichens is caused by trampling as reindeer seldom graze dry lichens.

In early July, approximately 1,000 reindeer of the Model Herd were running to avoid insects. They ran to the top of a small pingo mound. The herd bunched up and began to mill in a tight circle about 75 by 100 ft. The animals on the outer edge of the circle were continually running and trying to work into the circle, while the animals in the center either stood still or moved around slowly. They milled for 12 min., then broke and ran into some shallow ponds. Before the reindeer milled on the area, it was typical dry sub-type of the Eriophorum-Carex-dwarf shrub meadow type with Carex spp. dominating on a large moss (Sphagnum spp. and Polytrichum spp.) layer. In the process of this tight milling, the reindeer completely destroyed the vegetation. All that remained were fragments of sedges, lichens, and shrubs covered by shredded, displaced moss. Within two days, water seeped up through the moss and completely inundated the trampled area. In mid-September, the area was still covered by water, and there was a small flow running off the site. This is probably the first step leading to the severe destruction of vegetation and eventual erosion of the soil Bos (1967) observed on the west end of Nunivak Island.

In mid-August, the area on the Eriophorum-Carex-dwarf shrub meadow where the herd grazed during favorable conditions was sampled. Five hundred throws were taken with the ft^2 frame to determine the extent of the damage caused by trampling during the summer. Sixty-eight per cent of the lichens was dislodged and 16% was shattered into segments less than 1/2 inch in length.

Discussion

The effect of dislodging the lichens is not fully understood since most forms derive nutrients from the atmosphere. Dislodged lichens are more susceptible to drying by the wind and are generally totally desiccated on warm, dry days, whereas those that are not disturbed will retain some moisture at their bases since they commonly grow in or on the moss layer which retains some moisture even under drying conditions. Andreev (1954) indicates that growth occurs only when lichens are moist.

It is possible that shattered segments will regenerate (Andreev 1954, Fink 1935, Skuncke 1967, Faegri 1937, and Llano 1944). However, in the USSR, segments of podetia that were less than two internodes long required over 2 years to initiate growth (Andreev 1954), and not all of the segments regenerated.

The average annual linear growth rate on the principal forage lichens, *Cladonia alpestris*, *C. rangiferina*, and *C. sylvatica*, on the Seward Peninsula was 5 mm. Using this value plus the 2 years indicated by Andreev which is required for reestablishment, but during which no linear growth takes place, it would require at least 10 years before the segments would be large enough to be grazed.

In any calculation of carrying capacity on ranges where lichens are an important component of the forage, the effect of trampling and selective grazing must be considered. On summer ranges, where lichens comprise at least 30% of the available forage, at least 15% of the lichens should be considered as unavailable because of trampling.

Succession in Tundra Vegetation

During the 1920's and 1930's, L. J. Palmer and others established several fenced exclosures on Alaskan reindeer ranges. Within these exclosures they laid out 1 m^2 quadrats that were treated in various manners to simulate different intensities of grazing or trampling. The quadrats were examined periodically, and in 1945 Palmer and Rouse reported the changes that had occurred in the quadrats.

During the summer of 1965, I attempted to relocate as many of the exclosures as possible to determine the changes that had taken place in the vegetation since their report. I found eight of the exclosures, but in three, which were in very poor condition, I was unable to locate the boundaries of the quadrats within the exclosures. One other exclosure, on Nunivak Island in the fenced lead to the reindeer corrals, has been subject to severe disturbance during the annual roundups.

In the following descriptions of the quadrats, they are grouped according to the vegetation type in which they occur and the type designation used by Palmer and Rouse (1945) is in parentheses.

Dwarf shrub-lichen

(Tundra-Lichen)

One of the exclosures, about 3 miles north of Unalakleet, was established in 1922 and contained four 1 m^2 quadrats. The soil was a deep loam with a good humus layer. The moisture was sufficient to support a good growth of vegetation. As was the case at all of the exclosures located, the fences had fallen down. Reindeer have not been in the area of this exclosure for over 20 years, so the quadrats can still serve their purpose.

Scraped quadrat.--This quadrat was established early in the spring while the ground was frozen. All the vegetation above the frozen surface was scraped clean. The base of the plants remained intact. The original vegetation cover was complete and composed of 80% lichens, 10% sedges, and 10% browse according to Palmer and Rouse (1945).

In September 1932, the cover was 95% and composed of 50% lichens, 30% browse, 15% grass and sedges, and 5% moss. The recovery of the lichens was slow, and Palmer and Rouse (1945) reported that in 10 years they regained only half of their former height and abundance.

In June 1965, the cover was complete and composed of 65% lichens, 30% browse, and 5% sedges. The lichens averaged 1.5 inches more in length than when the quadrat was originally established, but they have not been able to regain their former abundance.

Clipped quadrat.--The top half of the vegetation was removed in 1922. Originally the cover was complete and composed of 80% lichens, 10% browse, and 10% sedges. In 1927, the composition was 30% lichens, 65% browse, and 5% sedges. Palmer and Rouse (1945) stated that 10 years after establishment the lichens averaged 3 inches in height. The cover was complete and composed of 50% lichens, 45% browse, and 5% grasses and sedges.

In June 1965, the cover was 95%. The browse species had evidently crowded out some of the lichens that were present in 1932, as the composition is now 10% lichens, 85% browse, 3% sedges, and 2% moss.

Denuded quadrat.--The cover was complete and similar to the two previous quadrats when established in 1922. At that time all the vegetation was scraped off to ground level. In 1928, there were 40% lichens, 20% browse, 30% sedges, and 10% moss and the lichens showed a vigorous regrowth.

In September 1932, the cover was 80% and composed of 35% lichens, 40% browse, 15% sedges and grass, and 10% moss. The lichens averaged about 1 inch in height according to Palmer and Rouse (1945).

In June 1965, the cover was 95% with 30% lichens, 65% browse, and 5% sedges.

Check quadrat.--This one was left undisturbed to serve as a check. The cover was complete and composed of 80% lichens, 10% browse, and 10% sedges. The lichens averaged 3 to 4 inches in height. In 1927, the composition had changed to 50% lichens, 40% browse, and 10% sedges. Palmer and Rouse (1945) stated that they suspected the quadrat was accidentally trampled when it was established as many of the lichens had died.

In 1932, the composition was the same as in 1927; this indicates the importance of avoiding trampling of lichens when laying out permanent study plots.

In June 1965, the cover was complete and composed of 70% lichens, 27% browse, 1% sedges, and 2% moss. The lichens are finally regaining their original abundance. Table B-5 shows how lichens of the Cladonia group are replacing the Cetraria lichens. The lichens now average 5 inches in height.

(Overgrazed Tundra Browse-Lichen Type)

An exclosure was established on Stuart Island in 1920. The island had been used as a winter range through 1918. The quadrat was established to study the succession on an overgrazed range. The vegetation present at the time of establishment was mostly young lichens and some sedges, Polytrichum, Empetrum, Arctostaphylos, and Ledum. Palmer and Rouse (1945) reported that initially the lichens showed the largest increase, later the browse species predominated. By 1931, the cover had increased to 95% composed of 15% lichens, 50% browse, 8% sedges, and 27% moss.

By June 1965, the exclosure was completely destroyed and reindeer have severely overgrazed the area in the past few years. The quadrat had 35% cover, the remaining portion of the quadrat was covered by dead Empetrum nigrum. The live vegetative cover consisted of 15% lichens, 65% browse, 15% sedges, and 5% moss. The area was apparently recovering while exclosed, but after the exclosure was destroyed the vegetation was again reduced.

(Lichen-Browse Type)

The exclosure near Nome was found, but unfortunately it happened to be near an old mining camp. There were old wine bottles and tin cans on some of the quadrats. At the present time, the browse species completely dominate all the quadrats. The surrounding area contained the best growth of lichens I have ever seen. This striking difference between the quadrats and surrounding area was probably caused by activity associated with the mining camp.

