RANGE MANAGEMENT AND THE GENUS *RANGIFER*: A REVIEW OF SELECTED LITERATURE.

A THESIS

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by

Alan M. Courtright

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PREFACE

L. J. Palmer, a biologist with the U. S. Bureau of Biological Survey (now the Bureau of Sport Fish and Wildlife of the U. S. Fish and Wildlife Service) and other government agencies, spent some twenty-five years in Alaska beginning about the early 1920's. Much of this time was devoted to studies of the genus Rangifer; Palmer probably wrote more about reindeer and caribou than any other single researcher. It was to abstract and make available his findings (many of them unpublished and most of which--published or unpublished--are inaccessible or poorly distributed) that this study was initiated.

During the early stages of the investigation the writer found that a considerable body of literature pertaining to caribou and reindeer range management exists. This material, much of it Russian, is sometimes even more difficult to obtain than Palmer's work. Often only one or two copies (if any) are available in North America and therefore are frequently unknown to contemporary researchers. For this reason the project was expanded to include such works as well as Palmer's writings.

Actual use of data or ideas from the above would frequently depend on obtaining microfilms or translations. Even when copies of the original work are available, those engaged in research on the genus Rangifer are often so situated that obtaining them is a time-consuming process. Accordingly, a primary objective of this paper is to enable

the reader to determine whether a particular writing is worth the expense and effort required to obtain it. I have also included some of the more significant data and ideas from the listed works; those who require only a few figures or other items may thus find it unnecessary to obtain the originals.

This paper is divided into three main sections. The first consists of a brief review of the research that has been conducted on the foods, food habits, and food requirements of the genus Rangifer, and the relationships of these studies to general range management in the north. It is intended primarily as a guide and framework for the reading of the individual items in Section II. The reader who wishes to review the general subject of range management is referred to the works cited in the footnotes in Section I and other such texts. In Section II the individual papers which have been abstracted, summarized, reviewed or otherwise treated are listed in alphabetical order (by author). The third section is composed of tables, lists, and other "compiled" and tabulated data selected from the works in Section II; these are grouped according to subject for easy comparison. The material in all three sections is indexed; the more obvious subjects, such as "reindeer," "lichens," etc. are not included in this index, as they are mentioned so frequently that their inclusion would render the index unwieldy.

Evaluation of writings (or presenting enough material to allow the reader to make his own evaluation) and extraction and presentation of pertinent data are often incompatible

with the objective of including as many works as possible. My solution of this problem here has been to avoid a standardized format--aside from the strictly bibliographical data--in the material presented in Section II; one entry may thus include only a table of contents or list of tables; others are briefly abstracted or annotated, and a few consist of only slightly condensed versions of a paper, section of a report, or salient chapter of a book. This does not mean that the value of a listed work is proportional to its length. The time at which each work was procured, estimated costs of translation, general availability to the reader, pertinancy, and other factors all had a part in determining the length of the evaluatory material.

Publications cited in Section I which do not pertain specifically to the genus Rangifer or the regions it inhabits have not been entered in Section II but appear as footnotes in the text.

Russian periodicals posed several problems. First, there is no complete list of their titles in the United States, to my knowledge. It is often difficult to determine whether volumes that appear to be missing in the library are actually present but listed under another title. English subtitles in a series often vary from one volume to the next, there appear to be duplicate titles on some concurrent series published by the same organization, and the library collections of a series are often incomplete.

To avoid further confusion I have abbreviated the titles

considerably and included a key to these abbreviations, with Library of Congress call numbers, at the end of this preface. Most American readers who wish to see the originals will find it easiest to obtain microfilms from the Library of Congress; the inclusion of call numbers should help in assuring that the right publication is photographed. Some of the call numbers refer to U. S. Government libraries other than the Library of Congress; microfilms of these can usually be obtained from the latter library.

Russian authors' names are necessarily transliterations, and spelling may not agree with other bibliographies. Transliteration of titles and publication names has been omitted, with one or two obvious exceptions: such transliterations are more often confusing than useful.

Many of the works listed in Section II were written in the 1920's and 1930's. The scientific names of a few plants may therefore be obsolete; the original names and spelling have been followed throughout. An exception to this is my use of the letters "Cl." rather than "C." to designate the genus Cladonia. In this I have followed the Russian example in order to eliminate any possible confusion with the Cetrariae, which bear the generic abbreviation "C." Hustich (1951) uses the generic name "Cladina" for the members of that subgenus of the Cladoniae. Although there is some precedence for this, the practice is not generally accepted; I have followed it only in my abstract of Hustich's paper.

As indicated in the title, the works included in Section II represent a selected group. A few of the entries may give

rise to queries concerning the reasons for their inclusion. A letter written by L. J. Palmer, for example, gives some figures for the amount of range burned in the interior of Alaska; although the letter does not constitute a scientific paper, the figures nevertheless represented readily available estimates made (or obtained) by a reputable scientist, and furnish an example of the magnitude of range burning. A very few entries, briefly reviewed, are included as being excellent sources for a broad review of the subject of northern range management. Although they contain no useful data or new ideas, they thus can serve as beginning texts for those who are commencing work in an unfamiliar field.

Translations of Russian papers (other than the English summaries which are included in many such publications) are the work of several semi-professional linguists. The author, however, accepts full responsibility for any errors of either commission or ommission in all such translated material as well as that originally written in English.

All unpublished material, unless indicated otherwise, was found in the Palmer Collection which is now the property of the University of Alaska. Most, if not all, of the "Anonymous" writings are probably Palmer's work, and were found in the above collection. A few of those which would ordinarily be in this classification were credited to Palmer on the basis of a title or other indication of authorship; such indications appear in parentheses after the author's name.

ACKNOWLEDGEMENTS

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Thanks are due to Dr. John L. Buckley for conceiving of and implementing the project and for other assistance; to Sigurd T. Olson, Drs. F. C. Dean and A. W. Johnson, and Robert F. Scott for critical reading of the manuscript and many helpful suggestions; and to Drs. I. V. Larin and V. N. Andreev for providing books and periodicals which would otherwise have been very difficult to obtain.

The help of Georgia Milner in typing much of the rough draft was much appreciated. Special thanks are due to Polly Hull for the considerable task of typing the final draft, during which she pointed out many errors and inconsistencies which my over-familiarity with the manuscript would have led me to overlook.

ABBREVIATIONS AND LIBRARY CALL NUMBERS

LC - Library of Congress, Washington, D. C.

DI - U. S. Dept. of Interior Library, Washington, D. C.

DA - U. S. Dept. of Agriculture Library, Washington, D. C.

ACWRU - Alaska Cooperative Wildlife Research Unit, College, Alaska

Trans. Inst. Polar Agr. - Transactions of the /U.S.S.R./ Institute of Polar Agriculture, Animal Husbandry, and Fishing and Hunting Industry. The Chief Administration of the Northern Sea Route Editors, Leningrad. /Some periodicals of this title bear the subtitle "Series 'The Reindeer Industry'" and others have no subtitle. All have the LC number SF401.R4L45./

U.S.S.R. Inst. Reindeer Indus., Sov. Reindeer Indus. - The U.S.S.R. Institute of Reindeer Industry, /Series?/ The Soviet Reindeer Industry. /These bear the same LC call number as "Trans. Inst. Polar Agr." This does not appear to indicate a title change, as there were duplicate volume numbers in the two series./

Arctic Inst. U.S.S.R., Sov. Reindeer Indus. - The Arctic Institute of the U.S.S.R. /Series?/ The Soviet Reindeer Industry. The Chief Administration of the Northern Sea Route Editors, Leningrad. /Some of these did not have the indicated subtitle, but

appear to be in series with those which did. LC call number was SF401.R456./

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ABSTRACT

RANGE MANAGEMENT AND THE GENUS *RANGIFER*: A REVIEW OF SELECTED LITERATURE

This study, financed by the Arctic Institute of North America and the Alaska Cooperative Wildlife Research Unit, is designed to provide a review of the present status of knowledge concerning the foods and food habits of reindeer and caribou. Much of the literature on this subject is poorly distributed and little known, and is therefore frequently overlooked by contemporary researchers.

The report is divided into three sections. The first is a general review of the subject by the writer: this is followed by selected abstracts of pertinent writings, and a section containing numerical and other tabulated data constitutes the third part.

The genus *Rangifer* being of a nomadic disposition, the results of over-utilization of the food supply are more difficult to define than is the case with most other ruminants exhibiting greater spatial stability. The same factors require study in connection with range management, however: the supply and availability of food plants, nutrition, and ecological relationships. Whether more knowledge of these factors will enable man to induce caribou and reindeer to remain in desired localities is conjectural, but the food supply seems the most likely key to nomadism.

There appear to be no indications in the literature that plants--with the exception of lichens--serving as foods for Rangifer are deficient in any essential nutrients. However, few if any analyses of nutrient composition have been made of plants gathered during the winter, when the protein content is lowest. The oft-reported deficiency of proteins, and to a lesser extent minerals, in lichens requires further study of the animals' requirements before it can be labelled "critical." The lichens, closely associated with reindeer and caribou in the literature, have not been proven essential in the diet: both animals exist at present in areas where these cryptogams are relatively scarce or absent. Lichens do, however, appear to be a "preferred" food item, and their exact role in northern range ecology remains to be determined. The food preferences and nutritional requirements of Rangifer have been studied to some extent, but these factors also require further investigations if the range is to be properly managed.

INTRODUCTION

Among the ruminants, the genus Rangifer presents some rather special problems in respect to its food supply by virtue of being primarily associated with a type of vegetation of exceedingly slow growth potential, the "lichen forests" and tundra of the North. The genus is also of a distinctly nomadic disposition, further adding to the number of questions which must be answered in order to properly manage reindeer and caribou.

The consequences of excessive populations and the concomitant over-utilization of the food supply are, among spatially stable populations of ruminants such as the white-tailed deer, usually fairly obvious; malnutrition and, ultimately, losses through starvation-induced factors such as increased predation, susceptibility to disease and parasites, and inability to withstand severe weather. Malnutrition may also have its effect on reindeer, which in most cases are controlled in their movements by humans, and on caribou and feral reindeer confined to a specific area by natural barriers. Caribou on unrestricted range, so far as the writer has been able to determine, have never been observed to suffer from such effects. Presumably, when the food supply becomes depleted (or, perhaps, merely "undesirable") caribou seek a new area where the vegetation is more to their liking or better able to support the population. Thus the problem in caribou management may be one

of inducing the animals to remain in a particular area or areas where they can be utilized to the greatest extent or are most necessary in the economy of residents of remote regions. Even reindeer, at least in North America, are frequently lost to proper utilization through wandering off either alone or with passing caribou herds. These losses are not necessarily a result of range depletion, nor is there any assurance that proper management of the food supply will induce either caribou or reindeer to remain in a given area; there may be other reasons for their wandering. The food supply, however, seems to be one of the most likely keys to nomadism.

There appears to be no essential difference between reindeer and caribou--insofar as food habits are concerned--other than the fact that movements of the former can be controlled. Certainly L. J. Palmer, who conducted feeding studies with both animals (1926, 1934), noted no such difference. It would appear safe to assume, until proved otherwise, that the two animals are identical in their food requirements, although their range requirements may differ.

The complex nature of the science of range management, which requires a knowledge of such fields as plant and animal physiology, ecology, taxonomic botany, protozoology, bacteriology, and nutrition, is reflected in the diversity of the literature. In the realm of reindeer and caribou management (which could be termed "northern range management") reports and publications of interest and value can be divided into

several general classifications. It must be understood that these classifications are by no means mutually exclusive, nor do they include all of the entries listed in this publication. The classifications include:

1. Investigations of a region or area: usually conducted with particular reference to reindeer or caribou, this type of study might be termed a "general ecological" investigation; descriptions of history, climate, general geological features, and flora are usually included. Such reports may also discuss utilization of the region as a whole or of specific portions thereof, descriptions of soil types, the effects of both micro- and macro-climate on the production and availability of forage, effects of grazing on the flora, palatability of various species of plants, history, and other information of a type generally familiar to range managers and wildlife biologists. For examples of this type of report, see Andreev (1934), Cringan (1956), Igoshina (1934, 1937), Salaskin (1934), and Skoog (1955). Others of this type included in this publication are Bogdanowskaya-Guiheneuf (1938), Florovskaya (1939), Hustich (1951), Igoshina and Florovskaya (1939), Klein (1958), and Sambuk (1934).

2. General studies of the flora: these may include such aspects as forage values of various species, reaction to grazing, chemical analyses, recovery after fire, digestibility and palatability, etc. Examples of this type of investigation include Alexandrova (1937, 1940), Glinka (1939),

Larin et al (1937 et seq.) Palmer and Rouse (1945), and Temnoev (1939).

3. Investigations of reindeer or caribou in general: information given in the first two classifications above is often included in these reports, as is data on diseases and parasites, anatomy and physiology, reproduction, results of feeding experiments, analysis of stomach contents, marketing of hides and meat, and other ecological and management data. Investigations of this kind may be confined to the animals of a single region or may concern reindeer or caribou per se. Reports by Banfield (1951, 1954), Bonner (1958), Gul'chak (1954), O. Murie (1935), and Palmer (1926) are illustrative of this type.

4. Investigations more specific than those above: these usually report on some single aspect of biology or, in some cases, two or three closely related aspects. Frequently quoted by authors of the more inclusive works classified above, reports of this nature which are of interest here might be further classified as:

a. Studies of growth or regeneration of flora after grazing, fire, or other disturbance. Gorodkov (1936), Igoshina (1939) and Salaskin (1937) reported on lichen growth, while Palmer (1941a) and Lutz (1956) reported on the effects of fire.

b. Investigations of the chemical composition of flora. Most of these studies are concerned primarily with lichens, but a few also include other forage plants.

Florovskaya (1939) and Spencer and Krumboltz (1929) for example, reported specifically on this subject.

c. Results of feeding experiments. These experiments usually have several objectives, among which are the determination of palatability, consumption, nutritional requirements, and the digestibility of various plants or their nutrient components. Aksenova (1937), Dmitrochenko (1935), Kennedey and Titus (nd), Spigul (1937) and Terent'ev (1936) reported on experiments of this nature.

d. Analyses of stomach contents. The primary objective is usually to determine the types and relative amounts of plants eaten; coupled with analysis of the relative abundance of various plant species on the range, however, such analyses can furnish a relative index of "desirability." See for example Chatelain (1953) and Courtright (1957).

REVIEW AND DISCUSSION

Any attempt at "complete" range management must include consideration of the following: floral composition of the range; availability of the forage; nutritional composition of the forage; palatability of the plants on the range; nutritional requirements of the animal or animals for which the range is being managed; effects of utilization on the forage; effects of fires, other animals (including man), and climatic

changes on the range.

These are not the only factors which require consideration; others, such as the inherent limitations on the growth and distribution of plant species, should require no explanation. The fact that there are relationships between factors is likewise considered obvious enough that each factor can be discussed separately in the interests of lucidity.

FLORAL COMPOSITION OF THE RANGE, AVAILABILITY OF FORAGE, AND GRAZING CAPACITIES

A determination of the kinds and relative amounts of plants present on the range should, ideally, take into consideration the availability of the forage to the animals. A general analysis of species and quantity is of little use if part of the area, or many of the species of plants, are unavailable due to natural barriers. An area containing a preponderance of less nutritious or unpalatable plants may in some cases be more valuable than one with an abundance of highly nutritious or palatable plants when accessibility is considered. This fact has apparently received little attention by researchers, although it would seem to be particularly important in northern areas. Bogdanowskaya-Guiheneuf (1938), and Glinka (1939) for example, have given figures for the amount of forage produced per unit of area with little or no mention of how much of this forage is available.

While this might seem at first glance to be a rather

serious oversight, it is in reality an expression of the extreme difficulty of determining "availability." "Natural barriers" includes not only physiographic features but other factors as well: deep snow, frequent snow crusting, large populations of noxious insects which drive the animals to high windswept areas, dense growths of brush or trees, predation, and many other factors can be as effective as mountains and oceans in preventing utilization of otherwise favorable areas.

Some approximate estimates of grazing capacity which included a factor of about 20 per cent for unavailable range appear in the "Reindeer Management Handbook" (Anon., nd.) which was probably written by L. J. Palmer. One hundred and four acres is given as the requirement for one reindeer for one year, of which only 8 or 9 acres are required in the summer. Earlier estimates by Palmer (1926, 1945) ranged from 40 to 100 acres per head per year. Hustich (1951) gives a figure of about 13 reindeer to the square mile (i.e., about 49 acres per head) as the capacity of the lichen woodlands of Labrador, an area where there has apparently been little recent utilization; this figure also includes an allowance for "unavailable" range. Hustich also quotes figures from several other investigators, ranging from 16 hectares (40 acres) per animal to 55 hectares (about 137 acres). Skoog (1955) estimates about 185 acres per caribou in an area of East-central Alaska where lichens are relatively scarce.

It should be quite evident from the figures quoted above that grazing or carrying capacity must be determined for each individual area, and that data quoted for one area are probably of little use for other regions. Each area should be that utilized by one particular group of animals; in other words, carrying capacity should be based on what, for lack of a better term, might be called "herd units."

The most useful index of grazing capacity is usually one based on winter forage requirements of the animals. The more severe climatic values should be used to determine winter availability of forage if minimum risk of overgrazing is desired. Hustich (op. cit.) bases his estimates on winter requirements only: here, as in other literature, there is no mention of whether mean, maximum, minimum, or other values for snowfall, snow crustation, and other climatic limiting factors were used. This is perhaps to be expected considering the little that is known about forage requirements.

Banfield (1951), Cringan (1956), Hustich (op. cit.), Palmer (1922), Bogdanowskaya-Guieheneuf (1938), and Kelsall (1957) included figures on relative or specific amounts of forage species in reports which included estimates of grazing capacity. Since the latter figures are invariably only rough approximations, the former are of doubtful value at present, although they will no doubt prove valuable in the future. Two of the above publications (Banfield and Kelsall) should be quite readily obtainable by those

who wish to compare forage composition and grazing capacity.

NUTRITIONAL COMPOSITION OF THE FORAGE

The value of forage in nutrition is usually expressed in terms of the chemical components of the various plants. The components commonly determined by chemical analyses include proteins, fats, ash, nitrogen-free extracts and fiber. The percentage of these components in a plant is affected by the moisture content, and the latter, expressed in per cent, is usually included in the analyses.

Proteins

The protein content of plants is usually determined by ascertaining the nitrogen content and multiplying by a factor which varies somewhat according to the type of plant being analysed. The usual multiplier is 6.25, since, on the average, about 16 per cent of proteins is nitrogen.[1] The term "crude protein" is sometimes used in tables, as the determination is usually of the total nitrogen compounds in the plant, and some of these are not "true proteins" but consist of various amino acids and other nitrogenous materials. "Protein" may ordinarily be interpreted as synonymous with "crude protein"; if any differentiation is required, the "true proteins" will be labelled as such.

The protein content of plant tissues is usually highest when they are young and succulent, and decreases through the summer, reaching the lowest point after the plant or

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1. Morrison, Frank B. 1950. FEEDS AND FEEDING. 21st Ed. Ithaca, N. Y.: The Morrison Publishing Co. 1207 pp.

its leaves have turned brown in the fall. Plants which remain green longest and those which are "evergreen" usually retain a higher protein content longer than those which turn brown and dry early in the year. The protein content is usually considerably higher in the leaves than in the stems of browse species due to the higher proportion of cellulose and lignin in woody parts.

Unfortunately, most of the analyses given in the tables in Section III do not mention either the date of collection nor the part of the plant analysed. It is probably safe to assume in most cases that protein determinations in the browse species were confined to the leaves and young twigs, and in some cases the values may represent averages for that part of the year when the plants are in green condition. It appears, however, that further analyses, with more attention being paid to these factors, are required.

The tables in Section III indicate that fungi (mushrooms) have the highest protein content of any of the natural Rangifer foods on which analyses have been made. Next come the browse species, with willow high on the list; the grasses and sedges, for which only a comparatively small number of analyses exist, contain a lesser amount of this nutrient, and the lichens the least amount.

Many of the Russian tables of plant nutrient composition include "albumen." The writer has been unable to determine the significance of this factor; it was thought at first that "albumen" might perhaps be analagous to the term "digestible protein" but one of the Russian nutrient

determinations gives a higher figure for the proportion of "albumen" than for protein, making this interpretation unlikely, unless the figures are typographical errors (which seems quite possible). Albumins (note spelling), according to Dutcher et al.[2] are simple proteins which usually lack none of the indispensable amino acids; these are the main constituent of egg white, and only small amounts occur in plants.