Dryas fell-fields

(Alpine-Dryas Type)

This exclosure is situated on top of a small hill just north of Egavik. The soil is very shallow and rocky and the vegetation is composed of decumbent forms. There have been reindeer in the general vicinity for short periods of time, and they may have utilized the area.

Spaded quadrat.--The cover, when the plot was established in 1929, was 50% and composed largely of Dryas and Tofieldia. In 1932, Palmer and Rouse described the vegetation as being composed of six Carex clumps, three forbs, two Dryas, one Salix, and six clumps of mosses.

In June 1965, 36 years after establishment, the cover was 40% and mainly moss and Dryas. These were encroaching in from plants on the periphery. There were a few forbs and some small lichens present.

Cut quadrat.--Originally the cover was 60%, again mostly Dryas and Tofieldia. All vegetation was cut to the ground surface. By 1932, the cover was 30%, mainly Dryas according to Palmer and Rouse (1945).

In June 1965, the cover was 75% with Dryas octopetala composing 70% of the cover. Luzula nivalis was well distributed throughout. Thamnolia vermicularis was the predominant lichen in all the quadrats.

Check quadrat.--This quadrat had a 70% cover and was left undisturbed to serve as a check. Dryas was predominant with some Oxytropis, Tofieldia, and Festuca present. In 1932, the cover had increased to 85% due to the Dryas mat spreading over the bare ground.

In June 1965, the cover was 95% with 90% Dryas. The only lichens are a few scattered Thamnolia vermicularis individuals.

Hagemeister Island

Hagemeister Island has extensive areas in which the succession of grass tussocks to solid stands of lichens can be observed. One good area is near the large creek in the north-central portion of the island in the vicinity of the exclosure set up by the Bureau of Land Management in 1966. Adjacent to the creek there are extensive stands of Calamagrostis canadensis and Festuca altaica tussocks. Farther inland Spiraea beauverdiana begins to become established, then several browse species invade the area, predominantly bog blueberry, dwarf alpine birch, and crowberry. Often the crowberry forms solid mats over the tussocks. Farther inland _Cladonia rangiferina_, _C. sylvatica_, and _C. mitis_ begin to break through the crowberry mat until they completely replace the crowberry.

Conclusions

Lichens grow best on dry and open areas. Once the lichen mat is broken and browse species establish themselves, lichens have a difficult time regaining their former abundance. _Empetrum nigrum_ and _Arctostaphylos alpina_ are especially detrimental to lichens as they form mats through which lichens have a difficult time penetrating.

An exclosure on the tussocks that are undergoing succession on Hagemeister Island could provide valuable information on the time that it takes for a crowberry stand to be replaced by lichens.

Stereocaulon and _Cetraria_ are the early invading lichens which are replaced by the _Cladonia_ types.

The Alpine-_Dryas_ type is very slow in recovering from overuse, and most of the new growth comes from plants that are already established rather than from new plants.

Management Recommendations

The reindeer industry in Alaska is not currently at its maximum potential. Hanson (1952) and Palmer (1945) have pointed out several useful suggestions for the proper management of reindeer.

The basic question that must be resolved before any kind of management plan can be suggested is: do the reindeer owners and people having interest in present and potential reindeer rangelands want commercial or subsistence types of reindeer herds? The management plans for the two types of herds are so radically different that until this question is decided upon, management recommendations are often going to be ineffective.

Under either type of management, the following quote from L. J. Palmer (1945), who was more conversant with the reindeer herders and the industry than anyone else in Alaska, is appropos:

> If we are going to raise reindeer as a domestic animal we must forget the wildlife angle and seek control. It is on this premise that rotational use of the range is being proposed. In the absence of proper herding, suitable management practices are, of course, impossible. It is control that must be sought if the reindeer are to be maintained successfully as a domestic species.

From the extensive data reported by Andreev (1954) concerning lichen growth and recovery, it is apparent that efficient use of lichen ranges can only be accomplished by careful management. Experiments conducted by Andreev (1954) and Skuncke (1967) show that as more of the lichen podetium is grazed, the longer is the period of recovery. Andreev (1954) suggests grazing the top 1/4 to 1/3 of the podetium, which contains 45% of the weight of a single lichen plant. At this level of grazing, recovery occurs in 3 to 5 years (Andreev 1954, Table 26). However, if the entire podetium is grazed, it will require from 30 to 50 years for recovery (Andreev 1954, Skuncke 1967, and Palmer and Rouse 1945).

The importance of "top cropping" and rotational grazing can be illustrated by determining the production of reindeer over a period of years using this method compared to complete utilization of the lichens and then resting the pasture until the lichens have recovered.

The forage production values determined in the dwarf shrub-lichen type (Table B-2) on the Model Herd range near Nome are used in the illustration (Table 7). It should be emphasized that these production values do not take in the yearly growth fluctuations of the vegetation. This particular range has not been grazed for several years and the lichen growth is more abundant than on any other range with the possible exception of the Koyuk area. The dwarf shrub-lichen community is also the most productive type so the figures should not be directly applied to other ranges or vegetation types.

Table 7 shows all of the calculations used to rate the two methods of herding. In the following description of each step, the numbers in parenthesis will be from the top cropping column so that a quick comparison can be made to Table 7. The dwarf shrub-lichen type near Nome has an average total production of 3,094 lb. per acre of the living portion of the fruticose Cladonia and Cetraria lichens.

With complete grazing, as much as possible of this is grazed, then the pasture is allowed to recover for 30 to 50 years. With "top cropping", 45% of the mass is available for use (1,392 lb.). The winter use shrubs, bog blueberry and dwarf alpine birch, produce 535 lb. per acre. The total preferred winter forage that is produced per acre is the sum of these two quantities (1,927 lb.).

Palmer (1944) suggests that 57% of this forage is not utilized by reindeer due to their grazing habits or trampling. Andreev (1954) states that reindeer dig up and graze 20 to 25% of the total forage supply during the winter. I used a figure of 50% for this problem which is slightly less than Palmer's figure and a little more than Andreev's when the total forage production is considered. Therefore, about

TABLE 7. Winter grazing capacity of the same pasture near Nome by two methods of herding in dwarf shrub-lichen type. The mathematical processes are shown adjacent to the appropriate columns.

	Complete use	Top cropping
lb/acre of fruticose <u>Cladonia</u> and <u>Cetraria</u> lichens	3094	3094
mass in top 1/3 of podetium		x .45
lb/acre available for use	3094	1392
lb/acre of preferred shrubs	+ 535	+ 535
lb/acre of available preferred winter forage	3629	1927
per cent of forage actually eaten	x .50	x .50
lb/acre actually eaten	1814.5	963.5
daily forage requirements for a 250 lb. reindeer	÷ 5.25	÷ 5.25
reindeer grazing days/acre	345.6	183.5
days on winter range; Oct. 15 to April 15	÷ 180	÷ 180
reindeer/100 acres during a winter season	192	102
number of rotation periods during the 30 to 50 years required for recovery after complete use	1	10
reindeer/100 acres during a 30 to 50 year period	192	1020
net increase of reindeer by "top cropping" during one 30 to 50 year period/100 acres		828
increase in efficiency by "top cropping"		531%

963.5 lb. per acre is actually eaten by "top cropping". Palmer (1944) reported that the forage requirement of a 250 lb. caribou is 5.25 lb. per day. Dividing the lb. per acre actually eaten (963.5 lb.) by the daily forage requirement (5.25 lb.), the number of reindeer grazing days per acre is determined (183.5).

Reindeer are on the winter range from about October 15 to April 15, a period of 180 days, and this is divided into the number of grazing days determined (183.5) to derive the number of reindeer per acre that can be maintained through the winter season. The acreage is increased to 100 to avoid having portions of reindeer on an acre (102). This value is then multiplied by the number of times the pasture can be grazed by "top cropping" during the 30 to 50 year period that is required for recovery after complete use (10).