Fats

The fat content of the various reindeer and caribou foods seems to follow about the same order as the proteins, with mushrooms at the top of the list and lichens at the bottom. There appears to have been no attempt by investigators to determine what proportion of the ether extract of these foods actually consists of fat. Because of the higher proportion of carbon and hydrogen in the fats, these compounds furnish about 2.25 times as much energy per pound as the carbohydrates.[3]

The "fat" content of plants is more accurately termed "ether extract." "Lipids" is another frequently used term. All three expressions include not only the fats, but other ether-soluble substances such as the sterols, carotenes, phospholipids, chlorophyll, waxes, and essential oils. In some cases the actual fat content of ether extract may be less than 50 per cent.[4]

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2. Dutcher, R. Adams, Clifford O. Jensen, and Paul M. Althouse. 1951. INTRODUCTION TO AGRICULTURAL BIOCHEMISTRY. New York: John Wiley and Sons. 502pp.

3. Morrison, op. cit.

4. Ibid.

Ash

The ash content of plants furnishes an index to the amount of minerals available. Since this factor is determined by burning, some of the minerals will be lost as gases and will not appear in the ash. As a rule, most of the mineral compounds are found in plants in sufficient amounts for ruminant nutrition; among the most frequently lacking are phosphorous and calcium with NaCl also sometimes deficient. The lichens have been found to be poor in total ash content, but Socava (1933) indicates that they may be a good source of phosphorous if this element is lacking in other range plants.

According to Stoddart and Smith[5] the total phosphorous content of plants is a good indicator of nutritive value, since phosphorous and sulphur, phosphorous and protein, and phosphorous and crude fat vary directly, while phosphorous and crude fiber and phosphorous and total ash vary inversely. Lutz (1956) includes a brief discussion of soil chemistry, which is the main factor on which the mineral content of plants depends.

There appear to be relatively few analyses of the elements or compounds in the ash of reindeer and caribou foods; those found by the writer appear in Table 3 in Section III.

Nitrogen-Free Extracts, Fiber, and Cellulose

The carbohydrates, which form three-fourths of the

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5. Stoddart, Laurance A., and Arthur D. Smith. 1955. RANGE MANAGEMENT. 2nd Ed. New York: McGraw Hill. 433 pp.

dry weight of the plant world,[6] are ordinarily separated into two classes; the nitrogen-free extracts (frequently abbreviated to NFE) and crude fiber, usually referred to simply as fiber. The term cellulose is sometimes used as a synonym for fiber, although it is actually a separate compound which forms only a part of the fiber.

The nigrogen-free extracts are the more soluble, and therefore generally the more digestible and useful, of the carbohydrates. Unfortunately, the NFE is determined by subtraction after the proportions of all the other compounds have been determined, and therefore contains not only the soluble carbohydrates but also a few poorly digestible materials, of which lignin is the most prominent. The NFE determination is relatively simple, however, and for that reason continues to be favored as a means of indicating the relative values of the various carbohydrate components.

Hustich (1951) and Llano (1956) indicate that the main value of lichens lies in their high carbohydrate content; as can be seen in Table 1, most of these carbohydrates appear as nitrogen-free extracts, indicating high carbohydrate digestibility; moreover, the lichens contain little or no lignin, which may further add to their digestibility as compared to plants in which the NFE content may be as high but includes lignin.

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6. Maynard, Leonard A., and John R. Loosli. 1956. ANIMAL NUTRITION. New York: McGraw Hill. 484 pp.

The crude fiber and cellulose content of plants (probably excluding lichens) increases with the age of the plants, as does the proportion of lignin. The cellulose content not only increases with age, but it also becomes more woody and resistant through the formation of complex substances such as combinations of cellulose and lignin.[7]

A few of the analyses in Section III give not only the crude fiber content but also the proportion of cellulose and hemi-cellulose of a few plants, which makes possible an occasional determination of whether an author was actually referring to cellulose or crude fiber when a column is headed "cellulose." Hemi-cellulose is more soluble than cellulose, and is included in the nitrogen-free extract portion of the carbohydrates along with the starches, sugars, and more soluble parts of the pentosans and complex carbohydrates (including a part of the cellulose). Alexandrova (1940) classifies lichenin--which Llano (op. cit.) states is the main carbohydrate constituent of lichens--as a hemicellulose.

Vitamins and Trace Elements

The vitamins and certain "trace element" are required for normal growth and activity. Their importance was discovered only recently, and it is not surprising that little mention of either appears in the literature on the genus

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7. Morrison, op. cit.

Rangifer. It should be mentioned also that in addition to the comparative recency of investigations, studies of micronutrients are frequently reported in journals and periodicals seldom seen by investigators in the field of range management. The writer was able to find only two specific references to the vitamin content of caribou and reindeer foods; both concerned lichens. Blix and Rydin (1932) reported on the ergosterol content of Cladonia rangiferina, while Ellis et al. (1933) determined the relative amounts of vitamins A and D in several lichen species. The latter found that the "short growth" lichens contained more vitamin A and less vitamin D than the "tall growth" forms; they attributed the fact that their test animals (rats) could exist on the short forms but not the tall forms to the difference in vitamin A content. Llano (op. cit.) states that the B-complex vitamins are not present in lichens (a statement also made by Ellis et al.) and quotes Kursanov and D'yachkov (1945) to the effect that proteins, fats, minerals, and vitamins are critically deficient in lichens.

Llano (op. cit.) notes that the normal development of the bacterial flora in the colon of ruminants appears to require at least trace amounts of certain specific minerals, which may include some of the trace elements. The reader should consult any recent range management or animal nutrition textbook, such as those appearing in the footnotes in this section, for a review of the importance of vitamins and trace elements in the diet of ruminants.

PALATABILITY OF THE FORAGE

The most favorable nutritional composition of a forage is useless if the forage is not palatable. Palatability is commonly determined by comparing the amount of a particular plant on the range with the amount eaten. It should be evident that such determinations are of a relative nature only. They are never constant, varying with the stage of growth of the plant, time of year, amounts of other plants of greater or lesser palatability available, familiarity of the animals with the plant, and other less tangible factors. In some cases only a certain portion of the plant may be palatable; Larin (1937), for example, mentions that the dead bases of lichens are unpalatable. Reindeer and caribou appear to eat only the leaves and very small twigs of browse species, which may be true of some of the forbs as well. Such factors as these must be taken into consideration when determining the forage resources of an area. Some fairly extensive determinations of palatability by Palmer and other investigators are given in Table 10.

NUTRITIONAL REQUIREMENTS OF REINDEER AND CARIBOU

Aksenova (1937) conducted some extensive investigations of the digestion of various foods. Like other tests conducted by Kennedy and Titus (nd), Spigul (1937), Terent'ev (1936) and Palmer (1926) these are mostly concerned with amounts of various feeds eaten and comparative values of various plant species rather than determination of the amounts of nutrients required. A complete translation of the work

by Aksenova may, however, yield some information on the latter problem.

The number of variables to be considered in determining the nutritional requirements of ruminants is so large that many years of feeding experiments would be required to make such determinations. For instance, Stoddart and Smith[8] state that when an animal receives adequate amounts of carbohydrates and fats, the protein requirement is reduced to a minimum. Such factors tend to introduce some questions concerning the conclusions reached through experiments with reindeer and caribou. As an example, a number of authors state (often quoting from earlier works) that reindeer cannot maintain weight on lichens alone and sometimes interpret this to mean that lichens have little value as food (see Terent'ev, 1936). With the exception of Palmer (1934) however, they appear to make no distinction between the various kinds of lichens. Furthermore, reindeer and caribou probably never subsist on lichens alone. Certain kinds or combinations of lichens may be excellent sources of nutrients, particularly if a few of the nutrients in which they are only slightly deficient are supplied by the large variety of other plants which the animals eat even in winter. Palmer (op. cit.) showed that animals fed on what he terms "short growth" or "moist site" lichens will gain in weight even though no other food is given. The same animals lost weight when fed only "tall growth" or "dry site" lichens. Palmer attributed this to the fact

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8. Op. cit.

that the short growth lichens contained vitamin A while the tall forms did not. He states in a later paper (1944) that the short forms also contain more protein than the tall forms.

Several facts concerning the nutrient requirements of ruminants in general (most of which have been determined in tests with cattle and sheep) are of interest here. One of these is the well-authenticated fact that ruminants are able to obtain a significant portion of their protein requirements from other nitrogenous materials such as urea. The "protein requirement" is in actuality an amino acid requirement. Several of these compounds have been found to be necessary in nutrition, and nearly all of the proteins which can be digested are ultimately broken down and utilized in the form of amino acids. The ability of ruminants to form amino acids from cellulose and non-protein nitrogenous materials such as urea is due to the presence of bacteria in the digestive tract. These bacteria digest cellulose and other complex carbohydrates and are the principal reason ruminants are able to utilize such large amounts of roughages. Ruminants are able to digest these bacteria in the anterior portion of the digestive tract, and may thus secure the amino acids they need, even though their food contains an amount of certain amino acids which would be inadequate for simple-stomached animals.[9]

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9. Morrison, op. cit.

The role of protozoa in the rumen has apparently received little attention by investigators. The writer has found (1958) that large amounts (by volume) of protozoa exist in the rumina of caribou. The Alaska Agricultural Experiment Station, at the writer's request, kindly determined the protein content of samples from four caribou rumina. Two of these samples were screened to eliminate most of the plant material, the retained portion consisting mostly of protozoa (probably 90 per cent or more judging from previous experiments [1958] by the writer). These two samples contained more than twice as much protein (42.6 and 46.4 per cent) as the unscreened samples (19.9 and 20.7 per cent) which contained both plant material and protozoa. Thus it is indicated that the protozoa may be a primary source of protein if caribou are able to digest these organisms. It is unfortunate that no references on amounts of protozoa in other ruminants could be found in the literature for comparative purposes, especially in view of Palmer's statement (1934) that reindeer and caribou are more efficient than domestic ruminants in digesting crude fiber. Aksenova (1937) gives a high rating to the digestibility of cellulose in lichens; it is probable that this is due, at least in part, to an incorrect definition of cellulose or perhaps incorrect translation, since lichens contain little cellulose proper although they contain large amounts of substances (lichenin and isolichenin, sometimes called "lichen starch") resembling cellulose. Some

figures concerning the digestibility of various nutrients are given in Table 9, Section III.

Stoddart and Smith[10] state that mature range cattle require seven to eight per cent total proteins with 4.5 per cent digestible proteins quoted by them as being recommended by the National Research Council. The Morrison feeding standards for cattle are the requirements expressed in terms of amounts (not percentages) required for gaining weight, growing animals, bulls in service, or milk production. These are, nevertheless, the only extensive figures readily available. The indicated requirement for fattening 2-year old cattle of 800 pounds weight is 19.6 to 22.2 pounds of dry matter, 1.46 to 1.62 pounds of digestible protein, 14.1 to 15.9 pounds of total digestible nutrients, 0.044 pounds of calcium and the same amount of phosphorous, and 45 milligrams of carotene per head per day. Stoddart and Smith[11] give 20 pounds per day per 1000 pound animal as the requirement for cattle on the range. On the basis of weight alone caribou and reindeer would require about one-third to one-half of this amount. A more accurate basis for computation is the 0.75 power of the body weight, a figure which reflects the fact that metabolic rate varies with the body surface.

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10. Op. cit.
11. Ibid.

Hustich (op. cit.) states that reindeer eat about 5 tons of lichens annually, or approximately 27 pounds per day. This appears to be somewhat excessive in view of the figures quoted by Palmer (1934) of 15 pounds per day (an earlier work gives 10 pounds per day as the requirement for stalled animals) and by Terent'ev (1936) and Aksenova (1937) of about 6 pounds per 100 pounds live weight per day. This latter figure is for animals being kept in stalls; both authors approximately double this amount as the requirement for working animals; thus their figures are approximately the same as Palmer's.

EFFECTS OF UTILIZATION ON THE FORAGE

Green forages grazed or browsed early enough in the growing season often send out new growth. This secondary growth has been termed "after-grass" in the Russian literature, and has been the object of at least one intensive study (see Avramchik, 1939a). The term appears to apply not only to the grasses, but to other green forage as well. The above study indicated that the ability of different forage species to put forth secondary growth varied considerably according to the species and the time of year the initial removal of growth took place. Removal of leaves from both shrubs and grasses in late summer allowed very little new growth to develop; the willows, grasses, and sedges produced a small amount, while Betula nana produced none at all. The latter species also produced very little

new growth even when clipped early in the growing season, while the willows were found to produce a considerable amount, as did the grasses and sedges.

Avramchik (op. cit.) also found that the nutritive value of the "after-grass" was very high. In other words, early cuttings of new growth as noted previously have a higher protein content and less fiber than the same growth allowed to mature to the end of the growing season. If this original growth is removed, replacement growth also has a high protein content; thus, two clippings from a single plant would contain more protein and be more digestible than a single clipping at the end of summer.

Lichens, being plants of extremely slow growth, do not produce anything analogous to the secondary growth of the green forages. Igoshina (1939), however, has noted that certain species, when clipped, may produce accessory branches; this could result in production of a greater volume of forage than when the plants are allowed to grow undisturbed.

A number of investigators (Larin, 1937; Skoog, 1958; and Igoshina and Florovskaya, 1939) have noted the susceptibility of lichens to damage by trampling, especially when the plants are dry. This extremely frangible condition is obvious to anyone who has picked up a handful on a dry summer day. In a moist condition, on the other hand, lichens are fairly resilient and considerably more resistant to breakage. However, one genus, Stereocaulon, appears to

the writer to be almost as easily damaged when moist as when dry.

Due to this factor of damage through trampling, grazing capacity on lichen ranges may not be directly proportional to animal numbers. A range which appears to be only half utilized might support not twice as many animals but perhaps only half again as many. On the other hand, lichens are known to reproduce by fragmentation, and this may even be the primary method of reproduction for some species. Larin (1937) among others has noted that lichens after reaching a certain height tend to decay at the base while growing apically. The decayed lower portion is not only unpalatable as noted previously, but has no reproductive potential. Thus, as noted by Larin, a certain amount of grazing could be beneficial to the range, perhaps even requisite to maintenance of good grazing conditions. The "grazing capacity" thus might have a lower, as well as an upper, limit for maintenance of optimum conditions.

EFFECTS OF FIRES, OTHER ANIMALS (INCLUDING MAN) CLIMATE, AND OTHER FACTORS ON THE RANGE

Due to the catholic tastes of the genus Rangifer in regard to non-lichen forage--Igoshina (1937) mentions 130 species as being a part of the diet in summer, 30 to 40 in winter--and to the fact that the value of lichens has not been properly defined, there appears to be little profit in making definite statements concerning the effects of fires, man, climate, or other factors on the grazing

capacity of northern ranges. The following generalities however, have been repeated by one or more authors with varying amounts of substantiation and are worth noting:

1. The fact that lichens are sensitive to smoke and air pollution and for this reason disappear from the vicinity of large cities is mentioned even in encyclopedias. While admittedly this may be the best explanation of the relative lack of these plants in some areas, there have to the writer's knowledge been no actual tests of the ability of lichens to grow in air containing impurities of the kind found near populated areas.

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

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

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

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

Although other animals may utilize many of the plants which caribou and reindeer eat, there does not appear to be any competition worthy of serious consideration. This, however, might be due to inadequate knowledge concerning the habits of other animals. In the case of at least one animal, the musk-ox, the lack of competition is primarily a matter of present distribution, there being only one or two relatively small areas where the two genera utilize substantially the same habitat.

ADDITIONAL NOTES ON LICHENS AND NORTHERN RANGE MANAGEMENT

Palmer (1926) states that the main value of lichens in reindeer and caribou range management lies in their distribution and abundance rather than in any inherent nutritional qualities, although he later (1941) states that at least 50 per cent lichens are required in the winter diet for maintenance of condition. Llano (op. cit.) lends some support to the latter view, quoting from Kursanov and D'yachkov (1945) to the effect that if lichens are excluded from the diet, diarrhoea results, due to the fact that lichen acid apparently effects a binding action on the mucous membrane of the intestines. In opposition to these statements is the fact that both caribou and reindeer have existed for some time in areas where lichens are not present in sufficient amounts to constitute any significant portion of the diet. Several islands off the west coast of Alaska have suffered from overgrazing in the past, resulting in almost complete removal of the original lichen cover; these islands still support small herds of reindeer or reindeer-caribou hybrids, as does the island of South Georgia as reported by Bonner (1958). He indicates that lichens are almost nonexistent, those that remain being mostly inaccessible. Analyses of the rumen contents of several animals from this island indicate a rather high proportion of mosses in comparison with other areas; several authors state that mosses are eaten only in times of inadequate food supply. This may indicate an inadequacy in the food supply of the reindeer of South

Georgia, but it cannot be stated definitely that the inadequacy is of lichens.

Alaska's arctic regions north of the Brooks Range, which support considerable numbers of caribou, contain only small and scattered amounts of lichens according to U. S. Fish and Wildlife Service biologist S. T. Olson (viva voce); although some of the animals in this region may winter to the south where lichens are more abundant, many remain on the tundra the year round. It is logical to assume that they exist there with only small amounts of lichens in the diet.

A number of feeding experiments have been conducted with both reindeer and caribou in which non-lichen forage has been fed for varying lengths of time. None of the investigators other than Kursanov and D'yachkov have noticed any dietary or intestinal disturbances resulting from a lack of lichens in the diet. It appears, therefore, that the only reasonable statement concerning lichens which can be made at present is that they may be desirable, and that the animals seem to prefer them to other foods as has been demonstrated by Palmer (1946).

The slow growth of lichens has been mentioned several times previously. Palmer (nd) has compared this growth and reproduction to that of a forest. Gorodkov (1936), Igoshina (1939), and Salaskin (1937), have studied the growth of lichens, and other figures are quoted in Hustich (1951) and Larin (1937). There appears to be general agreement that annual growth of these cryptogams is

approximately one-sixteenth to one-fourth of an inch per year, with small variations in this figure to be expected in various situations and among various species. Igoshina and Salaskin (op. cit.) conducted their investigations with the intention of establishing a method of determining the age, and thereby the annual growth, of lichens in the field without the aid of previous marking. Details of these investigations will be found in Section II.

Although there have been relatively few comparisions of the relative growth rates of various lichen species under standard conditions, it seems to be generally accepted that the genus Stereocaulon grows more rapidly than either the Cladoniae or the Cetrariae. The former may thus occupy excessively grazed or trampled areas with greater facility than the latter two. Lutz (op. cit.) for example, quoted several authors to the effect that Stereocaulon paschale grows to maximum size in about 15 years in contrast to the ordinary minimum of about 25 years required for the Cladoniae and especially the Cladina group. Hustich (op. cit.) states that old caribou and other trails are visible long after the last animal has trod on them due to the growth of Stereocaulon which replaced the damaged original vegetation.

The relative importance of the various lichen species appears to be more a function of volume and area coverage than of differences in nutritional value, although it is true that a few species growing in considerable abundance in some areas (particularly the foliose lichens) are of

relatively little value as reindeer or caribou food. Many authors, for example, state that Stereocaulon is of only secondary importance: according to Larin (1937), this genus is the primary lichen food of the reindeer in the Northern Ural region due mainly to the extent and volume of its growth. Stereocaulon is usually placed third in the order of preference, after the Cladoniae and Cetrariae.

Alexandrova (1940) states that palatability is a function of the lichenous acid content; the favored Cladoniae contain smaller amounts than the less eaten Cetrariae, which in turn contain less than the little eaten Alectoria ochroleuca. He also notes that the Cladoniae have the lowest protein content of the forage lichens.

Some observations by Palmer (1944) indicate a relative predictability in the succession of lichen species after removal of original growth or in invasion of new areas. When his data (see Table 6) are examined more critically, however, it is seen that each of the stages of succession listed contains a number of lichen species; the author probably did not intend to imply that all of these species were present in a specific area at a specific stage in succession, but that one or a few of the listed species would appear according to the site and other factors.

It is the writer's belief that there have been far too many generalized statements concerning the importance or value of lichens in the lives of caribou and reindeer. Many of these statements have been rather unquestioningly perpetuated without any investigations having been made of their truth.

The lichens have not been proven to be an essential part of the diet. It is unfortunate that the precise nature of their value has not been determined. Like a number of other facets of caribou and reindeer range management, this appears to require a critical reexamination.

1. Aksenova, M. J. 1937a. [THE PROBLEM OF REINDEER FEEDING.] Arctic Inst. U.S.S.R., Sov. Reindeer Indus., 10:5-124. Eng. sum. pp. 123-4. 106 tables, 22 refs. ACWRU (Eng. sum. and transl. of titles of tables.)

Only the titles of tables in this publication were translated. A complete list will give some idea of the extent of the investigation and its potential value.

1. Temperature of the animal yard used in experiments.

2. Botanical analysis of the lichen feed [per cent by weight].

3. Average indices of lichen feed [?].

4. Changes in the consumption of lichen feed by reindeer during the experimental period.

5. Changes in the live weight of experimental reindeer "during lichen feeding."

6. Botanical analysis of the "feed remainder" [probably uneaten portion; per cent by weight].

7. Botanical analysis of feed number 3 and its uneaten part.

8. Quantity of consumed mixtures in feed number 1.

9. Chemical composition of the lichen feed in percentages.

10. Content of food substances in [oven dry] lichen feeds in per cent.

11. Chemical composition of lichen feed, grass, and hydrophytes.

12. Chemical composition of the upper and lower parts of Cladonia alpestris.

13. Chemical analysis of remainders [of feeds].

14. Comparative table of the chemical composition of [eaten and uneaten parts, per cent by oven-dry weight] of feeds.

15. Analysis of feces.

16. Digestion of feed number 1.

17. Digestion of feed number 2.

18. Digestion of feed number 3.

19. Digestion of feed number 4.

20. Digestion of feed number 5.

21. Digestion of feed number 6.

22. Average coefficients of digestion [in per cent].

23. Coefficients of digestion of lichens according to various authors.

24. Chemical composition, digested food substances, and starch equivalents of lichen feeds.

25. Starch equivalents of lichen feeds during [sic] 15 per cent humidity.

26. Average quantity [gm.] of urine eliminated daily.

27. Quantity of nitrogen in the urine [in per cent].

28. Daily nitrogen balance [gm.].

29. Feed consumed daily [kg.].

30. Chemical composition of green feeds [in per cent].

31. Chemical composition of Polygonum according to data from various regions [in per cent of oven-dry weight].

32. Quantity of dry matter in green feeds eaten by the average animal during an average 24 hour period [in [illegible].].

33. Changes in the live weight of reindeer during the period of experimental feeding with green feeds.

34. Chemical analysis of feces [in per cent].

35. Digestion of feed number 7 [green willow leaves].

36. Characteristics of feed.

54. Chemical composition of hay [in per cent].

55. Chemical analysis of feces [in per cent].

56. Digestion of willow leaves.

57. Digestion and starch equivalent of dry willow leaves.

58. Chemical composition of brown hay.

59. Chemical composition of swamp and weed [?] hay.

60. Edibility of brown hay [in kg.].

61. Botanical composition of the remainders of brown hay.

62. Chemical composition of the remainders of brown hay.

63. Chemical analysis of the feces of bulls.

64. Digestion of brown hay.

65. Coefficient of digestion of feeds.

66. Composition, digestion, and nutritive value of brown hay.

67. Prescription[?] of combined feeds.

68. Characteristics of experimental animals.

69. Temperatures of the animal yard.

70. "Edibility of mixtures by bucks on a daily average for the calculated period."

71. Chemical analysis of the feed.

72. Chemical composition of fish flour [meal?] according to various sources.

73. Chemical composition of bran according to various sources.

74. Chemical composition of the remainders of feeds.

75. Quantity of dry materials in the daily ration "during the calculated period."

76. Changes in the live weight of experimental animals [average data from three weighings each experiment, in kg.].

77. Average elimination of excrement by reindeer "for the calculated period."

78. Chemical composition of feces.

79. Digestion of food substances in feeds 14 and 15.

80. Average coefficients of digestion of the mixture of combined feeds and combined feed number 3.

81. Starch equivalents of "briquette combined"feeds.

82. Nourishment value of feeds.

83. Coefficients of digestion of food substances in feeds 16 and 17.

84. Average coefficients of digestion of experimental mixtures in feeds 16 and 17.

85. Coefficients of digestion of food substances in feeds 18 and 19.

86. Average coefficients of digestion of mixtures 18 and 19.

87. Digestion of feeds 20 and 21.

88. Average coefficients of digestion of mixtures 20 and 21.

89. Fatness and live weight [in kg.] of experimental animals.

90. Quantity of dry matter and starch equivalents necessary to maintain live weight of reindeer [per 100 kg. live weight].

91. Comparison with other groups of animals [horse, sheep].

92. Two groups of reindeer [?].

93. Loss [use?] of productive fodder at work [per 100 kg. live weight].

94. Changes of live weight of reindeer by place[?].

95. Changes in the growth in live weight of reindeer by place [? in kg.].

96a. Changes in the growth in live weight of reindeer by place [in per cent].

96b. Change in live weight of reindeer according to age groups.

97. Changes [= differences?] in live weight of bucks in May and August.

98. Salt composition of lichens [in per cent].

99. [As 98 - different lichens?]

100. Quantity of the principal elements of salts consumed by reindeer per day while feeding exclusively on lichens.

101. Salt composition in per cent for absolutely dry matter.

102. Quantity of principal elements as salt consumed by reindeer while feeding exclusively on leaves of dwarf birch.

103. [Same as 102 for Eriophorum angustifolium].

104. Live weight of experimental and control animals while feeding on fish flour [= meal?].

105. Changes in live weight of experimental and control bucks feeding experimentally on common salt.

106. Changes in live weight of experimental and control animals feeding on salts from reindeer horns and on common salt.

According to the English summary, this report is the result of tests of digestibility of various feeds made on 50 animals. Lichens showed a high coefficient of digestibility of nitrogen-free extracts (71.1 per cent); cellular tissue (73.2 per cent), and raw fat (68.3 per cent). Nitrogenous substances and ash were poorly digested or not digested at all. The starch equivalent of lichen, depending on quality, varied from 10.74 to 16.71 kg. [Per 100 kg. of lichens?]. The low quantity of protein and ash in lichens, and their low digestibility, makes them a one-sided food on which reindeer suffer nitrogen and ash starvation. Green foodstuffs (tests were made with Betula nana, Salix lanta, Eriophorum angustifolium and mixed herbs consisting primarily of Polygonum bistorta) proved to be highly digestible, and all of them had high starch equivalents. Green foods, in contrast to lichens, contain a high percentage of protein and ash and provide an exceptional protein balance; they also improve the mineral metabolism.

At rest in stalls, reindeer were found to require 2.45 kg. of dry substances and 1.22 kg. of starch equivalents per 100 kg. live weight at -11° [probably Centigrade]; the requirements when working were found to be 4.5-4.8 kg. of dry substances, 1.80-1.94 kg. of starch equivalents, and 0.204 to 0.257 kg. of digestible albumen. [Additional

numerical data will be found in Section III.]

2. Aksenova, M. J. 1937b. [SOME DATA ON PHYSIOLOGY OF DIGESTION OF REINDEER.] Arctic Inst. U.S.S.R., Sov. Reindeer Indus., 11:7-30. Eng. sum. pp. 29-30. 13 tables, 28 refs. ACWRU.

Titles of tables are:

1. Weights of stomachs of new-born calves.
2. Weights of stomachs of calves one month old.
3. Growth of alimentary canal in relation to age of reindeer.
4. Weight and volume of reindeer stomachs at age of four to five months.
5. Weight and volume of stomachs of mature reindeer.
6. Characteristics of experimental animals.
7. Percentage of colored feed in dry matter in the paunch [see summary].
8. "Quantity of undigested remainders in feces of reindeer and sheep on different days" [in per cent].
9. Flow of secretion of the gland in the ear region [parotid?].
10. "Salivation during rumination and its absence."
11. "Salivation while keeping reindeer on free pasturing on lichen feed."
12. "Concentration of hydrogenous ions in the reindeer containing paunch."
13. Analysis of abomassum while reindeer is feeding on lichens.

The following is an abstract of the English summary.

New-born fawns have a poorly developed paunch which is not well adjusted to digestion of hard foods. During the first month of life rapid growth of the first three sections of the stomach was observed. After 2.5 weeks manifestations of rumination are observed. All milk taken by fawns 4.5 to 5 months of age goes directly into the abomasum.

The epaunch [?] of the adult reindeer has a capacity of 32 to 40 litres; all rough hard food and liquid food enters the paunch in adults.

Colored lichens fed to experimental animals first appeared in the abomasum after 3 to 4 hours and in excrement after 13 to 14 hours. Colored lichens remained in the digestive organs for 15 to 18 days, and in the paunch for 12 to 14 days. Feeding experiments should therefore be continued for at least 20 days.

Saliva represents a very significant and necessary element for the proper working of the paunch and second and third stomachs. By reason of its high alkalinity (pH 8.0 to 8.4) it neutralizes the contents of the paunch where the various fermenting processes are taking place. The continuous secretion of the abomassum glands depends on the flow of food to this organ from the paunch and second stomach. Salivatory discharge of the parotid gland decreases sharply at night and upon cessation of rumination, and is also influenced by age and fatness of the animals. When lichens are fed, the pH of the abomassum varies from 2.7 to 3.5.

3. Alexandrova, V. D. 1937. [WINTER FORAGE OF REINDEER IN NOVAIA ZEMLAIA.] Arct. Inst. U.S.S.R., Sov. Reindeer Indus., 9:127-139. Eng. sum. p. 139. ACWRU.

The summary mentions that reindeer paunches were collected, but gives no figures, only some general conclusions regarding snow cover and green feed in winter.

4. Alexandrova, W. D. [V.D.?] 1940. [FORAGE CHARACTERISTICS OF THE PLANTS IN THE FAR NORTH OF THE U.S.S.R.] Trans. Inst. Polar Agr., 11:1-96. 104 refs. ACWRU. (Original and transl. of selected species description.)

The bulk of this report consists of a summary of the forage characteristics of 396 species of plants found in northern U.S.S.R., including chemical analyses for most species. Numerical data for a few selected plant species will be found in the tables of Section III. An abstract of some of the more pertinent information from the above and from other sections of the report follows:

The most eaten and most important of the lichens, the Cladoniae, are the poorest in protein. The average protein content of eight species of Cladoniae was 2.62 per cent; the average raw protein content of five species of Cetrariae was 3.84 per cent, while Stereocaulon paschale contains a minimum of 7.5 per cent. In comparison, the best green forages of the reindeer contain considerably more raw protein; for example, Betula nana contains 18.77 per cent when the hygroscopic moisture is 7.97 per cent, and Menyanthes trifoliata, when the hygroscopic moisture is 7.55 per cent, was found to contain 13.34 per cent protein.

The cause of the"better edibility" of Cladoniae, in spite of the "extreme poverty of" their nitrogen compounds and in particular their albumen, is their low content of lichenous acid, the presence of which usually causes the bitter taste of lichens. These acids predominate in volatile extract (so-called "raw fat"). In Cladoniae, raw fat (average of nine species) amounts to 1.33 per cent; Cetrariae, not eaten quite as much, contain 3.54 per cent, while the little eaten Alectoria ochroleuca contains 10.19 per cent.

Carbohydrates in lichens are found mainly as hemicelluloses, among which lichenin often takes first place. The latter is closely related to starch and is found exclusively in lichens. It is found in large quantities in Alectoria ochroleuca (67.02 per cent) and in Cetraria cucullata (36.71 per cent), but in the Cladoniae there is very little.

Cellulose proper is found in lichens in insignificant amounts; from 0.83 per cent in Alectoria ochroleuca to 5.25 per cent in Cladonia rangiferina. Lichens are also "very poor" in ash; what amount there is contains a high percentage of SiO_2 (30 to 85 per cent) and thus is not readily assimilable. The sum of the basic elements in the ash considerably exceeds the acid ones.

Until recently it was thought that lichens were poor in vitamins. It has now been shown that Cetraria cucullata contains vitamin C and has a decidedly antiscorbutic action.

It has been shown by experiment that reindeer digest raw cellulose and nitrogen-free extracts well, but digest protein badly or not at all, and do not digest mineral

substances (ash). Raw fat showed a fairly high coefficient of digestibility.

[This paper contains a number of references dealing with digestibility of forages, etc., most of which could not be found by the writer. The paper is, essentially, a summary of the work of others.]

5. Andreev, V. N. 1934. [FEEDING BASE OF THE YAMAL REINDEER INDUSTRY.] U.S.S.R. Inst. Reindeer Indus.; Soviet Reindeer Indus., 1:99-159. Eng. sum. pp. 158-159 ACWRU (Eng. sum.).

Contents:

Sources serving as a ground [=basis?] for the [determination of?] characteristics of the feeding base.

General physical-geographical outline.

Vegetative formations.

Information on the edibility of different kinds of the Yamal flora.

Productivity of the vegetation cover.

Geobotanical regions.

General character of the Yamal Reindeer economy.

Grazing resources and their exploitation.

6. Anonymous. nd. SOME RESULTS IN THE FEEDING AND BREEDING OF REINDEER IN ALASKA. Unpubl. typed (carbon) ms. 5 pp.

This is a general discussion of pasture feeding, and a slightly more detailed discussion of the crossing of reindeer with caribou. The following is an abstract.

Introduced in 1892, now [probably about 1925] numbering more than one million, reindeer are raised solely as range animals. Progress has been made in recent years towards

scientific management of the herds. Improved methods have become necessary with increased numbers; the original old-world methods no longer suffice. Major studies aimed at improving the herds included experiments in feeding and breeding. It was found that reindeer may be handled much as other live-stock. They can be conditioned on cultivated foods. During the summer, they must be protected from insects, preferably by selection of a proper grazing site. Salting is desirable; the feedlot requirement is 5 lbs. per annum, the pasture requirement 4 lbs. Reindeer prefer shrubs in summer and lichens in winter, although they will feed on a great variety of items. They will gain weight in fall and early winter if held on mixed forage with a limited amount of lichens; feeding on lichens alone at this season will result in loss of weight.

Several types of hay and meals have been successfully fed to reindeer. Corn is highly palatable but too harsh for young stock; it may result in fatal derangement of the digestive tract. A mixed feed is preferable; too much of a single high protein feed may have bad results. A sudden change in feed is dangerous, and change from pasture to feedlot is best made at the change of seasons. A tapering off on lichens is advised for a few days prior to change, except in spring and fall; a week to ten days is required to establish a cultivated food diet. On hay and grain, 20 to 30 lbs. per 1000 lbs. live weight per day is required. Whole oats, crushed barley, and mixed chop [sic] feed are choice grains. Reindeer

do well on grains; they may gain as much as one pound per day on a suitable ration. One part digestible protein to five or six parts of other digestible nutrients appears desirable. Aside from improving weight, [supplementary] feeding has a marked physiological effect; shedding of winter coat, and onset of the rut, are advanced by as much as three weeks.

In selective breeding, selection of both sexes is important; the female impresses her color and conformation strongly on her offspring. White and spotted animals are inferior, and should be eliminated. Steel-gray animals are suitable for breeding: in general, the dark animals are superior in size. Selected inter-herd breeding is being promoted, and cross-breeding of reindeer and caribou is being studied. The average dressed weight of reindeer steers is 150 lbs., while the woodland caribou will frequently dress 300 lbs. On Nunivak Island, introduction of caribou is apparently increasing the size of animals in the reindeer herds. Adult crossbreds, weighed during the summer of 1931, averaged 50 lbs. heavier in live weight than pure reindeer stock; a few were 100 lbs. heavier. Male caribou are more aggressive, and are leaders in the Nunivak herd.

At College, [Alaska] cross fawns were born in May; the birth weight was 13 to 16 lbs., while birth weight of reindeer is usually 10 to 13 lbs. At two months of age, average weight of some reindeer fawns was 38.5 lbs.; caribou cross fawns averaged 62.6 lbs. at this time. Female reindeer bred between September 5 and September 16 and the caribou bred between

October 1 and October 4. A general average gestation period of 240 days is indicated for reindeer and caribou; reindeer took 210-255 days, caribou 224-240.

7. Anonymous. nd. "RE BURNED OVER RANGE, INT. ALASKA." A one-page penciled note listing square miles of burned range by area for 20 areas plus 6 reservations, as follows.

Area	sq. mi.	Reservation	acres
Kenai Peninsula	1,000	McKinley Park	1,939,493
Susitna	2,000	Glacier Bay	2,300,000
Matanuska	1,000	Katmai	2,000,000
Broad Pass	300	Semidi Is.	8,920
Nenana	1,000	Nunivak Is.	1,000,000
Fairbanks	2,000		
Goodpaster	1,000		
Big Delta	200		
Paxton Lake	1,000		
Upper Tanana	1,000		
Ruby	500		
Nulato	1,000		
Holy Cross	500		
Tuluksak	300		
Lake Clark	2,000		
Kvichuk	2,000		
McGrath	2,200		
Hiway & R.R.	1,000		
Woodbine	100		
Circle	200		

8. Anonymous. nd. "FEEDING TESTS." On U. S. Dept. Int., Fish and Wildlife Serv. stationery; 1 p. penciled note.

"17 trials muskox Av. % of feed utilized 84%

16 trials reindeer Av. % of feed utilized 57%

Muskox utilized 52% of the lichens

Reindeer utilized 37½% of the lichens."

9. Anonymous. 1946. REINDEER MANAGEMENT HANDBOOK, ALASKA. U. S. Dept. Int., Bur. Ind. Affairs. Semi-completed, typed unpublished copy. Approx. 75 pp.

Section headings--there is no table of contents--are:

I. The Reindeer.

II. The Range.

III. Forage and Feeding.

IV. Management of Herds.

V. Range Improvements.

VI. Management of Range.

VII. Produce of the Reindeer.

VIII. Diseases and Parasites.

IX. Predators.

X. Miscellaneous.

XI. Administration.

This report contains in general the information given in "Raising Reindeer in Alaska," "Progress of Reindeer Grazing Investigations in Alaska," "Reindeer in Alaska," and "Study of the Alaska Tundra with Reference to its Reactions to Reindeer and other Grazing," by Palmer. Some additional information is included:

A palatability scale is given for 28 species of plants. These range from lichens, mushrooms, and willows, with a

palatability percentage of 100, down through sedge at 75 per cent, grasses, birch, cranberry, and three other species at 50 per cent, and ten species with negligible palatability including Spiraea and aspen. Several poisonous plants are also listed, the most dangerous of which is Cicuta. [See Table 10, Section III for detailed palatability ratings.]

Grazing capacity figures are given as follows:

> Spring, summer, and early fall (April 15 to October 15)--.462 forage acres per month or 2.77 forage acres per season. 1.386 surface acres per month or 8.32 surface acres per season. (Forage factor in this case was .333) Late fall and winter (October 15 to April 15)--six months on lichen vegetation--1.27 forage acres per month x 50 years recovery (15.9) or 95.4 surface acres per season. (Forage factor .4) Total requirement 40.87 forage acres or approximately 104 surface acres per head per year, which will allow about six reindeer to the square mile. The summer requirement is approximately 1-1/2 times that for sheep and 6/10 that for cattle. The reindeer country comprises approximately 150,000 square miles. It is likely that part of the total area may be inaccessible or unsuitable to raising reindeer because of location, waste range or difficult terrain. A factor of twenty per cent of unavailable area is allowed for this. On this basis and the grazing capacity requirement indicated above, the reindeer country should eventually carry a maximum of 720,000 reindeer.

10. Avramchik, M. N. 1939a. [THE WINTER FEEDING OF REINDEER IN THE YAMAL NORTH] Trans. Inst. Pol. Agr., Ser. "The Reindeer Industry," 4:47-66. Eng. sum. pp. 65-66. 5 tables, 5 refs. ACWRU (Eng. sum.).

The following abstract is derived from the English summary.

Analyses were made of the rumen contents of nine reindeer killed for food, and 27 tests were made of the contents of the rumen of a steer in which a fistula was placed. The analyses showed that lichens composed 65 per cent of the

rumen contents, vascular plants 33 per cent, and mosses 2 per cent. All reindeer were kept on an experimental plot. It was found that the center of the fenced area was utilized more heavily than the borders, and that the areas, usually alongside rivulets, which had a combination of green plants and lichens were more heavily grazed than areas with a uniform lichen cover. Utilization was also considerably influenced by snow cover and other limitations to accessibility.

11. Avramchik, M. N. 1939b. [THE AFTER-GRASS OF SOME FORAGE PLANTS ON TUNDRA PASTURES.] Trans. Inst. Pol. Agr., 4:89-131. Eng. sum. pp. 129-131. 14 tables, 10 figures, 2 refs. ACWRU (Eng. sum.).

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

The following is an abstract of the English summary.

There were three objectives in this study:

1. To establish the ability of tundra forage plants to "grow the after-grass."

2. To determine the quantity of after-grass and the time at which it grows.

3. To determine the chemical composition of the after-grass and its palatability to reindeer.

Two different experiments were made; one to determine the growth after cutting in early summer (beginning of July) and the other to determine growth after cutting in the beginning

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

1. Green growth of grass-plants [i.e. grass-like plants ?] removed from moist hillock land at the beginning of July results in regrowth at the end of July or the beginning of August.

2. Removal of shrub foliage in the middle of July results in new growth at the beginning of August in the case of Salix; Betula nana does not put forth a significant amount of new growth.

3. Secondary growth of sedges removed at the beginning of August appears at the end of that month but does not attain ["normal"] height due to unfavorable weather. It grows to a height of 10-12 mm.

4. Regrowth of shrub foliage removed in late summer varies with the species and the amount of foliage removed. Betula nana does not put forth any new growth. Salix lanata puts forth a very few new buds and leaves when the foliage has been 100 per cent removed; when only 50 per cent of the primary growth is removed the regrowth is greater.