As seen in Table 7, by complete use 192 reindeer can be maintained during the winter while by "top cropping" 1,020 reindeer can be maintained over the same period of time on the same 100 acres. This is an increase of 828 reindeer per 100 acres.

This increase is not all profit as "top cropping" involves closer attention to herding and it necessitates having a predetermined grazing plan so that only the top 1/4 of the podetia are grazed and so that the area is grazed uniformly. To get uniform grazing, the areas where snow accumulates must be grazed early and the areas of least snow accumulation and ice crusting are reserved for late use.

This problem illustrates the gain in efficiency (531%) that can be obtained by proper management and that the solution to revitalizing the industry is not necessarily expansion into new areas, but simply increasing the efficiency of the present herding techniques.

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APPENDIX A

PLANTS COLLECTED OR IDENTIFIED IN THE VARIOUS VEGETATION TYPES DURING THIS STUDY

Moss and lichen authorities are presented with each species, vascular plant nomenclature follows that of Anderson (1959) unless otherwise noted.

Numbers for each vegetation type are as follows:

1. White spruce-tall shrub
2. White spruce-lichen
3. White spruce-Alaska birch
4. Alaska birch-shrub
5. Willow-herb
6. Alder-herb
7. Birch
8. Birch-willow
9. Dwarf shrub-lichen
10. Four-angled heather-moss
11. Alpine bearberry-rhododendron
12. *Dryas*-fell-fields
13. Beach-*Elymus*
14. Grass tussocks
15. *Calamagrostis*-*Arctagrostis* grassland
16. Ruderal
17. *Eriophorum* tussocks
18. *Eriophorum*-*Carex*-dwarf shrub meadow
19. Sedge-*Sphagnum*-moss
20. Rock-foliose lichens

Lichens

Cladoniaceae

Cladonia alpestris (L.) Rabh.	2, 4, 9, 12, 20
C. amaurocraea (Flörke.) Schaer	2, 9, 12, 17, 18, 20
C. boryi Tuck	9
C. coccifera (L.) Willd.	9, 12, 20
C. cornuta (L.) Hoffm.	8, 9, 20
C. crispata (Ach.) Flot	9, 12, 14, 18
C. crispata var. cetrariaeformis (Del.) Thoms.	2, 9
C. ecmocyna (Ach.) Nyl.	9
C. gonecha (Ach.) Asah.	2, 8, 9
C. gracilis (L.) Willd. var elongata (Jacq.) Fr.	2, 7, 9, 12, 14, 18
C. impexa Harm.	9
C. lepidota Nyl.	9, 14
C. mitis Sandst.	9, 18
C. rangiferina (L.) Web.	2, 4, 7, 8, 9, 12, 17, 18, 20
C. subfurcata (Nyl.) Arn.	9, 12, 18
C. subsquamosa (Nyl.) Sain.	9, 18
C. sylvatica (L.) Hoffm.	2, 4, 7, 8, 9, 12, 17, 18, 20
C. uncialis (L.) Web.	2, 9, 12, 18, 20
C. wainii Sav.	9
Pilophoron aciculare (Ach.) Nyl.	20

Lecanoraceae	
Icadophila ericetorum (L.) Zahlbr.	18
Ochrolechia frigida (Sw.) Lynge	18
O. upsaliensis (L.) Mass	18
Parmeliaceae	
Cetraria alaskana Culb & Culb	12, 20
C. andrejevii Oksh	9, 18
C. cucullata (Bell.) Ach.	7, 9, 12, 18
C. islandica (L.) Ach.	2, 4, 7, 9, 12, 14, 18
C. nigricascens Elenk.	9, 12
C. nivalis (L.) Ach.	12
C. richardsonii Hook.	9
C. tilesii Ach.	9, 12
Parmelia centrifuga (L.) Ach.	5, 12, 20
P. incurva (Pers.) Th. Fr.	12, 20
P. omphalodes (L.) Ach.	5, 12, 20
P. saxatilis (L.) Ach.	12, 20
Peltigeraceae	
Nephroma arcticum (L.) Torss.	9, 12, 19
N. bella (Tuck.) Nyl.	5, 9
N. expallidum Nyl.	9
Peltigera polydactyla (Neck.) Hoffm.	2
Sphaerophoraceae	
Sphaerophorus globosus (Huds.) Vain.	12, 20
Stereocaulaceae	
Stereocaulon alpinum Laur.	5, 9. 16, 18
S. paschale (L.) Hoffm.	5, 9, 16, 12
S. rivulorum Magn.	9, 16, 18
S. vesuvianum Pers.	20
Stictaceae	
Lobaria linita (Ach.) Rabenh.	9, 12, 18
Umbilicariaceae	
Umbilicaria hyperborea (Ach.) Ach.	12, 20
Usneaceae	
Alectoria americana Mot.	1, 2
A. nigricans (Ach.) Nyl.	9, 12
A. ochroleuca (Hoffm.) Mass.	9, 12
Cornicularia divergens Ach.	9, 12
Dactylina arctica (Hook.) Nyl.	9, 12
Evernia mesomorpha Nyl.	1, 2
Thamnolia subuliformis (Ehrh.) Culb.	9
T. vermicularis (SW.) Ach *ex* Schaer.	9, 12

Mosses

Amblystegiaceae	
Drepanocladus uncinatus (Hedw.) Warnst.	9
Aulacomniaceae	
Aulaconmium palustre (Hedw.) Schwaegr.	9
Bryaceae	
Pohlia nutans (Hedw.) Lindb.	18
Ditrichaceae	
Ditrichum flexicaule (Schwaegr.) Hampe.	9
Entodontaceae	
Pleurozium schreberi (Brid.) Mitt.	16, 18
Polytrichaceae	
Polytrichum commune Hedw.	9, 18
P. juniperinum var. gracilius Wahl.	18
Sphagnaceae	
Sphagnum fimbriatum Wils. ex Hook	9, 18, 19

Vascular plants

Polypodiaceae	
Athyrium felix-foemina	5
Cystopteris fragilis	9, 12
Dryopteris austriaca	5
Woodsia glabella	5, 12
Equisetaceae	
Equisetum arvense	1, 5, 6, 9, 13, 14, 16
E. scirpoides	9, 12
E. sylvaticum	1, 5, 6, 9, 13, 16
Lycopodiaceae	
Lycopodium alpinum	9
L. annotinum	9
L. selago	9
L. sitchense	9
Pinaceae	
Picea glauca	1, 2, 3

Cyperaceae	
Carex anthoxanthea	18
C. aquatilis	18, 19
C. atrofusca	18
C. bigelowii	9, 12, 18
C. canescens	5, 18
C. glareosa	12, 18
C. kelloggii	18
C. laxa	18
C. macrochaeta	13
C. membranacea	5, 16, 18
C. montanensis	9, 16, 18
C. nardina	12
C. physocarpa	5, 9, 18
C. podocarpa	9
C. rariflora	5
C. spectabilis	9, 16, 18
Eriophorum angustifolium	18, 19
E. chamissonis	18
E. scheuchzeri	18
E. vaginatum	17, 18
Kobresia simpliciuscula	18
Iridaceae	
Iris setosa	5
Juncaceae	
Juncus biglumis	18
J. castaneus	18
J. triglumis	18
Luzula confusa	5, 9, 16
L. multiflora	5, 9, 16, 18
L. nivalis	9, 12, 18
L. spicata	9, 16, 18
L. wahlenbergii	9, 18
Liliaceae	
Fritillaria camtchatcensis	5, 9
Melanthaceae	
Tofieldia coccinea	12, 16
T. pusilla	12, 16
Veratrum album	5
Zygadenus elegans	9, 16
Orchidaceae	
Habenaria obtusata (Pursh.) Richards	9, 16