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

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

12. Banfield, A. W. F. 1951. THE BARREN-GROUND CARIBOU. (Canada) Dept. of Resources and Development, Ottawa. Mimeo., v + 56 pp. ACWRU.

This is a general survey containing little of interest on range or food habits. A list of six plants found to be preferred by caribou in the summer and eight "less often eaten," as determined from 14 stomach analyses is included. Mushrooms and lichens are the first two in the former class although nothing is said about whether the plants are listed in order of preference.

13. Banfield, A. W. F. 1954. PRELIMINARY INVESTIGATION OF THE BARREN GROUND CARIBOU. (Canada) Dept. of Northern Affairs and National Resources, National Parks Branch, Canadian Wildlife Service, Ottowa. Wildlife Management Bulletin, Series 1, No. 10, A & B. A, 79 pp., B, 112 pp. ACWRU.

Part A includes "Former and present distribution, migrations, and status." Part B is a study of life history, ecology, and utilization. The following abstract is confined to those parts of "B" pertaining to ranges, foods, and food habits.

Data on plant coverage in several representative vegetation types were obtained by means of systematic sampling with a Raunkiaer's circle. [This data appears in several tables; due to their length, they are not included here. The data

thus obtained were used to determine palatability when used in combination with analyses of stomach samples. Palatability scales thus obtained will be found in Table 10, Section III.]

On the white spruce of the taiga several arboreal lichens are found. Two of the more common species, Evernia prunastri and Alectoria jubata, are important sources of winter food for the caribou. Where caribou were known to spend the winter in the taiga, little evidence of utilization was noted other than of the arboreal lichens mentioned above and light browsing of willow and birch twigs. On the tundra, however, there were many areas showing heavy utilization; over large portions of the central tundra lichen growth is restricted by heavy caribou use. It was found that discarded antlers are avidly chewed during the winter months.

14. Blix, Gunnar, and Hakan Rydin. 1932. UBER DAS VORKOMMEN VON ERGOSTERIN UND D-VITAMIN IN DER RENNTIERFLECHTE. Upsala Lakareforen. Forhand. 37(5/6): 333-340. 1932. Abst. in Biol. Abst. #8, Jan. - May, 1934.

Ergosterol was identified as the main constituent of the sterol mixture extractable from Cladonia rangiferina. The ergosterol content in a series of common lichens was 0.03 to 0.11 per cent. Reindeer lichen collected in August in the region near Upsala contained only traces of Vitamin D.

15. Bogdanowskaya-Guiheneuf, I. D. 1938. [NATURAL CONDITIONS AND REINDEER PASTURES ON KOLGUEV ISLAND.] Trans. Inst. Pol. Agr., 2:7-161. Eng. sum. pp. 159-161. 28 tables, 2 pp. refs. ACWRU (Eng. sum. and transl. of table of contents and table titles).

This is a comprehensive study of all aspects of the 3,460

sq. km. island in northern Russia, including geological, geobotanical, and ecological factors as well as utilization of the island by reindeer. Tables include climatological data, chemical analyses of island flora, analyses of reindeer rumen contents, amount of forage found in various plant associations, grazing capacities, live weights of reindeer at various times of year, secondary florescense of plants after grazing, etc. The following is an abstract of the English summary.

In early spring Eriophorum vaginatum is the chief food plant of the reindeer, followed a little later by Carex aquatilis and other species of these two genera; Salix glauca is especially favored in the summer, and other species of willows and numerous herbs are heavily utilized. Lichens, sedges, grasses, and some "still green herbs" are utilized in the autumn. Flora on the island is abundant and varied; however, the lichen stock has been greatly diminished through grazing. Cladonia mitis is the predominant lichen. The lack of lichens together with the periodic crusting of the snow constitute the main hindrances to the development of reindeer breeding on the island.

16. Bonner, W. Nigel. 1958. THE INTRODUCED REINDEER OF SOUTH GEORGIA. Falkland Islands Dependencies Survey, Scientific Reports, No. 22. Published for the Colonial Office by Her Majesty's Stationery Office, 8 pp. 2 tables, 3 double plates, 1 ref. ACWRU.

This is a general survey, and includes discussions of: introduction and history of the deer; material and methods; terrain; general behavior; feeding habits; condition of the deer;

mortality; hunting (the reindeer live in a feral state); and future prospects. A brief abstract of the section on feeding habits follows.

The deer feed principally on phanerogamous plants, chiefly "tussac grass," and "are thus peculiar in being probably the only stock of feral reindeer whose staple diet is not lichens." Lichens make up a very small part of the vegetation. Numerous species are to be found but none occurs in sufficient quantity to be of any importance. When first introduced, the deer probably had the opportunity to make the change from lichens to grasses gradually.

In seven stomach samples analysed, mosses were found in all, as was Acaena tenera and the rush Rostkovia magellanica; Poa flabellata was found in five of the seven, Poa annua in four, a small amount of Phleum alpinum in two, and a similarly small amount of Deschampsia antarctica in one sample. Three analyses by a previous investigator included Poa flabellata and Festuca erecta; Acaena adscendens was found in all three. The latter is now very scarce in the area occupied by reindeer, and has probably been grazed off. Only minute fragments of lichens were identified in the latter group of three samples, none in the first group of seven.

17. Chatelain, Edward F. 1953. SUMMER FOOD HABITS NELCHINA CARIBOU HERD. Alaska Game Comm., U. S. Dept. Int., Fish and Wildlife Serv., Quart. Rept. 7 (4):4-6. Proj. W-3-R-7. ACWRU.

Results of analyses of 38 caribou stomach samples collected

during the Fall, 1952 hunting season are presented. [See Table 7, Section III for tabulated data.]

"It is interesting to note that the total browse species comprised 44% of the caribou [food] during this season. Apparently browse is a more important caribou food than lichens or grass during the fall." The author believed that the browse species present in small amounts were consumed accidently due to their association with other plants rather than being specifically sought (cranberry, crowberry, and Ledum).

18. Courtright, Alan M. 1957. MANAGEMENT STUDIES OF ALASKA CARIBOU. Work Plan No. (b). Alaska Coop. Wildl. Res. Unit, Quart. Progress Rept. 8(4):1-16.

The following is an abstract by the author.

The contents of five caribou rumen samples were separated into several groups according to size of plant particles. Analyses of each of these groups indicated that the proportion of lichens in each sample increased as the size of particles decreased, and a corresponding decrease in the proportion of other plant groups (grass-sedge, browse plants, and fungi) was noted. It was tentatively concluded that rumen analyses based on the larger, more recognizable plant particles only would in most cases show a smaller proportion of lichens than was actually present in the rumen as a whole. Results of analyses of 37 rumina from which only the larger plant particles were measured are also presented. [See Fig. 1, Section III.]

19. Courtright, Alan M. 1958. CARIBOU STOMACH ANALYSIS. Job Completion Reports, [former Quart. Rept. series] U. S. Fish and Wildlife Serv., Fed. Aid in Wildl. Rest.,Alaska. 12(3):107-108. Proj. W-3-R-12. Caribou Management Studies. Jobs 1a, b; 2a, b, c; 3a, b; 4a, b; 5; 7.

The following is the author's abstract:

It was found that analysis of only the larger plant particles in caribou rumina may lead to assigning a much lower value to lichens than would be the case if the smaller fragments were analysed as well. Lichens eaten in a moist condition may be an exception, being less frangible.

It was also found that protozoa may occupy a greater volume in the rumen than vegetable material; less than half of the stomach contents were retained by a screen of 200 meshes per inch, and over 90 per cent of the escaping material, as well as a large portion of that retained by screens of 80 to 200 meshes per inch, consisted of protozoa.

20. Cringan, A. T. 1956. SOME ASPECTS OF THE BIOLOGY OF CARIBOU AND A STUDY OF THE WOODLAND CARIBOU RANGE OF THE SLATE ISLANDS, LAKE SUPERIOR, ONTARIO. M.A. Thesis, Dept. Zool., Univ. of Toronto, Toronto, Ontario, Canada. x + 300 pp., 24 figs. Biblio. 21 pp.

A review of the paper follows:

Pages 1 - 53 pertain to caribou systematics; pages 54 - 167 to the history of woodland caribou. The remainder, pages 168 - 269, concerns the food habits and an account of a range study. Only the latter is of interest for purposes of this review. It might be mentioned, however, that all members of the genus Rangifer are believed by the author to be members of the species tarandus, and are divided into 21 subspecies. Cringan shows reductions in populations since

1900 and population fluctuations in all subspecies. Thirteen native and two introduced races have occurred in North America in recent times. In summary, the author states that 20 per cent or less of the primaeval population now exists.

Range analysis was done through the use of 495 plots set out at 10-chain intervals along lines 20 chains apart (paced). The following data were recorded: forest type, height, density, age, site, aspect, slope, moisture, browse, herbs, mosses and lichens. The Aldous winter browse analysis system was used for browse analysis on plots 1/100 of an acre in size. The author, for some reason, considers that only space between 2 and 10 ft. above ground held browse available to caribou in winter.

Occurrence and areal density of plants were noted. Where density was 10 per cent or greater, an estimate of degree of grazing was made. Six principal forest types of the Slate Islands are described.

A discussion of food habits of woodland caribou and factors governing production of foods begins on page 210. "Woody forage is not heavily utilized by woodland caribou ...." Utilization of both "reindeer moss" and tree lichens was found to be severe. Only one stomach was analysed; taken in March, 1949, it contained 80 per cent lichens. Stomach and contents weighed 12 lbs. 6 oz.; the entire animal weighed 267 lbs. Relations of "reindeer moss" and other lichen growth to various ecological factors is treated fairly extensively. Relative utilization of various forest types is given in a table. An extensive digest of (mostly general observation

type) food habits of North American caribou, (by subspecies) is given, and there is a seven and one-half page annotated list of known food plants of R. t. caribou and R. t. sylvestris.

"The vest explanation of steady populations of woodland caribou is that these depend primarily on tree lichens rather than ground lichens." The author points out that density of the former is more stable and explains why.

21. Dmitrochenko, A. P. 1935. [REINDEER FEEDING EXPERIMENTS ON LICHEN.] The U.S.S.R. Inst. of Reindeer Indus., The Sov. Reindeer Indus., 4:17-44. Eng. sum. p. 44. Many (unnumbered) tables. Leningrad. ACWRU (Original and transl. of main headings, titles of tables).

An abstract of the paper follows:

This paper consists of a report on an experiment with three female reindeer which took place between December 22, 1932, and April 29, 1933. Data includes: description of the fodder used; description of the animals and their behavior; consumption of lichens and change in consumption during the experiment; characteristics of the eaten and uneaten portions of the fodder; determinations of the digestibility of the various lichen components; the nitrogen balance; and the influence of lichens on the chloride exchange in the animals. The principal conclusions were:

1. Continuous feeding on lichens leads to a decrease in consumption. Consumption is also influenced by amount fed.

2. The weights of two of the three animals could not be maintained on lichens alone, although there was plenty of food.

3. Cellulose is highly digestible (coefficient of

digestibility 78.4), followed by carbohydrates (78.3). The coefficient for proteins is 21.9; fats are poorly digested. [In lichens?]

4. The maintenance requirements per 100 kg. of live weight in a condition of rest and at a temperature of about 8° C. is 2.3 kg. of dry matter, 1.1 kg. digested [= digestible?] carbohydrates and 50 gm. digested protein.

5. One kg. of the consumed wet lichen contained about 323 gm. of dry matter, 2.67 gm. of digested protein, and 250 gm. of digested carbohydrates.

6. Introduction of about 5 gm. of NaCl daily increased the quantity of organic matter digested.

22. Edwards, R. Y. 1952. FIRE AND THE DECLINE OF A MOUNTAIN CARIBOU HERD. Jour. Wildl. Mgmt., 18 (4):243-251. 5 refs.

The author attributes the decrease of British Columbia's Wells Gray mountain caribou herd on extensive fires since 1926.

". . . caribou . . . appear to require mature lowland forests for winter range..."

23. Ellis, N. R., L. J. Palmer, and G. L. Barnum. 1933. THE VITAMIN CONTENT OF LICHENS. Jour. Nutrition, 6 (5):443-454, 1933. Abst. in Biol. Abst. 8, June - Dec. 1934.

Feeding tests with rats failed to show presence of vitamins B or G in either of two samples of short and tall growth lichens obtained in Alaska. The short growth type contained more vitamin A and less vitamin D than the tall growth type. The short growth was the more palatable for rats--they gained in weight on these lichens but lost weight when fed the tall forms.

24. Florovskaya, E. F. 1939. [THE CHEMICAL COMPOSITION OF SNOW-COVERED REINDEER FOOD IN THE WINTER PASTURES OF THE SARANPAUL STATE REINDEER FARM.] Botanicheskii Zhurnal, 24(4):302-313. Eng. sum. p. 313 LCQKI.V713. ACWRU (Eng. sum.).

The following is an abstract of the English summary.

The following results were obtained as a result of chemical analyses of both brown and green plants collected from under the snow in 1936-37:

1. Snow-covered green sedges (Carex rostrata, Carex aquatilis) proved to be richer in protein and ash than brown ones, but contained less than green summer plants.

2. Brown plants (sedges, Calamagrostis, Equisetum) contained one-half to one-third as much raw protein (from 6.4 to 8.6 per cent on the average) as green summer plants.

3. Brown plants were found to contain considerable amounts (15.6 to 41.6 per cent) of cellulose.

4. Nitrogen-free extracts were present in considerable quantities in brown plants; 44 to 66 per cent in brown sedge, 45-68 per cent in Calamagrostis, and 63 per cent in brown Equisetum.

5. Both brown and green plants from under the snow were rich in ash, which had a high content of SiO_2.

6. Lichens were "poor" in raw protein, but did not show any significa differences from plants collected in the summer.

7. Lichens contained 78 to 93 per cent carbohydrates.

8. All the tested lichen samples showed an inconsiderable amount of cellulose with the exception of Umbilicaria in which it reached 7.06 per cent.

9. Lichens had a low ash content which contained up to 50 per cent SiO_2 in Cladonia, 91 per cent in Umbilicaria, but only 10.8 per cent in Bryopogon.

25. Glinka, D. M. 1939. [THE SEASONS OF REINDEER PASTURES AND SIGNIFICANCE OF GREEN FORAGE IN THE WINTER FEEDING OF REINDEER.] Trans. Inst. Pol. Agr., 4:31-46. Eng. sum. pp. 45-46. 1 table, 1 diagram, 5 refs. ACWRU (Eng. sum.).

The following is an abstract of the English summary.

The author divides the year into nine pasture seasons according to the state[?] and accessibility of the forage. The main green forage plants during the winter season are: Festuca ovina, Deschampsia flexuosa, Antennaria dioica, Ranunculus repens (shoots) and "a majority of Carex" with a few others.

"Festica [sic] ovina during the winter time being in green condition, conserves 65-70 per cent of summer green vegetation, Deschampsia flexuosa - 20 per cent, Antennaria dioica 100 per cent." [The author may be speaking of nutritional value, or may mean only that the given percentages of the plants remain green in the winter.]

The percentages vary according to habitat, but are constant for the winter period. The general decay of under-snow vegetation begins with the thawing of the snow cover. "The quantity of green vegetation is usually..." 20 to 30 kg. per hectare. Observation indicates that utilization of green plants during the winter contributes largely in maintaining the live weight and fatness of reindeer during that period. In late winter the live weight of reindeer begins to decrease,

". . because of impossibility to reach the green forage under the deep and dense snow cover." This decrease continues until the green plants begin to appear in the spring.

26. Gorodkov, B. N. 1936 [A STUDY OF THE GROWTH OF LICHENS.] Sov. Reindeer Indus., Arctic Inst. U.S.S.R., 8:87-116. ACWRU (Eng. sum.).

The English summary is here abstracted.

In order to estimate the number of reindeer a given territory can support, it is necessary to know the yearly growth of lichens. This is difficult, for the fodder lichens grow very slowly in height, rotting at the same time at the base. This slow growth of lichens is due to the fact that their activity does not continue long in any one year, being associated with their moistening only by fog, rain, and thawing snow. Lichens in dry air fall into an anabiotic condition and their growth ceases. When under moist condition lichens "conserve their power of grow ." even at low temperatures close to zero [probably °C.] thus enabling them to extend their vegetative period in spring and autumn.

Lichens are preeminently light-loving organisms; their external appearance and chemical composition, and consequently their yield and edible qualities, are different with different illumination. Growth in fodder lichens depends on apical and intercalary growth, the former ceasing with the development of fruit bodies. The non-reproductive podetia of the most important fodder lichens of the genus Cladonia possess the ability to grow continuously in height, dying off continuously at the base. For the latter reason, the height of the podetia of

Cladoniae can never exceed a certain insignificant height although they may be more than a century old. "Unfortunately the majority of age estimations of lichens refer to crustaceous and foliose forms having no importance as fodder."

27. Gul'chak, F. IA 1954. [NORTHERN REINDEER INDUSTRY] [or REINDEER FARMING IN THE NORTH] 206 pp. State publ. House of Agric. Lit., Moscow. LC-SF401.R4.G8 (Microfilm Slavic 452 AC). ACWRU (transl. table of contents).

Contents include everything from history through product technology to anatomy and physiology. Sections of possible interest here include "Study of reindeer pastures and methods of utilizing them," p. 64; "Effect of feeding and maintenance conditions on reindeer," p. 80.

28. Hadwen, Seymour, and Lawrence J. Palmer. 1922. REINDEER IN ALASKA. U. S. Dept. Agric. Bull. No. 1089. Wash. D. C. 74 pp. LC-SF401.R3H3.

Contents:

I. Biology of Reindeer.

II. Reindeer as Range Stock.

III. Grazing and Range Management. ("Available grazing area." "Range suitable for reindeer." "Forage." "Grazing." "Carrying capacity." Overgrazing.")

IV. Herd Management.

V. Handling the Herds.

VI. Predation.

VII. Injuries and Diseases.

VIII. Parasites.

The following abstract is of the section on grazing and range management.

Lands in Alaska available for reindeer grazing al into two divisions, the coastal areas and the interior areas. Along the coast, summer grazing is mainly near the sea, while in the interior it is on the windy mountain tops. Most of the present grazing is on the coast ranges; the interior ranges, not so accessible, still remain largely untouched. The main grazing is about four chief centers; Kotzebue Sound country, Seward Peninsula, Norton Sound, and the Kuskokwim River Basin. Expansion into the interior will depend primarily upon the availability and accessibility of suitable range sites. Areas where there are caribou are not necessarily good reindeer ranges. Judging from a very general preliminary survey there are probably between 150,000 and 200,000 square miles of open grazing lands available. This area is estimated to be capable of supporting between 3,000,000 and 4,000,000 reindeer. The estimate includes all potential ranges; on the islands, along the coast, and in the interior.

[A table giving a summary of principal forage types on both the coast and in the interior is given on page 25; this table is too lengthy to reproduce in an abstract, as is the complete list, pages 70-74 of the range forage plants observed and collected on the reindeer ranges in Alaska. Table 3 of the report details the plants grazed in summer in order of their importance (see Table 10, Section III).]

Reindeer raising is entirely a range proposition involving year-round grazing. On the coast the grazing periods run about as follows: spring or fawning period, April 10 to June 10; summer, June 10 to September 15; fall, September 15

to November 15; winter, November 15 to April 10.

What local overgrazing there is at present may be attributed mainly to the method of handling--close herding, holding on a relatively small piece of range year after year, and in some cases using the same range both summer and winter. Many of the natives remain, as formerly, fisherman and hunters. While there is an abundance of available range, little or no attention has been given to the matter of carrying capacity or to the fact that with an increase in numbers it is necessary to use more range. Holding the herd locally under close herding means localized mechanical injury to the range in addition to overgrazing. Overgrazing does not necessarily imply complete destruction of the vegetative cover; on most ranges there is at least a small growth of plants of which the reindeer will eat very little, and a range should not be grazed until the stock are reduced to feeding on forage of low palatability. Parasitism and overgrazing commonly go together, the degree of infestation often being in direct ratio to the extent of overgrazing. From the surveys thus far made it appears that the range requirement for each reindeer is about 30 acres annually. This closely approximates the acreage required by cattle in the western states. Some Norwegian figures give 25 to 28 acres a year.

[The rest of this publication is concerned with a more or less detailed account of such things as breaking sled reindeer, packing, riding, dermatitis and other diseases, and parasites.]

29. Hanson, Herbert C. 1952 IMPORTANCE AND DEVELOPMENT OF THE REINDEER INDUSTRY IN ALASKA. Jour. Range Mgmt. 5 (4):243-251

An excellent general review of history, present status, and prospects.

30. Hustich, Ilmari. 1951. THE LICHEN WOODLANDS IN LABRADOR AND THEIR IMPORTANCE AS WINTER PASTURES FOR DOMESTICATED REINDEER. Acta Geographica. 12(1):48pp. Helsinki--Helsingfors, 1951. Tilgmann. ACWRU.

Contents:

I. The Labrador Forests. [Classifications, descriptions, regions. covered.]

II. The Lichen Woodlands in Labrador. [As above, includes Table 1: "Vegetation cover on sample plots from lichen woodlands."]

III. Lichen Woodlands in Other Parts of the World.

IV. On the Ecology of Lichen Woodlands. [Snow cover. Description of lichen growths.]

V. Regeneration of the Reindeer Lichen. [Growth rates. Comparison of burned and grazed regeneration rates. Age determinations of lichens. Mostly reference.]

VI. Forest-economic Importanc of Lichen Woodlands. ["Unimportant except as grazing area."]

VII. Capacity of the Labrador Lichen Woodland as Winter Pasture for Reindeer. [Mostly based on references. Good section; compares estimates in Asia and Scandinavia.]

Appendix. The Nutritional Value of the Reindeer Lichen. [Includes tables III and IV, giving nutritional content of some lichen species (See Table 1, Section III].

The Labrador Peninsula is divided into three main forest regions-- [Forest-Tundra, Taiga (Open Boreal Woodland) and Southern Spruce (Main Boreal Forest Regions), and 3 main forest types--Dry forest, Moist forest, and Wet forest. [Apparently the latter are not subdivisions of one of the former but a different classification of the same area.] This paper deals with the conifer lichen and conifer dwarf shrub lichen forest of the taiga and forest tundra regions, which are grouped under the collective name"lichen woodland." Sixteen sample plots were placed, each being 100 square meters, or 1/40 of an acre, and the ground vegetation was analyzed by ocular estimate on a 6-foot square sample plot in each. The frequency scale was 3 = dominant, 2 = common, 1 = scattered, x = occasional individuals of a species. The most important vascular plants were; Empetrum hermaphroditum, Vaccinium vitis-idaea, Betula glandulosa, Ledum groenlandicum, and Vaccinium uliginosum. Twenty-one other species were recorded, with only six of these being recorded as "scattered" on any of the 16 plots. The maximum depth of the lichen cover was 18 cm., with Cladina [i.e., Cladonia] alpestris being the most important, followed by Cl. mitis, Cl. rangiferina, and Stereocaulon spp.; nine other species of ground lichens were recorded plus two species (and genera) of "beard" lichens. Twenty-one additional species of lichens occurred but were not tabulated [they presumably did not occur within the sample plots]. The lichen woodlands of Labrador are very similar to those in other parts of the world, with pine taking the place of spruce in the Scandinavian countries.

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

Moist lichens contain 60 to 70 per cent water, and air-dried lichens 10 to 15 per cent. Beard lichens occur in all forest types; the most common of these is Alectoria jubata. The beard lichens are of importance as emergency food for caribou and reindeer during winters when the ground lichen is covered by deep snow, or when there is a heavy crust. In lichen woodlands other lichen species (other than the Cladinae) are only occasional intruders, except Stereocaulon spp. Stereocaulon usually seems to stand melting water longer than Cladina; it is sometimes found in small depressions, where the snow-cover has melted late in the spring. Stereocaulon is frequently found on or near old trails through the lichen woodland. Because of this the old trails are visible long after the last traveller, man or caribou, has passed along them.

In very exposed areas the reindeer lichen gives way to hardier species such as Cetraria islandica and Alectoria ochroleuca. In barren patches in the lichen cover Cladonia coccifera and other species intrude. They seem to be mere temporary visitors only, present only when the lichen cover is undisturbed. The Opisteria (Nephroma) and Peltigera species appear to be the only ground lichens which are not touched by the reindeer. [Note: Peltigera shows more than three times the amount of protein than appears in any other species of lichen analyzed by Spencer and Krumboltz (1929).] Of these

species only Opisteria arctica is occasionally seen in lichen woodlands; the other species belong primarily to the spruce-heather-moss forest type. Recovery of ground lichens after collection is said to take about 80 years, while recovery after grazing taken from 3 to 40 years. The large differences are caused by the varying opinions held as to when a lichen cover can be considered as "recovered." According to some Finnish Lapps a lichen-cover height of 2-5 cm. is enough to allow new grazing on a lichen field. The recovery of a lichen field is slower after a fire; various references give figures ranging from 30 to 50 years. The regrowth of a lichen field is dependent on the capacity of prolonged growth of the lichen podetions [sic, consistently. Podetium = stalk]. Generally the lichen-cover is not completely destroyed after a fire: inside the lichen cover several podetions may preserve their growth capacity. The height reached by a reindeer lichen cover is primarily dependent on how little the habitat has been disturbed. The author has noted about 18 cm. as the maximum height. Others have reported 25 cm.; in such places the lichen cover must have been undistrubed by grazing or fires for at least 100 years. One authority gives as maximum heights for the podetions: Cladina alpestris 18 cm., Cl. mitis 10 cm., Cl. rangiferina 15 cm. The annual growth of the podetions is slow. In studies of the annual growth of Cladina in northern Sweden, one investigator noted: Cl.alpestris, 1 - 2 mm., maximum 4 mm.; Cl. silvatica 2-3 mm., maximum 5mm.; Cl. rangiferina 3-4 mm., maximum 6 mm. The annual growth of

Stereocaulon was 3-4 mm., but in certain cases 9 mm., which partly explains why it seemingly more easily invades new areas. Igoshina found that the forest lichens grow more rapidly than the tundra lichens; that 15 mm. of the upper part of the reindeer lichens represent the zone of the most intense growth; and "The age of [the] podetion is equal to the number of its nodes hence the average annual growth of podetion [s] could be counted by division of the height of podetion into the number of its nodes." In other studies of the annual growth of reindeer lichens, using large numbers of measurements (5,000), one authority noted that the growth of lichens varies according to height, i.e. their age: those from 15-25 mm. high grew almost 3 mm. annually, those 26-40 mm., 3.25mm. annually, 41-60 mm. high specimens grew 3.55 mm. annually, and those more than 60 mm. high grew more than 5 mm. per year. A 5 cm. high Cladina alpestris podetion was found to grow 4.7 mm. annually, and Cl. silvatica and Cl. rangiferina podetions of the same height grew 4.9 and 5.9 mm. annually, respectively. In the arctic tundra Cl. silvatica grows an average of 2.6 mm. annually, in the subarctic tundra 3.4 mm., in the hypoarctic taiga [= probably a sparsely wooded taiga] 4.1 mm., and in the sub-boreal northern taiga region 4.6 mm. annually. Judging from the present condition of the lichen pastures in northern Finland, it appears that three to seven years will not suffice to keep the winter pasture in good condition. A rotation period of 10 years seems, according to verbal communications from reindeer owners in Northern Finland, to be much more appropriate.

[Section VII is here copied in toto, except for the last five paragraphs.]

> The Cladina species are the main winter food of the reindeer. If the area covered by lichen woodland can be estimated, the approximate capacity of these areas as winter pastures could be ascertained--if the approximate fodder requirement of one reindeer for one winter are [sic] known.
>
> The lichen woodlands represent only a part of all the lichen-covered areas in the Labrador Peninsula. There are vast lichen-covered areas in the tundra region. However, the domesticated reindeer generally grazes in the woodland in winter. When estimating the number of reindeer which can feed in Labrador it is, therefore, safe to limit calculations to the forest-tundra or the forested region only. As mentioned in H 1949 [a previous work by Hustich] the approximate area of lichen woodland in Labrador is about 40,000 sq. miles, spread over a forest-tundra region which covers about 130,000 sq. miles and through the taiga region which covers about 280,000 sq. miles. Lakes and rivers take up a large percentage of this area. The interior plateau of Labrador is, as is probably less known, richer in lakes than perhaps any other part of North America.
>
> How much lichen does a reindeer eat in one winter? Some interesting studies have been made in northern Scandinavia and in Russia and Siberia. Soczava puts "the annual maximum requirements for 1 reindeer (what it will eat and trample) as 5 tons of normal humid lichens and 0.7 tons of green forage (counted as hay)" (1933, p. 113). Lynge (1921), a Norwegian lichenologist, states that the best localities give 1,400-1,500 kg. of lichen per 1,000 sq. mi., i.e. 14-15 tons per hectare. Lynge himself says that this is an absolute maximum value. A Russian estimation (Dedov 1933, p. 35) calculates for a 5-6 cm. high lichen cover a weight of about 2.5 tons per hectare: this is probably a good average value. Old mountain lichen heaths of Yamal give 5-7 tons lichen [sic] per hectare with a annual increase of about 400 kg.; poor lichen grounds give 1-1.5 tons per hectare (Igoshina 1938). In all cases probably normal humid lichen is implied, i.e. lichen as eaten by the reindeer in winter time. Now, using the values obtained above:

1. There are about 10.5 million hectares of lichen woodland (i.e. about 40,000 sq. miles) in Labrador,

2. The amount of lichen on one hectare is about 2.5 tons,

3. The reindeer eat about 5 tons of lichen annually,

4. The rotation period of lichen field should be about 10 years to keep it in good condition,

the following conclusion can be drawn:

Considering these facts and that the percentage of trampled lichen (useful the following winter) is roughly about the same as the percentage of non-lichen cover in the lichen woodland, the Labrador Peninsula has good winter pasturage for at least 0.5 million reindeer.

It is perhaps of interest to make an estimation based on the total area required by one reindeer according to previous reports in the literature.

An old Finnish government report (1905) assumes that 200 reindeer require an area of about one Swedish sq. mile, i.e. about 50 hectares per reindeer. In northern Finland there are about 5-10% lichen woodlands according to the last national forest survey.

Porsild estimated that in NW Canada on the arctic coast about 24 hectares (60 acres) are needed for one reindeer, but in the Great Bear Lake area the pastures are better, only some 16 hectares per reindeer. This estimation is in close agreement with some Russian calculations. The carrying capacity of a good winter range area, about 1 million hectares in Norilsk near Jenisej, is about 50,000 reindeer; an average of 20 hectares per reindeer. Gorodkov estimated that in the Russian Far Eastern Province the capacity was 5.5 million reindeer on 964,500 sq. mi., which makes an average of 18-19 hectares per reindeer. In the Far Eastern Province "the reindeer capacity is limited by the pasture territory of the summer use." Soczava concluded, on the other hand, that the "lichen forage will determine the limit of saturation by reindeer in the Yakutsk tundra."

He estimated that 389,000 sq. km. in Jakutia could carry only 700,000 reindeer, i.e. about 55 hectares per reindeer. Stefansson estimated once that Alaska could support 4 million reindeer (the whole area is 1.5 million sq. km.), i.e. about 38 hectares per reindeer. Considering the nature of Alaska this was a very optimistic estimate, as has been proved recently. If it is taken:

1. that the whole area of the Labrador forest-tundra and its region is 410,000 sq. miles and

2. that at least 75 hectares is needed in this area rich in lakes for one reindeer, about 1.5 million reindeer could be grazed in Labrador. However, the very conservative estimate on p. 41, based on the area of lichen woodlands, probably gives a better picture of the situation, considering also the present activities of the mining and lumber companies.

In these calculations no account has been taken of the potential area of summer pastures. As mentioned above, the area of suitable summer pasturage limits the reindeer industry in the Russian Far Eastern Province. It looks as if the winter pastures should be comparatively better than the summer pastures in many areas in the interior of Labrador. From this point of view the more cautious of the two estimations of the carrying capacity of the lichen woodlands is preferable.

The following is an abstract of the Appendix.

The species Cladina rangiferina is not, in spite of its name, the species preferred by reindeer. In northern Scandinavia Cl. alpestris is the common "reindeer moss;" Cl. alpestris is also the commonest species in the Labrador lichen woodland. Miss Laina Rasanen studied the chemistry of Cladina alpestris--the mineral percentage of this species is 0.8, the water content, when dried at 100-105° C., is 9.8 per cent, and the etherial oil content about 0.1 per cent. The nitrogen content, determined according to Kjeldahl's method, was 0.72 per cent, or about 3.7-4.5 per cent proteins.

The nutritional value of the lichens is dependent on their carbohydrate content. V. Rasanen analysed the nutritional value of some lichen species: Cladina, he found, contains about 5 per cent water (except alpestris, which has only about 0.7 per cent), 0.61 to 0.72 per cent nitrogen, about 4 per cent proteins, and 2.5 to 3.6 per cent minerals. Of the total nutrients Isaachsen and Ulvesli found that 34.6 per cent is dry matter, of which 34 per cent is organic matter, of which, again, 1 per cent is crude protein, 1 per cent is fat, 17.6 per cent is nitrogen-free extract, and 14.4 per cent is crude fibre, with ash, of course, then constituting the remaining 0.6 per cent of the dry matter. In other words, 98.3 per cent of the dry matter is organic, of which 2.9 per cent is crude protein, 2.8 per cent is fat, 50.9 per cent is nitrogen-free extract, and 41.7 per cent is crude fibre. The water content of Alectoria jubata was found by V. Rasanen to be almost twice that of Cladina, while the mineral content was about one-third that of the three Cladina species. The figures of Presthegge agree closely with the above; he also found that the digestibility of organic matter in lichen was 57 per cent the digestibility of protein matter was negative, and that the ash contained 0.08 per cent calcium and 0.02 per cent phosphorus.

31. Isaachsen, Haakon. 1910. [INVESTIGATIONS OF THE DIGESTIBILITY AND FOOD VALUE OF REINDEER MOSS.] Tidsskrift for det Norske Landbruk 17 (6):287-302. Oslo. LC-11.T433.

Used goats as experimental animals. Probably not of practical value in Rangifer investigations.

32. Igoshina, K. N. 1934. [BOTANICAL AND ECONOMICAL CHARACTERISTICS OF REINDEER PASTURES IN THE DISTRICT OF THE OBDORSK ZONAL STATION.] U.S.S.R. Inst. of Reindeer Indus., Sov. Reindeer Indus. Vol. 1. ACWRU (Eng. sum.).

Contents:

Geomorphological description of the explored district.

Types of the Obdorsk tundras.

General description of the grazing area in the district of the Obdorsk station.

The English summary consists primarily of a listing of 12 tundra types found in the region. These are:

1. The lichen tundras.
2. The rubbly dwarf shrub tundra.
3. Moss-lichen tundra.
4. Moss tundra.
5. Meadow tundra.
6. Valley meadows.
7. Dwarf birch shrubs.
8. Dwarf willow shrubs.
9. Alder groves.
10. Low-lying swamps.
11. Peat bogs.
12. Forests.

Each of the above is briefly described, and the percentage of the area which each covers is given. Also given are a few average vegetational yields per unit area: since these are mostly in general terms in the summary (i.e.; "0.5 tons to 1 hectare" for birch could include leaves, leaves and

twigs, the entire plant, or those parts judged palatable) they are not reproduced here.

Carrying capacties are given for four separate areas; these range from 3 to 16 reindeer per sq. km. depending on season and area. These figures would not be of value unless the main body of the text were translated to provide the necessary geobotanical detail.

3. Igoshina, K. N. 1937. [THE PASTURE FOODS AND FOOD SEASONS OF THE REINDEER-HUSBANDRY OF THE PRI-URAL DISTRICT.] Arctic Inst. U.S.S.R., Sov. Reindeer Indus. 10:125-195. Eng. Sum. pp. 194-195. 31 refs., 8 tables, many lists. ACWRU (Eng. sum.).

The English summary consists of 20 numbered paragraphs, each dealing with a different point. The most important of these paragraphs are reproduced here (with corrected English).

2. The food ration of the reindeer depends in the main on the composition of the plant species in the pastures. There are few inedible species in the tundra flora.

3. Lichens, which are eaten the year round but mainly in the winter, "are not of full value" due to the insufficiency of ash and albumen. Stereocaulon, with an albumen content of 5.4 to 9.5 per cent "has the most favorable chemistry of" the lichens.

4. There are some 160 species of vascular plants in the area, of which 110 species are readily eaten: 70 of these are widespread and constitute the main food. The vascular plants make up 50 per cent of the entire flora of the area.

5. Some 130 species of plants are eaten in the summer, 30 to 80 species in the autumn, 30 to 40 in the winter, and

60 to 70 in spring.

6. Sedge plants (Carex spp. and Eriophorum vaginatum) "are largely developed" [= widely distributed?] on the marshes and marshy tundras, occupying seven per cent of the pasture area in the plains regions. They are characterized by a high content of "albuminous nitrogene" (9.9 to 27.5 per cent) and sugars (about 16 per cent).

7. Grasses are widely distributed in the tundra and forest pastures. They contain somewhat less albumen than the sedges (9.3 to 17.7 per cent). The monocotyledonous plants (Carex spp., Eriophorum vaginatum and grasses) are of great importance as food the whole year round. In the summer the monoctyledonous plants in the rumen of the reindeer amount to one-third of the entire contents. In the northern summer pastures (without brush-wood) they form the principal food group.

8. The herbs [forbs?] amount to 15 per cent of the whole supply of green foodstuffs in the mountains and 4 per cent in the plain; there are at least 80 species in this group that are readily eaten. The herbs are eaten chiefly in the summer and autumn.

9. Shrubs are "largely developed" in the tundras adjoining the Ural; their leaves amount to one-third of the entire supply of greens foodstuffs in the pastures. The quantity of shrub foliage eaten during the summer is very great. In the summer the foliage of shrubs in the rumen of the reindeer amounts to one-third of the whole mass of green foodstuffs.

10. During the summer the "sallow willows" are the most important of the shrubs.

11. "The mosses found in the rumen of the reindeer get there either accidently in biting off the lichens or else as a substitute food eaten at a period of food-scantiness."

[The remainder of the English summary consists of a division of the year into seasons and further divisions on the basis of food available and utilized (on a rather broad basis). Two more paragraphs might be added.]

14. The chief food of the reindeer in winter camps are the ground and "partly epiphytic" lichens; ". . . of great importance also are the herbs under snow cover (green shoots of monocotyledons, mare's tails [Equisetum?] dry foliage of shrubs, and of tiny bushes.)"

16. During the spring season the lichens are still the staple food, "to which gradually are added herbages." The first spring herbs [to be utilized?] are Tofieldia borealis and Eriophorum vaginatum.

34. Igoshina, K. N. 1939. [THE GROWTH OF FORAGE LICHENS IN THE URAL NORTH.] Trans. Inst. of Pol. Agr., Ser. "The Reindeer Industry." 4:7-29. Eng. sum. pp. 28-29 ACWRU (Eng. sum. and transl. of titles of tables.)

The English summary in this paper is rather a poor translation, and for this reason one or two of the conclusions there presented are omitted from the following abstract of the summary.

This paper is a report of investigations of four species of Cladonia undertaken during 1932-34 in the Ural Mountains and the forest-tundra of the Yamal district. The species

investigated were Cl. rangiferina, Cl. silvatica, Cl. alpestris, and Cl. uncialis.

The lichens under study were marked with india ink every 3 mm. of their length. Seventy podetiums were examined after three and one-half years. Branchy Cladoniae were found to form one new branch and one new "node" each year. The upper 15 mm. of the plants were found to be the region of most intense growth.

Cladonia rangiferina was found to grow more rapidly than Cl. silvatica or Cl. uncialis. [The amount of difference in growth is given, but is confusingly translated: "Cladonia rangiferina is growing more rapidly than Cl. silvatica and Cl. uncialis on 0.7 - - 0.2 mm."] Lichens in the forest regions were found to grow more rapidly than those in the mountain tundra, and those at 64° N. Lat. more rapidly than those at 67° N. Lat. Branches grow more slowly than the stem of the podetium, and after five to seven years usually attain their "stable" length and stop growing.

The age of the podetium was found to be equal to the number of its nodes, and the average annual growth can therefore be determined by dividing the height of the podetium by the number of nodes.

[There is a discussion of methods of determining the annual mass increase of a lichen pasture, with some annual-increase figures for good, average, and poor pastures. This section is too confusingly translated to be of much value.]

It was found that the speed of growth of lichens changed after mechanical damage. Cutting only the tops allowed almost

a normal growth. Cutting of [to?] the middle part of the podetium gave rise to two types of new growth: either one of the side branches near the cut may grow, or on the cut surface new branches begin to form. In four years the branches grow 1 to 3 mm., and the shoots of branches 0.2 to 2 mm.; they are entirely formed in the third or fourth year after cutting. The lower parts of the podetium ("turf parts") show a rather weak recovery. Lichens destroyed by fire did not show any recovery after three to four years.

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

The paper includes the following tables.

1. Length changes of nodes [internodes?] with growth of Cladonia rangiferina in mm. in the Yamal forest tundra.

2. Annual growth of lichens [in mm.].

3. Summary of the growth of lichens according to various methods of calculation [in mm.].

4. Generalized data of lichen growth for practical use.

5. Lichen growth for a year in different conditions.

6. Composition of lichen sod in dry pine forests of varying growth in Berezovo District.

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

35. Igoshina, K. N., and E. F. Florovskaya. 1939. [UTILIZATION OF PASTURES AND PASTURAGE OF REINDEER IN THE SUBARCTIS URAL MOUNTAINS (of the State Reindeer Farm of Saranpaul)] Trans. Inst. Pol. Agr., Ser. "The Reindeer Industry." 8:5-163. Eng. sum. pp. 160-163. 79 tables, many charts, 12 refs. ACWRU.