Poaceae	
Phalarideae	
Hierochloe alpina	5, 9, 12, 16, 18
Agrostideae	
Agrostis borealis	9, 12, 16
A. scabra	9
Alopecurus alpinus	5, 9
Arctagrostis latifolia	5, 6, 8, 9, 12, 14, 15, 16
Calamagrostis canadensis	2, 8, 9, 13, 14, 15, 16, 18
C. deschampsiodes	18
C. inexpansa	9
Aveneae	
Trisetum spicatum	9, 12, 13, 16, 18
Festuceae	
Bromus pumpellianus	5, 16
Festuca altaica	5, 8, 9, 14, 18
F. ovina L.	5, 9, 18
F. rubra	5, 9, 12, 14, 16
Poa alpigena (Fr.) Lindman	9, 12, 16
P. alpina	9, 13, 15
P. arctica	5, 9, 12, 16
P. glauca	9, 12, 16
P. pratensis	9
Hordeae	
Agropyron sericeum	16
Elymus mollis	13
Ammiaceae	
Angelica lucida	5, 13
Bupleurum americanum	12, 16
Conioselinum benthami	13
Heracleum lanatum	5
Ligusticum mutellinoides	2, 5, 9
Asterceae	
Achillea borealis	5, 9, 13, 14, 16
A. millefolium	5
Antennaria alaskana	12
Arnica lessingii	5, 9, 16, 18
A. louiseana	9, 16
Artemisia arctica	5, 6, 8, 9, 13, 14, 16, 18
A. borealis	16, 18
A. senjavinensis	12, 16
A. tilesii	5, 13, 14, 16, 18
Aster sibiricus	12, 16
Chrysanthemum arcticum	18
C. integrifolium	16
Erigeron humilis	12, 16

Asterceae (continued)

Erigeron hyperboreus	12, 16
Matricaria ambigua	16
Petasites frigidus	5, 7, 9, 13, 14, 18, 19
Saussurea angustifolia	2, 9
Senecio alaskanus Hult.	5
S. atropurpureus	18
S. congestus	16
S. lungens	5, 16, 18
S. resedifolius	5
Solidago multiradiata	5, 9, 16

Betulaceae

Alnus crispa	1, 3, 4, 6, 8
Betula kenaica	4
B. glandulosa	1, 3, 4, 7, 8
B. nana exilis	1, 2, 3, 4, 7, 8, 9, 10, 17, 18, 19
B. resinifera	3, 4

Boraginaceae

Eretrichium nanum (Vill.) Schrad var aretiodes (Cham.) Herder	9, 12, 16
Mertensia paniculata	5, 8
Myosotis sylvatica Hoffm. var. alpestris (Schmidt.) Koch.	9, 16

Brassicaeae

Cardamine pratensis	5, 8, 9, 13
Descurainia sophia	16
Parrya nudicaulis	9
Rorippa islandica (Oed.) Borbas.	16

Campanulaceae

Campanula lasiocarpa	12

Carophyllaceae

Arenaria peploides	13
Arenaria physodes	16
Cerastium arcticum	9, 12
C. beeringianum	5, 9, 16, 18
Lychnis apetala	16
Silene acaulis	9, 12

Cornaceae

Cornus suecica	5, 9, 13, 18

Crassulaceae

Sedum roseum	5, 8, 9, 13, 14, 16

Empetraceae

Empetrum nigrum	1, 2, 5, 7, 8, 9, 10, 12, 14, 16, 17, 18, 19

Diapensiaceae	
Diapensia lapponica	12
Ericaceae	
Andromeda polifolia	18
Arctostaphylos alpina	9, 11, 12
Cassiope tetragona	9, 10
Ledum decumbens	2, 7, 8, 9, 10, 12, 14, 17, 18, 19
Loiseleuria procumbens	9, 10, 12
Phyllodoce coerulea	9
Rhododendron kamtschaticum	9, 11, 12
R. lapponicum	9
Fabaceae	
Astragalus alpinus	12, 16
A. umbellatus	9, 12, 16, 18
Hedysarum alpinum	9, 16
Lathyrus japonica Willd.	13
Lupinus nootkatensis	5, 9
Oxytropis maydelliana	9, 12
O. mertensiana	9, 16
O. nigrescens	9, 12, 16
O. viscida	9
Gentianaceae	
Gentiana algida	5, 8, 9
G. glauca	9, 16, 18
Gentianella propinqua (Rich.) Gillett.	5, 6, 18
Geraniaceae	
Geranium erianthum	9
Lentibulariaceae	
Pinguicula vulgaris	5
Haloragidaceae	
Hippuris vulgaris	18
Onagraceae	
Epilobium angustifolium	5, 6, 7, 8, 12, 13, 14, 16
E. latifolium	5, 16
Papaveraceae	
Papaver radicatum	5, 9, 12, 18
P. walpolei	12, 16
Plumaginaceae	
Armeria maritima	9, 16

Polemoniaceae	
Phlox sibirica	12
Polemonium caeruleum L.	5, 6, 8, 9, 14, 16, 18
Polygonaceae	
Polygonum bistorta	5, 9
P. viviparum	5, 9
Rumex acetosa	5, 9, 18
R. acetosella	5, 18
R. arcticus	5, 9
Portulaceae	
Claytonia acutifolia	12, 18
C. arctica	5
Primulaceae	
Androsace chamaejasme	9, 12
Dodecatheon frigidum	5, 9
Primula cuneifolia	5
P. tschuktschorum	5
Trientalis europea	5, 14
Pyrolaceae	
Pyrola minor	5
Ranunculaceae	
Aconitum delphinifolium	5, 9
Anemone multiceps	9, 12, 16
A. narcissiflora	5, 9, 12, 16
A. parviflora	9, 16, 18
Caltha palustris	5, 18
Delphininum brachycentrum	9
Ranunculus chamissonis	18
Thalictrum alpinum	2, 9
Rosaceae	
Dryas integrifolia	12
D. octopetala	9, 12
Geum glaciale	12, 18
G. rosii	9
Potentilla biflora	16
P. fruticosa	1, 9, 18
P. palustris	18
P. vahliana	12
Rubus arcticus	5, 7, 8, 9, 18
R. chameamorus	5, 7, 16, 18, 19
Sanguisorba officinalis	5, 9
Spiraea beauverdiana	5, 6, 14, 16
Rubiaceae	
Galium boreale	5

APPENDIX B

TABLES

Salicaceae	
Salix alaxensis (Anders.) Colville	5, 16, 18
S. arbutifolia Pall.	18, 19
S. arctica Pall.	12, 16
S. brachycarpa Nutt. ssp. niphoclada (Rydb.) Argus	1, 5, 9
S. glauca L.	1, 3, 4, 5, 8, 9, 18
S. phlebophylla Anders	12, 16
S. pulchra Pursh.	1, 3, 4, 5, 8, 9, 16, 18
S. reticulata L.	2, 5, 9, 12, 18
S. rotundifolia Trautv.	5
Saxifragaceae	
Boykinia richardsonii	5, 9
Chrysoplenium tetrandrum	5, 18
Parnassia kotzebuei	5, 16
P. palustris	5, 16, 18
Saxifraga bronchialis	16
S. davurica	5, 9
S. flagellaris	12
S. hieracifolia	5, 16
S. hirculus L.	5, 9, 18
S. oppositifolia	9, 12
S. punctata	5, 16
Scrophulariaceae	
Castilleja hyperborea	9, 12
C. pallida	5, 9, 18
Lagotis glauca	5, 9, 18
Pedicularis capitata	5, 9, 16
P. labradorica	5, 9, 13, 18
P. lanata	9, 12, 16
P. langsdorfii	5, 18
P. oederi	5, 18
P. pennellii	18
P. sudetica	5
P. verticillata	5, 13
Vacciniaceae	
Oxycoccus microcarpus	18, 19
Vaccinium vitis-idaea	2, 5, 7, 8, 9, 10, 11, 12, 14, 18, 19
V. uliginosum	2, 5, 7, 8, 9, 10, 11, 12, 15, 17, 18, 19
Valerianaceae	
Valeriana capitata	5, 9, 18
Violaceae	
Viola achyrophora	5

TABLE B-1. The mean number of hits and coefficient of variation using three methods of recording on line-point transects in two vegetation types.