The following is an abstract of the English summary.

The authors were commissioned to undertake a complete investigation of the ranges and the utilization of foods, an investigation which took over a year.

> "The contemporary condition of the ranges were studied: the pasture area, composition, value, and reserve of forage, habits of growth of lichens and time required for their recovery on a grazed lichen area. The phenology of summer green forage and its aftermath were studied, likewise the grazing regime of the reindeer, its requirements in a grazing area and [amount of?] pasture forage [and] the quantity of forage taken [in] grazing once on [a] given range."

Measurements were made of the daily and seasonal intake of a reindeer; the method used to determine this was to measure the parts of plants analogous to those eaten by the animals. It was found that one reindeer eats from 300 to 450 kg. of naturally cured herbaceous forage per day. On ranges with a lichen cover the animals spend from nine to ten hours a day grazing lichens, giving an intake of 5 to 6 kg. of naturally cured lichens per day. In the area under investigation, each animal uses up to 5 ares [1 are = 0.2471 acres] per day,". . . and the area trampled and cropped on the area of pawed holes in the snow is equal to 0.7-0.8 are per head in 24 hours."

On the area of trampling and cropping up to 30-45 per cent of the total reserve of lichen forage is depleted. "The recovery of Iceland moss [= Cetraria?] begins 3-4 years after

trampling and cropping, the speed of growth is 3-4 mm. a year or 50-60 km. of Iceland moss from 1 t [probably a metric ton] of its fundamental reserve."

[As can be seen from the quotations inserted in the foregoing abstract, the English summary tends to be rather confusing. It is probable that the "300-450 km." of naturally cured herbaceous vegetation is actually meant to be "3.0 to 4.5 kg." in view of the figures given later in the article. I assume that "km." is an abbreviation for kilogram, and that "t" is a metric ton. There are some other figures given in the English summary which would probably prove useful were they not so confusing. There is one further paragraph which is fairly clear and may be of some value.]

> The forest Iceland mosses in glens are not utilized for pasture owing to the presence of wild animals. The area of a range used by the reindeer on autumn ranges is 11.5 ares in 24 hours; the area of damage by grazing is 0.8-0.9 ares in 24 hours. The forage taken diurnally consists of about 5 km. of lichens and about 1 km. of grasses.

36. Kelsall, John P. 1957. CONTINUED BARREN-GROUND CARIBOU STUDIES. Wildl. Mgmt. Bull. Series 1(12):148 pp. Can. Dept. Northern Affairs and Nat. Resources, Nat. Parks Br., Can. Wildl. Serv., Ottawa.

This is a "general survey" on the same pattern as Banfield (1954); it also contains some specific information on plant densities and methods of range analysis. There is a brief mention of carrying capacity, based on the literature.

37. Kennedy, G. H. and Harry W. Titus. nd. A REPORT ON DIGESTIBILITY IN REINDEER: THE DIGESTIBILITY AND NUTRITIVE PROPERTIES OF A MIXED RATION OF LICHEN AND OATS, OF A RATION OF LICHENS ALONE, AND OF A RATION OF ALFALFA HAY ALONE. Typed (carbon) ms., 54 pp. report, 18 pp. of tables not included in report as

originally found but added in binding by AMC. The latter are apparently original tables from which the report was written; they give a day-by-day breakdown as contrasted to the totals given in the report itself. The report is in two parts; one dated 1929, the other dated 1932, although the "digestion test" headlings are numbered consecutively from 1 through 6 (1-3 in 1929, 4-6 in 1932). Apparently the 1932 papers are results of experiments with different animals and different feed ("peahay"). Not so detailed as the earlier papers, they seem to be concerned more with amounts of food and water and digestion of the ration as a whole rather than of the nutrient components.

An abstract of the report follows:

This experiment was undertaken primarily to determine the coefficients of digestibility of various feeds. The report is concerned with the results obtained from digestion trials between October 1 and December 1, 1929.

Data, presented mostly in tabular form, include [for two animals, idential data for each of three feeds]: initial weights of animals, losses or gains during the experiment, [per day and per 1,000 lb. live wt. per day]: feed consumed [in lbs.]; weight of feed presented but not consumed: weights of fresh and air dried feces: chemical composition of the feeds [moisture, ash, true protein, non-protein; crude fiber, ether extract, NFE, total nitrogen, crude protein] and residues; chemical analyses of feces; per cent of nutrient components digested; nitrogen in urine (weight and per cent); weights of urine and feces; nitrogen balances.

The reindeer in the experiments gained weight when receiving 10 lbs. of alfalfa hay per day, lost weight on a ration of 9 lbs. of lichens plus 4 lbs. of oats as well as on ration of 12 to 18 lbs. of lichens alone. Approximately the same percentages of organic matter were digested in all

three rations. The digestibility of the nitrogen-free extract was also about the same for all rations. Crude fiber was less readily digested from the alfalfa hay than from the other two rations.

"The data presented on the change in composition of moist feces over a period of time are not sufficiently conclusive to warrant any remarks."

[The author does not mention that there was a wide gap between the figures on digestibility of some of the nutrients for the two animals. Especially notable for their disparity were the figures for ash, total nitrogen and "true" protein. The figures for some of the other nutrients were remarkably similar.

There was also, if figures are any criterion, either a difference in tastes between the two animals or a difference in ability to adjust to a new ration: one animal did not consistently eat more than the other; it varied with the ration. When fed alfalfa hay alone, the weight of food consumed per 1,000lbs. live weight per day was smaller than when lichens alone were fed. When fed alfalfa hay, the consumption was little more than half the consumption of the other feeds; yet the animals gained weight only on alfalfa. When fed on lichens alone, the animals ate an average of about 18 lbs. air dry weight per 1,000 lbs. live weight per day. It should be noted that the test was made for about 8 days on each ration.]

38. Klein, David R. 1958. SAINT MATTHEW ISLAND REINDEER-RANGE STUDY. U.S. FISH & Wildlife Serv., Fed. Aid in Wildl. Rest., Alaska. Job Completion Rpts. (Former Quart. Rept. Series), 12(2a): 1-39. Proj. W-3-R-12, Caribou Mgt. Studies. Work Plan B, Job No. 8. ACWRU.

Summer forage conditions appeared adequate for the existing herd. The winter range, a dry tundra of lichens, willows and sedges, showed serious over-utilization. Lichens have been almost completely eliminated on much of the winter range, while willows and sedges have increased their surface coverage and now support more of the winter utilization. Vegetation was studied and recorded through the use of line transects and meter square quadrats. Permanent range enclosures were constructed to serve as ungrazed control plots. [From paragraph two of the author's abstract.]

39. Kursanov, A. L., and N. N. D'yachkov. 1945. [LICHENS AND THEIR PRACTICAL UTILIZATION.] Acad. Sci. U.S.S.R., Arctic Bot. Gard. & Inst. Biochem. 56 pp.

Copy not seen. Quoted in Llano (1956).

40. Larin, I. V. (Ed.) et al 1937. [FORAGE PLANTS OF THE MEADOW AND PASTURE LANDS OF THE U.S.S.R.] U.S.S.R. Commissariat of Agric., All-Union Inst. of Forage Plants. Publ. House of the Lenin Acad. of Agric. Sci., Leningrad. 994 pp. Eng. sum. pp. 861-875. 157 tables, 840 plates, 316 refs. LC-SB193.L2. ACWRU (original and transl. of section "Lichens" pp. 82-111.)

The first 15 pages of this book are devoted to a history of the study of forage plants in the U.S.S.R. and seven pages to a collective study of plant groups and their characteristics. The remainder of the book is devoted to studies of individual families, genera, and species. A total of 2,839 species is entered, with varying degrees of discussion--ranging from a mere entry to listing of distribution, palatability, chemical analysis, feasibility of attempting cultivation, types of animals by which it is utilized, and general ecology. In many cases, families are grouped according to similarity

of habitat or other similarities (e.g. Fungi and Musci are treated in one section, Juncaceae and Liliaceae in another) for discussion; other families are treated alone. The following is an abstract of the section entitled "Lichenes," written by V. S. Govorukhin and T. A. Rabotnoff.

Lichens are a singular group of lower spore plants and are complex symbiotic organisms. Ascomycetes for the most part, they contain microscopic chlorophyll-bearing algae (mainly blue-green and green); captured by the fungi, the algae are vital for its existance, being, among other things, essential for fruiting. The symbiotic relations of the two components are far from equivalent; the rate of propagation of the algae is considerably lessened, and in contrast to the fungal element of the lichen the algae can live independently.

Lichens may reproduce by means of soredia, spores, or growth of broken-off fragments. Sporogenesis, which takes place only in the fungi, is less effective than the other two methods since the spores do not contain algal cells and must obtain them from their surroundings.

Lichens are divided into three groups according to the nature of their development.

1. Crust lichens, whose body (thallus) is an incrustation of smooth or uneven surface (granular or nodular) adhering closely to the substratum; in some species the thallus is completely in the substratum and only the apothecia appears outside. These are the most widely distributed lichens, and about 80 per cent of all lichen species belong to this group.

2. Papery lichens who thallus has a lamellar or plate-like form adhering to the substratum by means of so-called rhizoids (fascicles of fungous hypha). Species of the genera Peltigera and Parmelia are common representatives of this group.

3. Stalked lichens; the most highly developed group, their thalli have the form of a bush consisting of simple or branching "podetia." The thalli bear fructose organs and are attached to the substratum by their own bases. This comparatively greatly differentiated group can be subdivided into the following forms:

a. Bushy (branching type) exemplified by Cladonia silvatica, Stereocaulon, Alectoria, etc.

b. Tubular (non-branching type) such as Cladonia cornuta, Cl. gracilis, etc.

c. Funnel-like or goblet-shaped, exemplified by Cladonia coccifera.

d. Beard Lichens, the hanging epiphytes such as Usnea, Bryopogon, etc.

The above divisions are far from complete and are not accepted in scientific systematics: moreover, the same genera and even species (e.g. Cetraria) may in some conditions appear in more than one group. However, division by growth form is significant when studying forage groups of reindeer pastures.

About 15,000 species of lichens are known at present. The majority are inhabitants of the temperate and cold regions; as a group, however, they are noted for their cosmopolitanism.

The stalked lichens, which are the most materially interesting as forage plants, appear in greatest numbers in the limits of the tundra, forest-tundra, and the northern sector of the forest zone. They are seldom found in abundance in the south, being well developed only on poor acid sandy soils. They appear in varied ecological conditions, but grow luxuriously only in those places where they are not overwhelmed by stronger rivalry from higher plants, especially mosses and grasses.

Features of considerable similarity are observed in many lichens in regard to individual ecological factors. Thus, most lichens are sensitive to light to a significant degree; for the most part photophilous, they form a solid ground cover either in treeless spaces of plains or upland tundras or in depleted forests. According to Andreev, the least shade-tolerant is Alectoria; the Cladoniae, especially Cl. rangiferina, are most tolerant of shade. However, there are species which are even more shade-tolerant, such as the beard epiphytes Usnea and Bryopogon which grow in the dark northern coniferous forests. Most lichens are also similar in being extremely sensitive to air polution; they are rarely found, or found only in an oppressed state, near large cities. Stalked lichens grow best in dry or moderately moist substrata, chiefly sand or sandy loam. There are many exceptions to this, however: Cladonia rangiferina attains a length of 1.5 to 2.5 cm. in dry sandy soils and in peat bogs of humid forests it attains a height of almost 40 cm. Generally, lichens are more demanding in regard to moisture than in regard to chemical affinity of soils, since on the whole the soil is a place of

attachment and nourishment is mainly a concern of the algal component; however, most stalked lichens attain really luxuriant growth only in clearly acid substrata. Thus, according to T. A. Rabotnov, in southern Yakutia the most valuable and most nourishing lichens grow most often and best in substrata having a pH of about 4.0 (Cladonia alpestris, mitis, amaurocraea, uncialis, and rangiferina) while a smaller number of less useful species grow in less acid substrata (Cladonia gracilescens, Cetraria delisei, Stereocaulon, etc.).

Although stalked lichens, generally speaking, exhibit considerable tolerance to sever cold, many of the more important species require a snow cover to protect them against freezing, wild corrosion, and excessive evaporation. Lichens having a well-developed crust layer, such as Alectoria ochroleuca and A. divergens are adapted to growing in relatively snow-free areas, while A. nigricans, Cetraria nivalis, and C. cucullata are so adapted to a lesser degree. The most useful species (Cladonia rangiferina, Cl. silvatica, Cl. alpestris) as well as the little utilized Cetraria delisei and Stereocaulon paschale have no crust layer and usually require a heavy snow cover.

Under favorable conditions, lichen form a compact ground cover and substantially influence the lives of other plants living together with them. More often they are found in a mixture with mosses. In forests and brush areas, lichens are often found growing in the best lighted places while the mosses occupy the space under trees and other shaded areas. The most luxurious lichen cover is found in the forest-tundra and the

northern part of the forest zones, especially in regions with a mild, humid climate. Although lichens occupy considerable area in the tundra zone (according to V. N. Andreev they occupy 9 per cent of the general area of the tundra) their development there is less luxurious than in the forest-tundra and forest zones. On an average, the supply of lichens in tundra areas amounts to 35 to 40 centners [1 centner = 50 kg. or 110.23 lbs.] per hectare, with the lichens growing to a height of 5-8 cm.; in forest regions, the supply varies from 40 to 60 centners per hectare and may in some places reach 10 to 16 tons. Height of the lichen cover in the latter areas varies from 8 to 15 cm.; there is evidence that Cladonia rangiferina can grow to a height of 70 cm. Differences in supplies of lichens in different types of pastures are not caused solely by differences in natural conditions, of course, but depend also on the amount of utilization.

More important than the amount available is the amount produced annually. Only very recently has any study been made of this problem. In 1921 T. A. Tengvall, as the result of many years of experiments, established that in stalked lichens (he worked in Lapland with Cladonia rangiferina, Cl. silvatica, Cl. alpestris, Cl. uncialis, and Stereocaulon paschale) the rate of growth invariably decreased as the plant reached the limit of growth for that species, and that most rapid growth took place in the early years of the plant's life. Stereocaulon paschale, a pioneer species, was found to have the most rapid growth, attaining 60 mm. over a period of 15 years. The Cladoniae, on the other hand, attained this

height only after 30 to 45 years of growth. According to V. S. Govorukhin the greatest amount of growth takes place in the fall, very little in the summer dry period; considerable growth was also found to take place under the snow in winter, especially toward the end of this season. B. N. Gorodkov, based on studies by Krabbe, Palmer, and Tengvall, gives the following figures as the average growth of common stalked lichens: for the forest zone 4 to 6 mm. in the summer; 2 to 3 mm. for treeless subzones of the tundra; 1 to 2 mm. for subzones of the Arctic tundras. Growth of the lichens is apparently greater in maritime regions of the forest-tundra (Kola Peninsula, the Far East) than in the continental forest-tundra.

More important than linear growth is the question of the annual growth expressed in terms of weight. M. K. Baryshnikov made the first studies in this area, and his results were later confirmed by V. S. Govorukhin. Baryshnikov's observations in the Surgut region of Omsk Province showed that the older the pine forests were the less mass growth of lichens there was in them; in a sampled 15-year-old forest about 469 kg. of dry lichens were obtained from one hectare; 289 kg. were obtained in a 30-year-old forest and only 173 kg. in a 40-year-old forest.

Lichens in an unbroken cover undoubtedly affect growth of other plants in the vicinity. They have a high hygroscopicity, the capacity to absorb the moisture of rains, dew and fog, and subsequently dry out again very quickly. According to

Porter and Woolet, the lichen cover absorbs a quantity of moisture 4.5 times its own weight. Experiments by Jack showed that precipitation of 0.3 cm. was completely retained by Cladonia rangiferina. Thus a considerable quantity of atmospheric moisture falling during the summer never reaches the soil. It has been found that soils under lichen cover are relatively dry during wet periods, but conversely are more moist than surrounding soils during dry spells. Luxuriously developed lichen covers oppress grassy and bushy vegetation. According to Allen's observations, in North America one finds among compact lichen growths only the rhizomes of higher plants or plants whose seeds are distributed by rodents. His experiments also showed that plant seeds falling on lichen cover did not germinate completely due to inadequate and often variable moisture. He also describes the death of seed sprouts whose cotyledons were found in the lichen cover; following heavy dew formation or rains the sizes of the lichens increased, which pulled sprouts out of the soil.

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

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

Grazing is a most important factor in determining the type and extent of lichen growth. Moderate grazing exerts only a favorable influence on the development of lichens and undoubtedly increased the value of pastures. If growth is undisturbed a layer of dead lichens appears under the living cover, forming a so-called white peat. This peat, sheltered by the living lichens above so that it is prevented from drying out, is usually constantly moist and forms a substrata suitable for sphagnum mosses which, settling in these conditions, begin to crowd out the lichens. Such overgrown lichen is little eaten by reindeer due to the unpleasant odor and taste caused by the decaying lower parts of the plants. Andreev's experiments have showed that moderate grazing provides increased growth, and broken parts of grazed plants also lead to occupation of

new areas. Effects of grazing will, of course, vary with conditions; also, different species react in different ways. According to Andreev Cladonia rangiferina is the most sensitive to grazing, followed by Cl. alpestris and Cl. silvatica; Cetraria nivalis, C. cucullata and Sphaerophorus globosus are less sensitive.

V. B. Sochav distinguishes the following stages of grazing intensity according to effects on the vegetation.

1. First stage - - moderate grazing, when only the wholeness of the lichen cover is broken (normal intensity).

2. Second stage - - more intense grazing; Cladonia abundance is decreased, members of this genus being replaced by Cetraria nivalis, Stereocaulon paschale, etc. A rest period of several years is necessary to restore the former cover.

3. The third stage is characterized by a complete disappearance of stalked Cladoniae, the presence of only certain Cetrariae, the increase of green mosses (mainly Polytrichum and Dicranum) and the development of a grass cover (Festuca, Calamagrostis, Arctagrostis, etc.).

4. The fourth stage is characterized by the complete disappearance of lichens. They are restored only with much difficulty. After being wiped out, Stereocaulon, Cladonia coccifera, Cl. bellidiflora and a few other species are the first to appear in recolonization.

There are several features in the chemical composition of lichens which distinguish them from other groups of plants.

1. Presence of special lichen acids.

2. Presence of a specific carbohydrate - - lichenin.

3. A usual paucity of nitrogen compounds and ash.

There are published materials on the chemistry of lichens, but at present they are not very extensive. Specimens for analysis have frequently been gathered from different places without indication of time of collection: results are sometimes contradictory and often give rise to doubts as to their reliability. [See Table 1, Section III for data which were published in this volume as being reliable]. From those sources which are considered reliable, it is clear that the majority of lichens are characterized by a low raw protein content. Thus, for the most widely distributed and most useful Cladoniae the average raw protein content varies from two to three per cent, with variations from 1.56 to 3.82 per cent; the arithmetic mean from eight analyses is 2.85 per cent. The protein content is somewhat higher in Cetrariae; an average of about three per cent with variations from 1.88 per cent to 8.3 per cent. Bryopogan jubatum, Parmelia saxatilis, and P. encausta have been found to contain quite large amounts of raw protein (6.3-7.3 per cent) while Stereocaulon contains 7.5 to 10.9 per cent. It should be noted that Stereocaulon paschale, in contrast to the more economically useful Cladoniae, apparently grows well in less acid soils and reacts favorably to manure fertilizer.

As has been noted before, special lichen acids are typical of lichens. These acids are identified [included?] under the name of "raw fat" in the usual agricultural analysis.

In all, about 150 lichen acids are known; the most frequently occurring, however, are usninic and salicylic acids. The amount of raw fat in lichens varies considerably, from 0.27 per cent to 17.35 per cent; it may exceed 20 per cent in some species. In general, the more edible species of lichens are distinguished by a low content of this substance (usually 1.4 to 1.9 per cent in the easily digestible Cladonia alpestris, Cl. rangiferina, and Cl. silvatica, while many of the "poorly edible" or inedible species (Alectoria ochroleuca, Parmelia saxatilis) have significantly larger amounts; slightly more than 10 per cent for the former and over 17 per cent in the latter. The intermediately palatable Cetrariae are also intermediate in their content of raw fat -- 2.45 to 6.35 per cent. Lichen acids are bitter, and their relatively high content in certain species of lichens is one of the causes of poor palatability or unpalatability.

There is considerable disagreement among various authors concerning the amounts of cellulose, the carbohydrates lichenin and isolichenin, and starch in lichens: in many cases the dissimilarity of data can probably be explained by differences in method. In general it is probably true that the Cetrariae contain smaller amounts of cellulose (average of five analyses was 12.75 per cent) than the Cladoniae (average of seven analyses was 39.8 per cent).

When forced to feed exclusively on lichens for eight or nine months the body of a reindeer undergoes great changes in chemical composition. Lichen forage is far from a rich

food. Their deficiency in proteins, nitrogen, and ash is aggravated by the fact that nitrogen compounds of lichens have a very low coefficient of digestibility [See Table 9, Section III for digestibility of various chemical components of lichens]. Symptoms of nitrogen and ash starvation have been observed in reindeer toward the end of winter.

Judging from A. P. Dmitrochenko's experiments with reindeer, cellulose and nitrogen-free extracts from lichens possess a high coefficient of digestibility (78 per cent), while experiments by other investigators with rams and swine have shown a considerably lower, even a negative, coefficient of digestibility for these substances. Apparently reindeer are more efficient in digesting both cellulose and nitrogen-free extracts.

Many factors, still unexplained in the majority of cases, influence the consumption of lichens. Species heavily utilized in one area may be of only secondary importance in other areas; for instance, V. S. Govorukhin's observations indicate that Stereocaulon paschale is little utilized in the Ob'-Tazov tundra and on the Yamal Peninsula, while the same species of Stereocaulon is considered almost the most useful of all stalked lichens in the Northern Ural region. It has also been found that while in some regions lichens are mainly a winter food--the animals feeding mainly on shrubs and grasses in the summer--in other areas a considerable quantity of lichens is eaten throughout the year.

In evaluating the forage value of a lichen area a number

of factors must be taken into consideration. Accessibility, climatic conditions, age of the lichen growth, the degree to which the lichens are likely to be damaged by trampling, the presence of objectionable plants (e.g., the presence of Ledum palustre has been found to impart a special scent to lichens, rendering them unpalatable) and other factors all play an important part in the value of a pasture; the quantity and quality of the lichen forage are not the only factors which must be taken into consideration.

[The remainder of this chapter is devoted to discussions of some of the more important or prevalent families, genera and species of lichens; there is a "thumb-nail" sketch of some 100 species.]

41. Larin, I. V. (ed.). 1950. [FORAGE PLANTS OF THE MEADOW AND PASTURE LANDS OF THE U.S.S.R.] V. R. Williams All-Union Research Institute of Forage Plants. State Agricultural Pub. House, Moscow. Vol. I. (Intro., Algae-Orchidaceae). 688 pp. ACWRU. [See 43, below].

42. Larin, I. V. 1951. Ibid., Vol. 2. (Chloranhaceae--Leguminosae). 948 pp. ACWRU. [See 43, below].

43. Larin, I. V. 1956. Ibid., Vol. 3. (Geraniaceae--Compositae). 880 pp. ACWRU.

The three volumes above, with a total of over 2,500 pages, constitute a revised and expanded version of the 1937 work of the same title. Each plant family is treated separately in contrast to the grouping of like families in the earlier version. An English summary to all three volumes is given in Vol. 3, and a table of contents for all three likewise appears here. There is no English in the first two volumes, and there are far fewer tables in English than appeared in

the 1937 work. According to the editor (personal communication), Vol. 1 is now out of print.

44. Leopold, A. Starker, and F. Fraser Darline. 1953. WILDLIFE IN ALASKA. (An Ecological Reconnaissance). ix + 129 pp. New York: The Ronald Press Co. LC (card no.) 53-12201. ACWRU.

Contains a general review of the status of caribou (pp. 47-67) and the reindeer (pp. 68-82) in Alaska. Population declines of caribou are attributed variously to hunting, range depletion through grazing, and fires, depending on the area involved.

45. Llano, George A. 1956. UTILIZATION OF LICHENS IN THE ARCTIC AND SUB-ARCTIC. Econ. Bot. 10(4):367-392. 2 pp. refs. ACWRU. Abstracted in Biol. Abst. 32(6).

This is an excellent, although in parts somewhat generalized, review of lichens and their role as food for the genus Rangifer. The text is divided into sections on:

Utilization and related factors

General character of range lands

Morphology and reproduction of lichens

Growth and ecesis

Composition and interspersion of lichens

Lichen components and biochemistry

Other economic uses of lichens

Conclusions

For the most part, the paper is a review of work by other investigators. The author is somewhat uncritical in places in his choice of statements as is illustrated by the statement that "Lichens and snow are the primary sources of food and water for reindeer, caribou and muskox during the long critical

winter period; it appears, then, that lichens may provide these animals with their vitamin and mineral needs." When writing about his own field of lichenology, however, the author presents some important information, as for instance the quotations pertaining to chemistry as follows:

> The important foodstuff that composes the greater part of the thallus is held as reserve carbohydrates, cellulose-like polysaccharides of the hexose type sometimes described as polyglucides, of which lichenin is the most prevalent form. Isolichenin, a starch-like polysaccharide, occurs along with lichenin and differs from it only in being soluble in cold water, in staining blue with iodine, and in yielding maltose in enzymatic hydrolysis. Cellulose is less common in lichens, but in the Cladoniae it amounts to from six to ten per cent of the dry weight of the plant. . . Simple reducing sugars are rare in lichens . . . Through the action of aerobic and anaerobic bacteria primarily and not of enzymes, the polyglucides are hydrolized into simple sugars.

46. Lubinsky, G. 1958. OPHRYOSCOLECIDAE (CILIATA: ENTODINIOMORPHIDA) OF REINDEER (RANGIFER TARANDUS L.) FROM THE CANADIAN ARCTIC. I. ENTODINIINAE. Can. Jour. Zool. 36:819-835. 16 refs. ACWRU.

This paper, the first of a series recording findings from the rumen contents of 14 reindeer from the Canadian Arctic, redescribes 10 species of the protozoan Entodinium. A key to the species of Entodinium of reindeer is presented. The rumina were collected in December 1955 and December 1956. The food of most species described consists of bacteria, yeasts, and plant debris.

47. Lutz, H. J. 1956. ECOLOGICAL EFFECTS OF FOREST FIRES IN THE INTERIOR OF ALASKA. U.S. Dept. Agric., Tech. Bull. 1133. II + 121 pp. Wash. D. C. ACWRU.

A summary of the author's two page discussion of fires and caribou follows.

The effects of fires on caribou are generally agreed to be harmful or even disastrous. This animal normally lives in environments characterized by climax communities, tundra and forest-tundra transition. Fruticose lichens of the Cladonia group, together with certain beard lichens (such as species of Usnea and Alectoria) growing on trees, form the principal winter food for the caribou. These lichens are highly flammable when dry and readily susceptible to destruction by fire. Recovery is excessively slow. The length of time required for full recovery varies with the extent and intensity of the fires and site and microclimatic conditions, but an average of 40 to 50 years appears to be a conservative estimate.

48. Manweiler, John. 1938. WOODLAND CARIBOU STUDY IN NORTHERN MINNESOTA. Parks and Recreation, 22(2):74-78. Rockford, Ill. DA-98.8P23.

[The following notes were taken by Dr. John L. Buckley, former Leader of the Alaska Cooperative Wildlife Research Unit, who had access to this paper]: This is a history of the Minnesota caribou herd and the result of an intensive study with two to seven men on a 200 square mile area. The caribou were found to move from one-half to three-fourths of a mile per day, and used black spruce swamps as "yards" in winter. A list of the food preferences of the animals for March and April:

1. Cladonia rangiferina
2. Cl. uncialis, var. obtusata
3. Cl. alpestris
4. Usnea barbatus, var. hirsuta
5. Parmelia physodes
6. Usnea barbulus

7. Hypnum schreberi
8. Evernia prunastri
9. Peltigera aphtosa
10. Aulocomnium palustre
11. Populus tremuloides (leaves)
12. Chamaedaphne calyculata
13. Andromeda glaucophylla
14. Betula glandulosa
15. Bluejoint, timothy, & bunch grass
16. Betula pumila leaves
17. Linnaea borealis var. americana
18. Gragaria vesca leaves
19. Salix cordata
20. Cornus stolonifera

Dr. Buckley also noted from the article that;

The animals in the study did not utilize Labrador tea . . .

There is a tendency to select different foods at different times of the year . . .

In July the mosses, lichens and poplar leaves are preferred . . .

49. Metcalf, F. P. 1921. U. S. Fish and Wildl. Serv. Research Refuge, Letter in files at Patuxent, Md., dated May 17, 1921.

The stomach of Rangifer was examined with the following results: No. 3028 from Umnak Is., Alaska, Dec. 5, 1920, D. H. Stevenson. Contents: Carex spp. 70%; Equisetum spp. 15%; Mosses 10% including: Polytrichum strictum and P. alpinum; Misc. 5% including pieces of bark, leaves, and a fragment or two of lichens.

50. Murie, Adolph. 1944. THE WOLVES OF MOUNT McKINLEY. U. S. Dept. Int., Nat. Park Serv., Fauna Series, No. 5. XIX + 238 pp. Wash. D. C.

[Chapter 4, on the caribou of Mt. McKinley Park, includes a one-page general description of food habits.]

51. Murie, Olaus J. 1935. ALASKA-YUKON CARIBOU. U. S. Dept. Agr., Bur. Biol. Surv., North American Fauna Series, No. 54. Wash. D. C. 93 pp., Biblio. 7 pp. ACWRU.

Chapter headings in this publication are:

I. The Caribou in Relation to Man.

II. Status and Abundance of Caribou.

III. General Description of the Caribou.

IV. General Habits and Temperament.

V. Breeding Habits.

VI. Food Habits.

VII. The Migratory Habit.

VIII. Habitat.

IX. Distribution and Migration of Herds.

X. Taxonomic Status of Alaska-Yukon Caribou.

XI. Caribou of British Columbia and Alberta.

Subdivisions of the chapter (VI) on food habits are as follows:

Importance of lichens.

Year-round food.

Winter food

Spring feeding.

Summer and fall feeding.

Consumption of shed antlers and velvet.

Other food habits.

The following abstract is of the chapter on food habits only.

It has been customary to consider the food of the caribou as consisting more or less exclusively of lichens, or "reindeer moss." While lichens are an important item, they are not required throughout the year, nor are they indispensable if a proper substitute is available.

The caribou, however, has shown a craving for lichens, and in order to wean an animal from a lichen diet in captivity it is necessary for a time to deny it other food. In areas where few lichens are present and the caribou confined by

natural barriers, substitutes for lichens in winter food are evergreen species. Both leaves and berries of Empetrum nigrum Arctostaphylos uva-ursi remain in fair condition throughout the winter, as do Cassiope and certain species of Vaccinium.

> To obtain a fairly comprehensive list of the plants eaten, one would need to examine a large series of caribou stomachs. A long list of herbaceous plants enters in the choice of summer food, particularly since the caribou is such an inveterate wanderer.

[A table detailing the results of examination of 24 stomach samples is reproduced in Table 7, Section III.]

52. Palmer, L. J. 1922. MEMORANDUM-CHIEF OF BUREAU. A two page memo dated Nome, Alaska, Nov. 30, 1922, containing a complete summary of quadrats and their weights of air dried forage. The memo lists quadrats 1-29 and gives for each: lichen content (per cent), other content (general, as "browse" etc.), stand (density; all but two are 10/10), height of cover in inches, and air dry weight in tons per acre. Notes, as "above frost," "scraped," "cut," etc. are included.

An abstract follows.

> Generally stated, it may be said that the non-lichen, tundra types of vegetation of 6/10 to 10/10 density cover, comprising largely grass or sedge and browse species, will run in average air dry weight of forage 3-5 tons per acre.

Lichen areas of 10/10 density running 70 to 90 per cent lichens will contain 5 to 7 tons of air dry forage per acre. Or, a lichen area of 75 per cent content with growth 2 inches high will run about 5 tons per acre in air dry weight, and a stand of 80 per cent lichens with a growth 4 inches high will run about 7 tons per acre. It is indicated in the lichen stands that the top half of the cover runs much lighter in weight than the bottom half or base. This accounts for the

proportionately smaller weights attained where only the cover above frost was removed, and also for the very large weight attained in stands which included considerable dead material at base of the cover.

53. Palmer, Lawrence J. 1926. PROGRESS OF REINDEER GRAZING INVESTIGATIONS IN ALASKA. U. S. Dept. Agric., Dept. Bull. No. 1423. 36 pp. Wash. D. C. ACWRU.

Chapters are:

I. Growth of the Reindeer Industry.

II. Herd Owners.

III. Reindeer as Grazing Animals.

IV. Breeds and Types of Reindeer.

V. Sled Reindeer.

VI. Reindeer Meat.

VII. Feeding Experiments. [Feeding preferences of reindeer, tests with cultivated grains and grasses, importance of lichen forage, analysis of feeds.]

VIII. Nature of Grazing Use.

IX. Nature of the Range.

X. Influence of Climate on Reindeer Grazing.

XI. Soil Conditions in Alaska

XII. Forage Cover.

XIII. Carrying Capacity of Range.

XIV. Management.

The following is an abstract, with particular emphasis given to the material on range and feeding.

From the original stock of 1,280 animals imported from Siberia in the ten years prior to 1902 the reindeer in Alaska

have increased to about 350,000 head. In addition it is estimated that about 125,000 have been killed for food and clothing. The average increase per annum is between 33 and 45 per cent, and the average fawn crop runs between 50 and 60 per cent, although the better handled herds often attain 70 per cent and sometimes as much as 90 per cent. [The location of herds and the distribution of reindeer and range in Alaska are shown on a map.] From 1918 to 1925 more than 1,875,000 pounds of reindeer meat were shipped from Alaska. Steers for butchering sell (1925) at $10 to $12 a head. Breeding stock is valued at $18 to $30 a head. The average cost of production is about $1 per year per head. Scientific investigation of reindeer grazing by the Biological Survey was first begun in 1920 at Unalakleet; the investigation was moved to Nome in 1922 and in 1925 was moved to Fairbanks. One of the fundamental problems has to do with the relation of lichens to grazing. This publication is a second report on these investigations and deals with the forage and range management phases; the first report ("Reindeer in Alaska") dealt also with the biology and diseases of reindeer.

In addition to the Lapps, who were brought to Alaska to care for the original stock, there are three general classes of reindeer owners in the Territory: (1) Eskimos, (2) white men married to native women, (3) other white men. Of these, the Eskimo requires the most supervision; reindeer grazing to him is often of secondary interest.

[A table (see Section III) gives the food values of lichens, other forage plants, and cultivated grains and grasses. The average protein content of lichens was 4.03 per cent; browse contained 14.12 per cent (Salix); grasses 10.88 per cent. Of the cultivated foods meal contained 29.97 per cent proteins; grains 11.57 per cent and hay 10.1 per cent. Values are also given for mositure, ash, fat, starch, and cellulose for six species of lichens, five species of willow, two species of grass, three grains, three types of meal, and timothy and alfalfa hay.]

The physical nture of the soil varies greatly, producing three main types of range: (1) the dry tundra; (2) wet tundra; (3) rocky areas. The carrying capacity of each type varies considerably. The rocky type has a lower carrying capacity than the other two, and the wet tundra is usually intermediate due to the greater harm done by trampling. Presence or absence of trees furnishes another classification. The main value of forested areas in reindeer management lies in providing fuel and shelter for the herders.

Climatic conditions may affect reindeer grazing. Depth of snow, crusting, drifting, etc. may all affect the degree of use possible. Moisture is necessary for the development of lichens; growth of the thallus does not take place except under moist conditions. To a large extent soil and ground conditions determine the lichen cover. In Alaska the best lichen growth for forage purposes is made up of those species that grow on the soil and on decayed herbaceous vegetation.

The forage value is derived by multiplying the percentage of density of a forage stand by the percentage of palatability. Summer forage consists mainly of grasses, sedges, weeds and browse. [The forage values listed are the same as those in "Reindeer in Alaska." Two pages are devoted to listing lichens in order of abundance and in order of relative forage value. Heading both lists is Cladonia sylvatica sylvestris, while Cladonia rangiferina follows it in both cases. Some of these data are given in Talbe 4, Section III] The average growth of young lichen plants is about an eighth to a quarter of an inch per year, and the initial growth is usually about a sixteenth to an eighth of an inch. In numbers of new plants lichens apparently make rapid progress; on one overgrazed area they showed a progressive annual increase of 50 per cent in three years. On this basis it would require 7 to 10 years of protection for a lichen range to come back to normal volume following initial growth, and 15 to 20 years to attain a normal height of 4 to 5 inches. Quadrat studies were made; these tended to substantiate the above estimates.

54. Palmer, L. J. [In charge, reindeer experiment station] 1929. LETTER TO CHIEF OF BUREAU, BIOLOGICAL SURVEY, WASHINGTON, D. C. 3 pp. typed (carbon) dated College, Alaska, Jan. 10, 1929.

[Concerning lichens, their importance as reindeer food (a brief general discussion), and a suggested analysis of vitamin content.]

> A number of years ago when on the coast, I personally made analyses of the contents of a number of reindeer stomachs with following results: Fall feeding (November) - average of five stomachs; grass 8%, Lichen 50%, browse 15%, Sedge 17%, other 10%. Summer feeding (August) - average of seven

stomach; browse 25%, sedge 45%, lichen 25%, other 5%.

During the fall and early winter, where a minimum of lichens are available, the reindeer will graze and maintain fair condition on other forage such as natural cured sedge hay and leaves of browse species. However, where lichens are abundant the reindeer prefer to feed on them to a large extent, 15-25% in summer when plants are moist, 50% in fall and probably about 90% in winter.

Thus it is indicated that the lichens when available are eaten to an important extent in fall and even summer . . .

55. Palmer, Lawrence J. 1934a. RAISING REINDEER IN ALASKA. U. S. Dept. Agric., Misc. Pub. 207. 40 pp. Wash. D. C.

This is a later version of "Progress of Reindeer Grazing Investigations in Alaska" and contains only general additions to the latter publication. Some numerical data is included in Section III.

56. Palmer, L. J. [Senior Biologist] 1934b. PASTURING AND FEEDING REINDEER. Typed (carbon) ms. 8 pp.

This is a report detailing the results of studies made to determine:

(1) Carrying capacity of lichens. (2) Comparison of tall and short growth lichens. (3) Comparison of lichen and non-lichen forage in maintenance of reindeer. (4) Feeding requirements of animals on cultivated foods.

In the pasture experiments it was found that 14 reindeer, fed on short-growth lichens for 21 days between January 2 and January 23, 1928, in a pasture of 22 acres containing an estimated 9,430 lbs. of lichens, used approximately 32 lbs. per head per day and gained weight at the rate of 0.119 lbs. per day per head.

On a pasture of 28.4 acres containing an estimated 46,200 lbs. of tall-growth lichens, the animals utilized 50 per cent of the growth or about 20 lbs. per head per day between January 27 and April 20, 1928 (84 days). In this pasture, the animals lost an average of 0.0144 lbs. per head per day. "Thus a gain is indicated on short-growth forms, a loss in live weight on the tall-growth forms." It is postulated that the much higher vitamin A content of the short forms may be a factor in this. "Furthermore the high vitamin D content of lichens may also explain why there is a minimum of calcium deficiency in reindeer."

For a comparison between lichen and non-lichen forage, three pastures were used; one contained tall-growth lichens, the second sedges, browse and from 25 to 50 per cent lichens, and the third sedges and browse only. The first was used for one month between September 29 and October 29, 1928, the second for 36 days between October 29 and December 4, and the last for the 40 days between December 14, 1928 and January 13, 1929. Sixteen reindeer were used. On the first pasture, the animals lost an average of 2 lbs. per head per month, and on the second they gained 8.35 lbs. per head per month, and on the browse-only pasture they lost 4.3 lbs. per head per month.

On a second test, using only two pastues, one with sedges and browse and the other containing tall-growth lichens, 21 animals gained an average of 7.9 lbs. per head per month when fed on the first type for 93 days between August 7 and

November 8, 1929, and lost an average 1.62 lbs. per head per month on the second pasture in the 227 days between November 8, 1929 and June 24, 1930.

In the carrying capacity experiments reindeer ate 32 lbs. per head per day on short-growth lichen pastures and about 20 lbs. per head per day on the tall-growth pasture. Yield determinations of tall-growth lichen cover indicated that an acre of full cover and density yields about 14,000 lbs. It is estimated on this basis that the average lichen range in Alaska will carry 5,600 lbs. of lichens per acre. One reindeer during the winter period of five months will require about 3,550 lbs. of lichens (combined tall and short forms). On average range, therefore, and allowing a 30-year recovery period for the lichens, the carrying capacity figures out to 19 forage acres per head per year.

In feeding experiments, it was found that reindeer would gain weight on an alfalfa hay-chopped feed mixture and a mixture of alfalfa molasses meal, alfalfa hay, and oats, but lost weight on lichens and on a mixture of pea-hay and oats.