		Methods of recording hits[c]					
	Vege-tation	Mean number of hits			Coefficient of variation		
Species or group[a]	type[b]	First	All	Each	First	All	Each
Shrubs	D	52.42	93.70	80.30	29	33	32
	E	29.12	55.13	43.75	71	59	54
Vaccinium uliginosum	D	16.50	23.30	21.10	40	37	37
	E	7.13	13.03	10.77	72	78	78
Betula nana	D	9.90	14.10	12.10	62	61	58
	E	11.94	17.81	13.38	136	140	129
Empetrum nigrum	D	12.90	27.70	23.00	49	47	41
	E	2.31	4.19	3.94	78	105	102
Ledum decumbens	D	5.00	9.30	8.20	91	75	75
	E	2.25	3.75	3.31	149	138	144
Vaccinium vitis-idaea	D	2.40	5.60	5.20	84	71	72
	E	.63	3.13	2.75	210	111	102
Salix pulchra	D	1.70	1.90	1.70	194	190	194
	E	7.06	11.25	8.31	125	113	119
Loiseleuria procumbens	D	1.40	5.10	4.70	151	135	131
	E	-	-	-	-	-	-
Dryas octopetala	D	.80	1.40	1.20	165	155	151
	E	-	-	-	-	-	-
Salix reticulata	D	.50	1.10	1.00	194	198	189
	E	.25	.63	.63	224	218	218
Salix arbutifolia	D	-	-	-	-	-	-
	E	.56	.69	.69	194	204	204
Lichens	D	17.50	46.40	40.10	48	46	46
	E	8.75	22.69	15.88	115	109	97

TABLE B-1. Continued.

Species or group[a]	Vegetation type[b]
Cladonia rangiferina[d]	D
	E
Cetraria islandica	D
	E
Cladonia gracilis	D
	E
Cetraria cucullata	D
	E
Peltigera spp.	D
	E
Cladonia uncialis	D
	E
Lobaria linita	D
	E
Cladonia amaurocraea	D
	E
Sedges	D
	E
Carex spp.[e]	D
	E
Eriophorum angustifolium	D
	E
Eriophorum scheuchzeri	D
	E
Grasses	D
	E

Methods of recording hits[c]					
Mean number of hits			Coefficient of variation		
First	All	Each	First	All	Each
7.30	19.30	15.80	78	64	62
4.44	12.13	7.69	134	136	118
3.60	10.30	8.30	102	85	90
1.56	3.69	2.31	140	136	134
.80	3.50	3.50	99	65	65
1.31	3.44	2.75	171	148	149
2.10	5.80	5.20	102	92	87
.06	.19	.19	397	215	215
2.00	3.50	3.50	88	66	66
.69	1.38	1.38	157	121	121
.70	1.60	1.40	136	154	159
.38	.69	.38	154	197	165
.70	2.00	2.00	151	160	160
-	-	-	-	-	-
-	-	-	-	-	-
.25	.56	.56	231	171	171
3.60	4.90	4.70	70	111	106
16.31	26.00	20.25	53	59	58
3.60	4.90	4.70	70	111	106
9.31	16.19	12.44	70	68	61
-	-	-	-	-	-
3.63	6.19	4.81	156	158	159
-	-	-	-	-	-
2.38	3.63	3.00	191	173	173
3.40	5.50	4.80	185	181	174
9.69	15.19	11.63	139	140	133

TABLE B-1. Continued.

		Methods of recording hits[c]					
		Mean number of hits			Coefficient of variation		
Species or group[a]	Vegetation type[b]	First	All	Each	First	All	Each
Calamagrostis canadensis	D	1.50	1.70	1.60	238	232	242
	E	8.81	13.50	10.25	143	140	136
Poa spp.[f]	D	1.20	2.40	2.20	151	161	148
	E	.81	1.56	1.25	157	177	169
Forbs	D	3.60	7.50	6.30	211	210	191
	E	5.14	13.38	11.44	131	147	139
Polemonium acutiflorum	D	.40	.60	.60	211	179	179
	E	1.75	5.31	4.31	193	196	190
Rubus chamaemorus	D	-	-	-	-	-	-
	E	1.00	2.13	1.94	116	104	95
Rubus arcticus	D	-	-	-	-	-	-
	E	.56	1.81	1.56	171	160	163
Artemisia arctica	D	1.00	1.90	1.50	283	280	271
	E	-	-	-	-	-	-
Equisetum scirpoides	D	.40	.90	.90	175	117	117
	E	-	-	-	-	-	-

[a] Species present on two or less transects are not included
[b] D = Dwarf shrub-lichen; E = Eriophorum-Carex-dwarf shrub meadow
[c] First = First hit only; All = All hits; Each = each species hit
[d] Includes Cladonia sylvatica and C. mitis
[e] Primarily C. bigelowii in dwarf shrub-lichen type and C. aquatilis and C. kelloggii in the Eriophorum-Carex-dwarf shrub meadow
[f] Primarily Poa arctica

TABLE B-2. Average weight from 30 clipped and 100 estimated 2.4 ft^2 plots in the dwarf shrub-lichen type near Nome.

	Actual weight lb/acre	Estimated weight lb/acre
Total usable forage	5136	5861
Shrubs	1564	1896
Empetrum nigrum	393	536
Betula nana	314	298
Vaccinium uliginosum	245	269
Ledum decumbens	213	238
Loiseleuria procumbens	196	234
Vaccinium vitis-idaea	79	76
Salix pulchra	61	80
Dryas octopetala	26	31
Salix phlebophylla	23	28
Cassiope tetragona	0	27
Other shrubs	14	78
Lichens	3330	3623
Cladonia rangiferina, C. sylvatica, C. mitis	1836	1932
Cladonia amaurocraea, C. crispata, C. subfurcata	310	309
Cladonia uncialis, C. boryi	276	328
Cetraria islandica	294	289
Cladonia gracilis	276	285
Cetraria cucullata	80	136
Stereocaulon spp.	57	75
Lobaria linita	70	74
Peltigera spp.	38	23
Cladonia coccifera, C. gonecha	23	21
Thamnolia vermicularis	15	16
Alectoria nigricans, Cornicularia divergens	5	10
Other lichens	50	125

TABLE B-2. Continued.

	Actual weight lb/acre	Estimated weight lb/acre
Grass-like plants	246	314
Carex spp.	159	215
Poa arctica, P. glauca, P. alpina	29	27
Festuca altaica, F. rubra	14	21
Luzula spicata, L. confusa, L. multiflora	13	14
Calamagrostis canadensis, Arctagrostis latifolia	12	14
Agrostis borealis	14	12
Hierochloe alpina	4	11
Forbs	12	26

TABLE B-3. The differences of the per cent composition recorded on 20 permanent transects with four days between readings.

Species (or ground cover)[a]	Method[b]	No. of 2nd readings that agree	No. of 2nd readings that do not agree	% that agree	Total composition on all transects	Mean difference between 1st & 2nd readings	Standard deviation of differences	Range of the differences
Total usable forage	c	2	18	10	3005	3.25	7.72	-11 to +19
Litter	c	2	18	10	362	-2.70	4.59	-13 to + 4
Moss	c	1	19	5	565	- .75	5.45	-13 to +11
Rock	c	3	0	100	62	0.00	0.00	0 to 0
Bare ground	c	0	2	0	6	2.00	0.00	+ 2
Betula nana exilis	A	4	11	27	351	.87	4.14	- 4 to +13
	B	4	13	24	262	.59	2.67	- 4 to + 7
	C	5	12	29	251	.59	2.15	- 2 to + 7
Vaccinium uliginosum	A	3	16	16	291	.58	3.58	- 4 to + 9
	B	1	18	5	276	1.58	3.11	- 2 to +10
	C	3	16	16	273	1.53	3.27	- 4 to + 8
Empetrum nigrum	A	3	13	19	202	0.00	4.66	- 9 to +12
	B	4	13	23	206	- .41	2.53	- 5 to + 4
	C	3	14	18	213	- .29	2.80	- 6 to + 6
Salix pulchra	A	2	10	17	203	1.08	4.44	-10 to + 8
	B	5	8	38	215	- .69	1.70	- 5 to + 2
	C	2	11	15	196	0.00	2.86	- 6 to + 4
Ledum decumbens	A	3	12	20	137	.07	2.19	- 4 to + 3
	B	2	13	13	137	- .20	2.14	- 6 to + 2
	C	2	13	13	141	- .47	2.22	- 6 to + 2
Dryas octopetala	A	1	3	25	87	- .75	1.30	- 2 to 0
	B	1	3	25	76	- .50	2.07	- 3 to + 2
	C	0	4	0	79	- .20	2.22	- 3 to + 2
Vaccinium vitis-idaea	A	3	10	23	53	- .61	2.42	- 5 to + 5
	B	2	14	12	84	- .63	1.74	- 4 to + 3
	C	2	14	12	90	- .69	1.72	- 5 to + 3

TABLE B-3. Continued.

Species (or ground cover)[a]	Method[b]	No. of 2nd readings that agree	No. of 2nd readings that do not agree	% that agree
Loiseluria procumbens	A	1	3	25
	B	0	5	0
	C	0	5	0
Salix phlebophylla	A	1	4	20
	B	1	4	20
	C	1	4	20
Salix reticulata	A	2	6	25
	B	3	5	37
	C	3	5	37
Cassiope tetragona	A	1	2	33
	B	2	1	67
	C	2	1	67
Potentilla fruticosa	A	1	3	25
	B	1	3	25
	C	1	3	25
Salix arbutifolia	A	1	3	25
	B	1	4	20
	C	1	4	20
Arctostaphylos alpina	A	2	2	50
	B	4	1	80
	C	4	1	80
Salix glauca	A	0	4	0
	B	0	4	0
	C	0	4	0
Cladonia rangiferina[d]	A	4	11	27
	B	0	15	0
	C	0	15	0

Total composition on all transects	Mean difference between 1st & 2nd readings	Standard deviation of differences	Range of the differences
27	.75	2.21	- 2 to + 3
40	- .40	2.61	- 4 to + 3
44	- .40	2.51	- 4 to + 2
33	1.00	2.92	- 3 to + 5
24	1.20	2.28	- 1 to + 5
24	.80	2.17	- 2 to + 4
23	- .13	1.55	- 3 to + 2
23	.13	1.24	- 1 to + 2
23	.13	1.24	- 1 to + 2
16	-2.00	2.00	- 4 to 0
17	-1.00	1.73	- 3 to 0
17	-1.00	1.73	- 3 to 0
13	- .25	2.50	- 3 to + 3
13	.25	.96	- 1 to + 1
10	0.00	1.39	- 1 to + 2
10	.50	1.29	- 1 to + 2
10	.40	.89	- 1 to + 1
11	.60	1.14	- 1 to + 2
7	- .75	.96	- 2 to 0
9	- .20	.40	- 1 to 0
9	- .20	.40	- 1 to 0
5	1.25	.25	+ 1 to + 2
5	1.25	.25	+ 1 to + 2
5	1.25	.25	+ 1 to + 2
210	-1.07	2.66	- 6 to + 6
270	-1.87	2.77	- 6 to + 2
248	-1.4	2.72	- 5 to + 3

TABLE B-3. Continued.

Species (or ground cover)[a]	Method[b]	No. of 2nd readings that agree	No. of 2nd readings that do not agree	% that agree
Cetraria islandica	A	3	12	20
	B	4	11	27
	C	2	13	13
Cetraria cucullata	A	0	9	0
	B	2	9	18
	C	2	9	18
Cladonia gracilis	A	2	9	18
	B	4	10	29
	C	2	12	14
Peltigera spp.	A	1	10	9
	B	5	6	45
	C	3	8	27
Alectoria nigricans	A	1	2	33
	B	0	3	0
	C	0	3	0
Cladonia uncialis	A	1	6	14
	B	1	9	10
	C	1	9	10
Lobaria linita	A	1	1	50
	B	2	3	40
	C	2	3	40
Cladonia crispata	A	1	4	20
	B	1	5	17
	C	1	5	17
Thamnolia vermicularis	A	0	2	0
	B	2	2	50
	C	1	3	25

Total composition on all transects	Mean difference between 1st & 2nd readings	Standard deviation of differences	Range of the differences
145	-1.33	2.61	- 7 to + 3
178	-1.60	2.10	- 6 to + 1
157	-1.53	2.03	- 5 to + 3
48	-1.56	2.13	- 4 to + 2
71	-1.18	1.47	- 3 to + 2
66	-1.18	1.40	- 3 to + 2
37	-1.36	2.01	- 6 to + 1
59	- .64	1.28	- 3 to + 1
68	- .57	1.40	- 4 to + 1
34	.18	2.04	- 3 to + 3
34	- .18	1.08	- 2 to + 1
39	- .64	1.21	- 3 to + 1
41	-1.67	1.53	- 3 to 0
29	-2.33	.58	- 3 to - 2
27	-2.33	.58	- 3 to - 2
15	- .43	1.13	- 2 to + 1
25	-1.30	1.34	- 3 to + 1
24	-1.20	1.23	- 3 to + 1
7	- .50	.71	- 1 to 0
14	- .80	1.67	- 2 to 0
15	-1.00	1.22	- 3 to 0
13	1.00	.71	0 to + 2
15	1.17	.98	0 to + 3
16	1.33	1.03	0 to + 3
3	1.50	.70	+ 1 to + 2
12	.50	.57	0 to + 1
13	.50	.82	- 1 to + 1

TABLE B-3. Continued.

Species (or ground cover)[a]	Method[b]	No. of 2nd readings that agree	No. of 2nd readings that do not agree	% that agree
Sphaerophorus globosus	A	0	2	0
	B	0	3	0
	C	0	3	0
Cladonia amaurocraea	A	0	3	0
	B	0	5	0
	C	1	4	20
Carex spp.[e]	A	0	20	0
	B	2	18	10
	C	2	18	10
Eriophorum angustifolium	A	0	6	0
	B	2	5	28
	C	2	5	28
Eriophorum scheuchzeri	A	0	5	0
	B	0	5	0
	C	0	5	0
Calamagrostis canadensis[f]	A	1	9	10
	B	1	9	10
	C	2	8	20
Poa spp.[g]	A	1	9	10
	B	3	7	30
	C	2	8	20
Festuca altaica	A	0	5	0
	B	1	4	20
	C	1	4	20

Total composition on all transects	Mean difference between 1st & 2nd readings	Standard deviation of differences	Range of the differences
7	- .50	1.12	- 3 to + 2
11	.33	1.16	- 1 to + 1
11	.33	1.16	- 1 to + 1
5	- .33	1.14	- 1 to + 1
7	- .20	1.10	- 1 to + 1
8	- .40	.97	- 1 to + 1
362	2.40	6.03	- 9 to +12
331	2.00	3.57	- 6 to + 8
319	1.70	4.14	- 5 to +10
63	1.40	4.45	- 6 to + 6
62	0.00	3.87	- 5 to + 4
59	.60	3.50	- 3 to + 4
43	.83	3.49	- 7 to + 3
40	.29	1.60	- 3 to + 2
39	- .14	1.95	- 4 to + 2
198	1.80	3.16	- 3 to + 7
157	.90	2.69	- 4 to + 5
169	1.10	2.60	- 2 to + 6
32	.40	1.78	- 2 to + 4
36	1.00	1.89	- 1 to + 5
40	1.00	2.00	- 2 to + 5
11	- .20	1.10	- 1 to + 1
11	.20	1.30	- 1 to + 2
10	0.00	1.00	- 1 to + 1

TABLE B-3. Continued.

Species (or ground cover)[a]	Method[b]	No. of 2nd readings that agree	No. of 2nd readings that do not agree	% that agree
Polemonium acutiflorum	A	2	5	28
	B	1	8	11
	C	2	7	22
Rubus chamaemorus	A	0	6	0
	B	1	6	14
	C	2	5	28
Rubus arcticus	A	1	5	17
	B	1	5	17
	C	2	4	33
Valeriana capitata	A	0	4	0
	B	1	4	20
	C	2	3	40
Petasites frigidus	A	0	5	0
	B	1	5	17
	C	1	5	17
Artemisia arctica	A	1	2	33
	B	1	3	25
	C	1	3	25
Cardamine pratensis	A	1	3	25
	B	1	5	17
	C	0	6	0
Solidago multiradiata	A	0	3	0
	B	1	3	25
	C	0	4	0

Total composition on all transects	Mean difference between 1st & 2nd readings	Standard deviation of differences	Range of the differences
41	.71	1.11	- 1 to + 2
60	.22	1.60	- 3 to + 2
68	.44	1.43	- 2 to + 3
17	.17	1.33	- 2 to + 1
22	.57	1.27	- 2 to + 2
23	.14	1.35	- 2 to + 2
13	.50	.84	- 1 to + 1
23	.17	1.47	- 2 to + 2
24	.33	1.36	- 2 to + 1
11	2.25	2.50	- 1 to + 5
16	2.00	1.87	0 to + 4
16	2.00	1.87	0 to + 4
12	2.40	1.02	+ 1 to + 3
15	1.16	1.60	- 1 to + 3
16	1.33	1.86	- 1 to + 4
13	3.00	4.36	0 to + 8
14	2.50	3.70	0 to + 8
13	2.25	3.20	0 to + 7
11	-1.25	1.26	- 3 to 0
13	- .83	1.33	- 3 to + 1
13	- .50	1.23	- 2 to + 1
10	2.00	3.00	- 1 to + 5
13	2.25	2.22	0 to + 5
12	2.25	.96	+ 1 to + 3

TABLE B-3. Continued.

Species (or ground cover)[a]	Method[b]	No. of 2nd readings that agree	No. of 2nd readings that do not agree	% that agree	Total composition on all transects	Mean difference between 1st & 2nd readings	Standard deviation of differences	Range of the differences
Equisetum scirpoides	A	0	4	0	10	1.50	1.00	+ 1 to + 3
	B	0	6	0	11	.83	.98	- 1 to + 2
	C	0	6	0	11	.83	.98	- 1 to + 2
Equisetum arvense	A	0	3	0	5	1.00	1.73	- 1 to + 2
	B	1	3	25	5	.75	.41	0 to + 1
	C	1	3	25	5	.75	.41	0 to + 1

[a] Species recorded on only one or two transects are not included
[b] A = first hit; B = all hits; C = each species hit
[c] Values the same by all three methods
[d] Includes Cladonia sylvatica and C. mitis
[e] Primarily Carex bigelowii
[f] Includes Arctagrostis latifolia
[g] Primarily Poa arctica

TABLE B-4. The differences of the per cent composition recorded on 28 permanent transects with one year between readings.

Species (or ground cover)[a]	Method[b]	No. of 2nd readings that agree	No. of 2nd readings that do not agree	% that agree	Total composition on all transects	Mean difference between 1st & 2nd readings	Standard deviation of differences	Range of the differences
Total usable forage	c	4	24	14	4600	.053	3.59	- 7 to + 8
Litter	c	7	21	25	405	- .857	2.95	- 9 to + 3.5
Moss	c	3	22	12	461	.428	2.52	- 3 to + 5.5
Bare ground	c	1	4	20	26.5	- .192	1.56	- 3.5 to + 3.5
Rock	c	1	8	11	107	1.44	2.17	- 1.5 to + 4.5
Betula nana exilis	A	5	23	18	780	1.446	4.39	-15 to +10
	B	4	24	14	585.4	1.05	3.13	- 9.1 to + 7.1
Vaccinium uliginosum	A	7	18	28	624.1	1.035	2.58	- 2 to + 8
	B	3	22	12	491.8	.723	2.17	- 1.5 to + 5.3
Empetrum nigrum	A	10	17	37	501.5	1.167	3.03	- 5.5 to + 8.5
	B	11	16	41	459.7	1.448	2.25	- 1.5 to + 8.5
Ledum decumbens	A	8	19	31	344.5	.196	2.52	- 6 to + 6.5
	B	12	16	43	381.8	- .332	1.98	- 3.6 to + 4
Loiseluria procumbens	A	6	11	35	190	1.735	2.86	- 1.5 to + 6.5
	B	5	12	29	254	- .278	1.70	- 3.5 to + 3.2
Vaccinium vitis-idaea	A	11	15	42	139.5	- .21	1.91	- 3.5 to + 3.5
	B	6	22	21	206.5	- .875	1.88	- 5.9 to + 2.4
Salix pulchra	A	3	9	25	76	0	1.87	- 4 to + 3
	B	6	6	50	54.6	- .189	1.46	- 5.1 to + 1.6
Salix reticulata	A	2	2	50	19.5	.50	.71	- .5 to + 1.5
	B	2	4	33	20.2	.371	1.03	- 1.3 to + 2.1
Arctostaphylos alpina	A	4	2	67	16.5	.214	1.08	- .5 to + 2.5
	B	4	2	67	13.2	- .20	1.12	- 2.4 to + 1.4
Salix phlebophylla	A	2	2	50	9.5	- .214	.70	- 1 to + .5
	B	3	1	75	7.9	.063	.55	- 1 to + .7

TABLE B-4. Continued.

Species (or ground cover)[a]	Method[b]	No. of 2nd readings that agree	No. of 2nd readings that do not agree	% that agree
Rhododendron kamtschaticum	A	2	2	50
	B	3	2	60
Cladonia rangiferina[d]	A	8	18	29
	B	1	25	4
Cetraria islandica	A	9	15	38
	B	2	23	8
Cladonia gracilis	A	12	14	46
	B	5	21	19
Cladonia uncialis	A	3	10	23
	B	8	10	44
Cetraria cucullata	A	8	11	42
	B	15	7	68
Lobaria linita	A	8	4	67
	B	3	10	23
Cladonia amaurocraea	A	3	9	25
	B	3	13	19
Cornicularia divergens	A	4	3	57
	B	4	3	57
Stereocaulon spp.	A	6	2	75
	B	7	2	77
Peltigera spp.	A	2	5	29
	B	2	8	20
Cladonia small cup[e]	A	1	4	20
	B	2	7	22

Total composition on all transects	Mean difference between 1st & 2nd readings	Standard deviation of differences	Range of the differences
7.5	.25	.82	- .5 to + 1.5
4.9	.117	.65	- .8 to + 1.1
451	- .154	3.31	- 5 to + 7
618	.046	2.60	- 4.9 to + 7.4
267	-1.269	2.75	-10 to + 1.5
318.8	- .176	2.49	- 5.9 to + 5.6
80.5	- .611	1.13	- 3.5 to + 1
133.9	- .715	1.47	- 4.2 to + 1.6
58	- .47	2.08	- 5.5 to + 2
94.4	- .93	2.23	- 7.1 to + 1.9
55.5	- .59	1.21	- 4.5 to + 1
91.6	- .348	.65	- 2.4 to + .6
30	- .357	.97	- 3 to + 1.5
55.2	-1.07	1.38	- 5.5 to + .4
34	-1.6	1.33	- 4.5 to 0
45.9	-1.05	1.83	- 5.1 to + .7
37.5	.50	.41	- .5 to + 2.5
26.7	.687	1.11	- .1 to + 1.8
20.5	.278	.97	- .5 to + 2.5
25.3	.109	.53	- .5 to + 1.2
11	- .556	.92	- 1.5 to + .5
25.5	- .229	.83	- 1.6 to + .9
12	- .667	.75	- 2 to + .5
15.5	- .675	.63	- 2.4 to + .6

TABLE B-4. Continued.

Species (or ground cover)[a]	Method[b]	No. of 2nd readings that agree	No. of 2nd readings that do not agree	% that agree
Thamnolia vermicularis	A	1	5	17
	B	1	5	17
Alectoria ochroleuca	A	0	4	0
	B	1	3	25
Umbilicaria hyperborea	A	3	1	75
	B	3	1	75
All sedges	A	5	23	18
	B	8	20	29
Carex spp.[f]	A	2	26	7
	B	3	24	11
Eriophorum scheuchzeri	A	0	5	0
	B	0	5	0
Eriophorum angustifolium	A	0	4	0
	B	0	5	0
All grasses	A	8	10	44
	B	11	11	50
Calamagrostis canadensis[g]	A	2	14	13
	B	5	14	26
Hierochloe alpina	A	0	4	0
	B	1	5	17
Agrostis borealis	A	1	1	50
	B	2	4	33
All forbs	A	10	13	43
	B	10	14	42

Total composition on all transects	Mean difference between 1st & 2nd readings	Standard deviation of differences	Range of the differences
10.5	- .313	1.01	- 2 to + 1
12.7	- .485	.81	- 2.5 to + .9
10.5	-1.90	1.30	- 3.5 to - .5
8.7	-1.25	1.17	- 2.7 to 0
10.5	.1	.65	- .5 to + 1
8.1	.15	.40	- .3 to + .7
517	- .64	2.34	- 5.5 to + 3
404.5	.68	1.32	- 1.8 to + 3.6
481.5	-1.98	3.60	-10 to + 3
373.7	- .548	2.20	- 5.6 to + 3.2
20	2.5	2.62	+ .5 to + 7
17.1	1.71	2.01	+ .3 to + 5.4
16	2.67	2.66	+ .5 to + 6
13.7	1.96	1.92	+ .3 to + 5.7
82	- .247	1.62	- 4 to + 2.5
73.9	.422	1.43	- 2.2 to + 4.4
69	-1.05	1.48	- 4 to + 2.5
57.4	- .74	1.57	- 3 to + 4.4
9.5	.59	.66	- .5 to + 1
8	.53	.60	- .3 to + 1.1
4.5	.30	.84	- .5 to + 1.5
6.6	.49	.48	0 to + 1.2
89.5	.288	.99	- 2 to + 2.5
95.9	.559	.99	- 1.4 to + 3.3

TABLE B-4. Continued.

Species (or ground cover)[a]	Method[b]	No. of 2nd readings that agree	No. of 2nd readings that do not agree	% that agree	Total composition on all transects	Mean difference between 1st & 2nd readings	Standard deviation of differences	Range of the differences
Rubus chamaemorus	A	4	5	44	24	.10	1.05	- 2 to + 1.5
	B	4	6	40	27.2	.29	.87	- 1.4 to + 1.9
Artemisia arctica	A	2	1	67	6.5	.167	.58	- .5 to 0
	B	2	2	50	7.1	.381	.56	- .3 to + 1.2
Anemone parviflora	A	0	1	0	5.5	.9	.89	+ 2.5
	B	0	3	0	6	.8	1.02	+ .3 to + 3.1
Aconitum delphinifolium	A	0	3	0	6	-1.5	1.08	- 3 to - .5
	B	0	3	0	5.3	- .883	.65	- 1.7 to - .3

[a] Species recorded on only one or two transects are not included
[b] A = first hit; B = each species hit methods
[c] Values the same by both methods
[d] Includes *Cladonia sylvatica* and *C. mitis*
[e] Primarily *Cladonia coccifera*
[f] Primarily *Carex bigelowii* and *C. aquatilis*
[g] Includes *Arctagrostis latifolia*

TABLE B-5. Species composition in the tundra-lichen exclosure in a dwarf shrub-lichen stand near Unalakleet.

Scraped quadrat: April 1922 100% Cover

80% lichens	10% browse	10% sedges

September 1932 95% Cover

50% lichens		30% browse		15% grass, sedges 5% moss	
Cladonia	24%	Arctostaphylos	15%	Carex	14%
Cetraria	24%	Ledum	10%	Poa	1%
Stereocaulon	2%	Betula nana	2%		
		Vaccinium	3%		

June 1965 100% Cover

65% lichens		30% browse*		5% sedges
Cladonia rangiferina	40%	Arctostaphylos alpina	15%	Carex bigelowii
C. sylvatica[a]	10%	Ledum decumbens	10%	
C. alpestris	10%	Vaccinium uliginosum	3%	
Cetraria cucullata	4%	Empetrum nigrum	2%	
Stereocaulon spp.	1%			

Clipped quadrat: April 1922 100% Cover

80% lichens	10% browse	10% sedges

September 1932 100% Cover

50% lichens		45% browse		5% grass, sedges	
Cladonia	22%	Arctostaphylos	20%	Carex	4%
Cetraria	22%	Ledum	3%	Poa	1%
Stereocaulon	6%	Betula nana	3%		
		Vaccinium	19%		

June 1965 95% Cover

10% lichens		85% browse		3% sedges, 2% moss
Cladonia sylvatica	4%	Ledum decumbens	40%	Carex bigelowii
C. rangiferina	4%	Betula nana	30%	
Cetraria cucullata	2%	Arctostaphylos alpina	15%	
		Vaccinium vitis-idaea	10%	
		V. uliginosum	4%	
		Equisetum sylvaticum	1%	

*One seedling of Betula kenaica was about 8 inches high and growing in the quadrat.

TABLE B-5. Continued.

Denuded quadrat: April 1922 100% Cover

80% lichens		10% browse		10% sedges	

September 1932 80% Cover

35% lichens		40% browse		15% grass, sedges 10% moss	
Cladonia	12%	Vaccinium	20%	Carex	13%
Cetraria	13%	Arctostaphylos	10%	grass	2%
Stereocaulon	10%	Betula	5%		
		Ledum	5%		

June 1965 95% Cover

30% lichens		65% browse		5% sedges
Cladonia sylvatica	12%	Betula nana	20%	Carex bigelowii
C. rangiferina	8%	Arctostaphylos alpina	10%	
Stereocaulon spp.	5%	Empetrum nigrum	10%	
Cetraria cucullata	5%	Ledum decumbens	10%	
		Vaccinium vitis-idaea	10%	
		V. uliginosum	5%	

Check quadrat: April 1922 100% Cover

80% lichens		10% browse		10% sedges	

September 1932 100% Cover

50% lichens		40% browse		10% grass, sedges	
Cladonia	23%	Betula nana	15%	Carex	8%
Cetraria	23%	Vaccinium	10%	Poa	2%
Stereocaulon	4%	Arctostaphylos	7%		
		Ledum	8%		

June 1965 100% Cover

70% lichens		27% browse		1% sedges, 2% moss
Cladonia sylvatica	40%	Ledum decumbens	18%	Carex bigelowii
C. rangiferina	20%	Vaccinium	4%	
C. alpestris	4%	Betula nana	3%	
Cetraria cucullata	6%	Arctostaphylos alpina	2%	

[a] Includes Cladonia mitis