The amounts consumed varied from 109 lbs. per 1,000 lbs. live weight per day of lichens (dry weight) to 34 lbs. per 1,000 lbs. live weight per day of meal, hay, and oats mixture.

57. Palmer, L. J. 1941a. PROGRESS REPORT, CARIBOU VERSUS FIRE IN INTERIOR ALASKA (A STUDY OF BURNED-OVER LICHEN RANGES). 37 pp. typed (carbon) ms. (pp. 34-37 = 8 photographs) U. S. Dept. Int., Fish and Wildl. Serv.

Contents: Method of study, occupation by caribou, character of range, lichen occureence, burned-over range, effect of fire

on lichens, effect of over-grazing on lichens, species in stages of succession, transect results, rate of recovery, significance.

The following is an abstract.

Where a fire destroys the lichen food base, generations may be required for recovery; the range may even be permanently destroyed as far as the lichen forage is concerned. Fires since 1895 in Interior Alaska have burned from 20,000 to 36,000 square miles. The maximum figure is equal to 10 per cent of the interior range. In order to investigate the problem, a study was carried out between August 20 and September 20, 1941. Burns of various ages, and overgrazed areas at the former reindeer experiment station, were examined by the transect method. Generally speaking, the areas studied were areas occupied by caribou at some time during the year. The topography varied from rolling to rugged.

The best lichen growth seems to occur at elevations between 1,000 and 3,500 feet. Occurrence varies widely according to site condtions, which are many and complex. In the Interior, the best lichen growth is found in open timber. In the Fairbanks section fiar lichen growth covered about two-thirds of the range, little or no lichens being found on the other one-third. It is estimated at least 75 per cent of the lichen range has been burned over one or twice since 1900; 50 per cent of this being extreme burn with the food base [?] destroyed and 50 per cent being less severe, having occurred on moister sites on which recovery is apt to be more rapid.

The cycle of recovery on burned range seems to be first an invasion of browse species, followed by a rebuilding of the debris-moss-lichen base, and then spruce. Reintroduction of spruce is a causative factor in the acceleration of moss and lichen growth; these two factors together gradually crowd out the browse species.

Destruction of lichens by fire is usually total. Rate of recovery usually depends on the extent of damage to the food base. Where this base is totally destroyed, lichen succession in recovery occurs in three stages: the primary stage comprises the crustose forms, followed by the foliose and short-growth fruticose lichens of the secondary stage; the final stage, of tall-growth fruticose forms, follows in due course. Recovery after grazing is generally more rapid than after fire, since the food base is usually left intact.

Recovery of tall lichen forms requires less time on wet than on dry sites. On dry sites, the invasion of short forms is more rapid. Short forms are less prominent in recovery of grazed areas--they require an opening up of the ground cover for ready invasion. Full recovery of the short forms takes place in about 50 years after fire. Re-invasion to tall forms takes considerably more than 100 years. The recovery period varies greatly, depending on site and degree of injury.

[For a listing of species in the various stages of succession, see Table 6, Section III. Pages 10-29 are devoted to transect results, in tabular form: type of site, years

since burning or grazing, location, elevation, number of species, cover density, total lichen density, short lichen density, comparison between burned or grazed and protected areas for all figures shown].

Lichens, principally the tall-growth forms, constitute the chief winter forage of the caribou and reindeer.

> Experimentally, it has been determined that [they] require at least 50% lichens in the diet for maintenance of condition during the winter months. Where lichens are ample and readily available, reindeer and caribou will eat [them] by preference.
>
> By inference, realizing the slow growth habits of lichens, fire and overgrazing constitute a serious threat to maintenance of reindeer and caribou in Alaska.

58. Palmer, L. J. 1941b. LETTER TO DIRECTOR, FWS, WASHINGTON, D. C., DATED FAIRBANKS, AUG. 7, 1941. "Concerning Dr. Jackson's memo of May 15 re capacity of Alaska game ranges, all big-game species." 3 pp. typed (carbon).

> In actual range use, studies of fully stocked game ranges indicate the following occupation: Kenai moose - 1 and 1/2/sq. mi.; Mt. Hayes Mt. Sheep - 3 - 4/sq. mi. Reindeer . . . require 33 acres for yearlong grazing on a good range to 60 acres on a less favorable range. A normal caribou occupation seems to be 10 animals to the square mile.
>
> On a yearlong basis, the comparison between moose and cattle (Matanuska Velley) grazing requirements is about 1 moose to 40 cattle. In the Mt. Hayes region a recent survey indicates that one Mt. sheep requires as much range as 10 domestic sheep. On Kenai Peninsula, a rough estimate would be 1 moose to 15 cattle. Instead of saying, as per Mr. Rutledge's letter, that so many game animals equal one animal unit, it will probably be found that one game animal will equal a certain number of animal units. Studies now under way in Alaska may provide these equivalents. The problem of stating the range requirements of Alaskan game mammals in terms of domestic animal units is not a simple one --food is not

the only thing to be considered. Overcrowding of game species would expose that species to parasitism and disease - they cannot be treated as domestic animals.

[SUPPLEMENT (from a separate letter, ND., apparently in supplement to the above, bound with the above):]

In considering range capacity for game in comparison with domestic species, it is necessary to view the requirement in terms of wildness. Three ranges are required - summer, winter, and crossing or 'enroute' between the two. The latter must be free of fence or settlement. The estimates of carrying capacity for game must include all three.

59. Palmer, L. J. 1942. FOOD REQUIREMENTS OF SOME ALASKAN GAME MAMMALS. Typed (carbon), 11 pp.

[This report was published in final form in Journ. Mammal., 25 (1):49-54. Ann Arbor, Feb. 1944. LC-410.J823.]

The manuscript includes discussion of: Alaska investigations; feeding tests with musk oxen, reindeer, and caribou; suggested food requirements for Alaska game animals; the lichen as a food; game animal occupation in Alaska; principal forage eaten by Alaska game animals.

For tables and figures given in this report see Table 8, Section III.

The following is an abstract of the unpublished report.

Caribou ate an average of 2.10 lbs. of various types of food per 100 lbs. live weight per day. [Palmer also gives a figure of 3.70 lbs. "as fed" and uses these two figures as a basis for the statement that caribou (and/or reindeer) "Utilized 57% of the feed."] A food requirement of 10 lbs. per day per 250 lb. caribou is suggested. [No mention is

given to trampling in connection with this figure.] It is indicated that caribou and reindeer will lose weight on a ration of tall-growth lichens and gain slightly on the short-growth forms. However, the animals seem to find the tall forms more palatable. In an experiment with rats, it was found that the tall-form lichens were unpalatable and the rats would soon die if fed more than 10 per cent in the diet, while they could live and maintain weight on the short-growth forms. The probable reason for this is that the short-growth lichens contain, on the average, 2.6 times as much protein as the tall forms. Also, vitamin A is present in fair amounts in the short forms but absent in the tall; both contain vitamin D, the tall forms more than the short, and vitamin B-complex is lacking in both. The latter may explain in part the prevalence of skin diseases in reindeer and caribou, while presence of vitamin D may account for absence of rickets. General observations and study of specific areas indicate that the occupancy of game animals within their habitat in Alaska is about as follows: Caribou, 5 to 10 per sq. mi.; Moose, 1 to 1.5 per sq. mi.; Mountain Sheep 1.5 to 3 per sq. mi.; and Sitka deer 1 to 2 per sq. mi. Under natural conditions occupation is limited by factors of climate.

60. Palmer, L. J. 1944. ALASKA REINDEER 1944 (A FIELD REPORT). Unpublished typed (carbon) ms. headed U. S. Dept. Int., Office of Indian Affairs. 60 pp.

This paper discusses history and status, lack of herding, predation, other factors of reindeer losses, economic aspects, administration, Eskimos, location and character of range,

vegetative types, nature of lichens and occurrence, cycle of lichen recovery, lichen analyses, indicator plants, rotational use, seasonal ranges, character of country for herding, improved herding facilities, the reindeer as a grazing animal, herding methods, herd size, ownership problems, salting, food requirements, forage palatability, grazing capacity, range depletion, breeding, educational needs, conclusions and recommendations.

An abstract of the report follows:

The introduction of reindeer, done to provide for the Eskimos during the lean years, prospered under assistance by the Federal Government to the extent that white interests were attracted to the business as a commercial venture. These ventures failed, and after 20 years, and many controversies, the white enterprise was brought to a conclusion by Federal purchase of all white-owned reindeer. These purchases were concluded in 1939--the return of the stock to native interests had not been concluded at the writing of this report. From 1,280 reindeer introduced from Siberia during 1891-1902, there were 510,000 animals in 1931 in 70 herds along the Bering Sea-Arctic Ocean coast. There also were herds on seven islands, and three herds in the interior. The population was maintained at between 500,000 and 600,000 head between 1931 and 1938; then, following poor management and lack of interest, the population dropped to 377,712 in 1939. Continued losses reduced this to 128,700 in 1943, spread among 39 herds, of which 9 were Government owned. [Populations for eight separate years between 1902 and 1943 are given].

Heavy predation, made possible by the lack of proper herding, was one of the primary reasons for the decline. A total of 198 wolves were taken in the reindeer areas in 1943, ranging from 1 at Golovin to 45 in the Buckland-Kotzebue area. An unusual influx of wolves was reported in 1937--reindeer losses continued to grow thereafter. The increase of reindeer on Nunivak, where there are no wolves, is offered as substantiation of the predation-loss theory. The destruction of ranges by fire is probably a contributing factor in the interior. Excessive slaughter, improper use of range, straying, starvation and general lack of interest also contributed to the losses. The reindeer is important now as a reserve food supply and as a source of material for clothing. The caribou has disappeared from the coast--its place must be taken by the reindeer. Government financial assistance will be necessary. Reindeer are particularly important at Hooper Bay and other areas where conditions are most severe. There is a local market for meat and skins.

Four thousand of the estimated 15,000 Eskimo and Aleut population are somehow engaged in the reindeer business, most of them part-time. The per-capita consumption of animals is five to seven carcasses per year. The Eskimo prefers to work for wages under white direction, and many opportunities to do so exist. Reindeer herding is unattractive unless paid for by the government. Management of herds is under direction of the Reindeer Service; in isolated communities, teachers take over this function. The Eskimos have many racial characteristics which makes it necessary that only the most intelligent and industrious be used as herders.

The reindeer occupy the tundra zones along the west coast. Termed tundra, the main reindeer range includes seven major vegetative types with the tundra type predominating. Composition of the interior tundra is similar to the coastal areas. The overlap of forest and tundra, essentially tundra in forage composition, is included in the tundra belt. The forest is advancing onto the tundra; this advance has been noticeable within the last 20 years. The tundra is characterized by a hummocky appearance; it is divided into wet and dry types. Ordinarily the surface is completely covered with vegetation; the composition includes a mixture of lichens, mosses, grasslike plants, shrubs, weeds, and grasses. The coast range contains a predominance of sedges (Carex and Eriophorum) and shrubs and the inland areas a predominance of lichens and shrubs. There is a considerable mixture of minor sites within the two major types of dry and wet tundra. Carex and Cladonia are the climax dominants on an undisturbed tundra. Shrubs (Salix, Betula, Arctous, Empetrum, etc.) are subdominants. Prominant grasses include Festuca, Poa, Hierochloa, Arctagrostis, and Agrostis. Sphagnum and Polytrichum are the most common mosses. Characteristic weeds [forbs] include Pedicularis, Polygonum, Chrysanthemum, Arnica, Gentina [Gentiana?] Saxifrage, Senecio, Polemonium, Campanula, Primula, and Petasites frigida. The major forage types of the coastal tundra zones are: 1. Tundra (Sedge-lichen-shrub) which is broken into wet (sedge-lichen) and dry (lichen-shrub); 2. Sand dune or Beach (Grass-weed); 3. Forest (Spruce-lichen); 4. Shrub (Alder-willow-grass); 5. Alpine or Heath (Heath-lichen);

6. Aquatic (Water-plants) and 7. Barren or Waste (Rock-Crustose lichens). On the Aleutians and Pribilofs there is a greater proportion of grasses and weeds. [5 pages are devoted to listing the outstanding species in each of the above types]. There are three distinct range belts: 1. the coastal region, including the islands; 2. the far-interior country; and 3. an intermediate region, the inland-coastal or coastal valley belt. In the first, the summer range is along the coast, the winter range in the uplands inland. In the interior, the uplands are the summer range, with the winter range in the valley lowlands. In the intermediate region, choice of winter and summer range is determined by insects in summer and availability of lichens in winter. The Harriman Alaska Expedition in 1904 listed 400 species of lichens as occurring in the Territory. The Cladoniae are the most numerous and important, the Cetrariae second, after which come the Parmeliae, the Lecanorae, Buelliae, etc. The first two named also lead in forage value. Of the total species identified, about 60 per cent are of grazing value. Best lichen growth occurs between 1,000 and 3,500 feet. Generally, they occur on all exposures where atmospheric moisture conditions are favorable. The best growth, on the coast, is at the edge of timber. On the average summer range of this area, because of grazing disturbance, the herbacious and shrub vegetation comes into strong competition with the lichens and is predominant.

Within the stand, one or two species of lichens predominate, with many other species mixed in. The species most

frequently found on tundra and lower foothill sites are Cladonia sylvatica sylvestris, Cladonia rangiferina, and Cladonia sylvatica. On rocky sub-alpine sites of favorable exposure, the base plant is often Cladonia alpestris. In shady timber, Cladonia delesertii is often found in abundance with Cladonia rangiferina and Cl. sylvatic sylvestris. On higher range, Cladonia amaurocraea, Cl. uncialis, and sometimes Cl. sylvatica sylvestris predominate. On some upland areas subject to periodic inundation, Cetraria hiascens is a characteristic plant. Many other species are cosmopolitan and occur scatteringly mixed throughout. On most winter ranges, the lichens comprise an average of 50 per cent of the cover. In dry weight the average lichen stand will yield approximately four tons of forage per acre--and an 80 to 90 per cent stand may produce as much as seven tons to the acre.

When fire occurs the destruction of lichens is usually total, especially on the drier sites. Three stages of succession take place in recovery. The primary stage comprises chiefly the crustose lichens. The foliose and short-growth lichens come in during the secondary stage, and the climax stage brings a return of the tall-growth forms. The number of stages depends on the degree of injury. Recovery is more rapid after grazing, and the first stage is usually not evident, since the food base is not destroyed. [See Table 6, Section III for species in various stages of succession.] Depending on the type and degree of injury, the recovery may be to a changed composition--recovery to the original composition of lichens usually takes

40 to 65 years. Recovery of tall lichens is faster on wet sites than on dry due to decreased damage of the base. Short lichens require an opening up of the ground cover to permit ready invasion. Full recovery of a stand of mostly short lichens requires 25 to 50 years; a tall-growth recovery may take 100 years or more. For practical purposes of grazing management, combined recovery of both forms to a full stand is reached in about 50 years. Replacement of some of the tall forms by short growth lichens is offset by the greater protein and vitamin value of the short forms. In stages of succession and rate of recovery, the reaction of a damaged lichen stand closely parallels that of a coniferous forest.

Utilization of a range may be gauged aside from the physical depletion of the vegetation as a whole by indicator plants. Normal plant cover for any particular site must first be known. On sites of favorable atmospheric moisture, the presence of a predominence of crustose and short-growth lichens would indicate disturbance. In the case of herbaceous and shrub vegetation, disturbance usually results in replacement of the climax dominants, Carex and Cladonia, by a stand of Eriophorum, and in some cases Ledum. On wet sites in the interior, fire damage will temporarily bring in Marchantia, or in some places Epilobium, Equisetum, and grasses. Elsewhere on tundra areas, an unusual invasion of weeds and grasses probably indicates disturbance and change of site from wet to drier aspect, as a result of fire or trampling. Any disturbance of the physical surface has a tendency to change the

site from wet to drier aspect. A change in plant cover on summer ranges is not serious, even if the disturbance results in permanent loss of lichens, and replacement by grasses and weeds. On the winter range, such change can have serious consequences. [Four pages are given to a discussion of rotational use and seasonal ranges, and character of country for herding.]

In order to improve the herding by making it more attractive, line cabins should be built about seven miles apart. Otherwise the Eskimo tends to stay in one place too long, and thus his herd will overgraze local areas. The reindeer is a semi-domesticated animal, and must be watched much closer than sheep or cattle. Twenty-five hundred to 3,000 animals should be the optimum herd size, and these should be owned by the herder himself--absentee ownership does not work. The company or association idea has proved to be undesirable.

[For a discussion of food requirements see Palmer (1942) and for tables on food requirements and palatability see Section III. Four pages are devoted to the above subjects in this report.]

Depletion of the lichen range, following forty years of grazing, is general for a strip of about ten miles bordering the coast. Summer forage is on the increase; it is the lichen forage that is subject to depletion. On Nunivak serious depletion is threatened with a herd of 30,000 on a range that should carry no more than 8,000 animals.

[The remainder of this report is taken up by a discussion of breeding ("the average reindeer has decreased in weight

from 25 to 50 lbs. due to lack of control over breeding"), need for educating the Eskimos in reindeer management, and conclusions and recommendations concerning making a comeback in the reindeer industry.]

61. Palmer, Lawrence J., and Charles H. Rouse. 1945. STUDY OF THE ALASKA TUNDRA WITH REFERENCE TO ITS REACTION TO REINDEER AND OTHER GRAZING. U. S. Dept. Int., Fish and Wildl. Serv., Res. Rept. 10. Wash. D. C., 48 pp. ACWRU.

Contents:

The following is an abstract.

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

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

The tundra merges gradually into the boreal forest so there occurs a transition type of cover composed of open tree growth with an under-cover of tundra vegetation. It has been recognized that the forest is slowly advancing onto the tundra. The predominating soils of the tundra include a black sandy loam and a sandy-clay loam and intermixtures over a blue-clay subsoil. They are rich in humus and often become peat-like in nature. Rocky areas on the crests of ridges or on the beach are chiefly of gravelly sandstone, quartz, limestone, or, in places, of igneous rocks of recent volcanic origin. On the coastal tundra permanent frost occurs 1 to 3 feet below the surface. [Four pages are devoted to a list of tundra plants. Of these Carex spp. and Cladonia spp. are dominants in the tundra climax. Subdominants include species of Eriophorum, Ledum, Salix and Betula (low-growing forms), Vaccinium, Empetrum nigrum, Arctous [Arctostaphylos] alpina, and Rubus chamaemorus. Prominent grasses are Festuca, Poa, Arctagrostis, and Agrostis. The most common mosses are Sphagnum and Polytrichum. Characteristic forbs include species of Pedicularis, Polygonum, Chrysanthemum, Arnica, Gentiana, Saxifrage, Senecio, Polemonium, Campanula, and the Arctic coltsfoot (Petasites frigida).]

In the quadrat studies various treatments were employed to simulate grazing by reindeer. These were applied to each important type of tundra vegetation. They included picking lichens by hand to imitate complete cropping, cutting the vegetation at different heights to represent various degrees

of utilization, denuding by spading up and removing the plant cover to simulate extreme overgrazing, and protecting from disturbance as a check.

The average plant composition of the tundra as a whole is about as follows: lichens 30 per cent, shrubs 25 per cent, and grasses, weeds and mosses 20 per cent. A sampling of numerous areas indicated a forage production of five to seven tons air-dry weight of lichens per acre. Areas sampled were those in which the lichens comprised from 50 to 90 per cent of the vegetation. Cladonia, because it was the most abundant and of taller growth, generally gave the largest yields.

In the tundra lichen types the range reacts quickly to any disturbance. The recovery time is proportional to the degree of disturbance. Trampling is more damaging to the lichen cover than either grazing or total removal. Disturbance of the lichen cover on a moist site is followed by an invasion of vascular plants, chief of which is cotton sedge. On dry sites an accelerated growth of shrubs follows reduction of lichens by grazing. Recovery of lichens is more rapid on dry than on moist sites. Grass-browse will bear heavy grazing; recovery of this type is rapid. The heath type is unstable and recovers slowly. In the lichen-browse type recovery is rapid under light cropping but slow under heavy grazing. Opening of the woodland moss type allows competition of lichens with the mosses; recovery after overgrazing in this type is slow but a recovered stand contains a large proportion of lichens. On overgrazed browse-lichen turndra the browse species

are most aggressive in recovery. Complete recovery would probably require 25 years or more. In general, invasion and re-establishment of vascular plants on grazed or otherwise injured range is much more rapid than recovery of lichens.

62. Porsild, A. E. 1942. REINDEER AND CARIBOU GRAZING IN CANADA. Trans. 7th N. Am. Wildl. Conf. Wildl. Mgmt. Inst., Wash. D. C. pp. 281-390., 20 refs.

A very general discussion, which could well serve as an introduction to the subject. Mentions that a range allowance of 40 acres per reindeer per year appears to be ample, judged by Canadian experience.

63. Reindeer Council of the United Kingdom, The. 1949-1950. FIRST ANNUAL REPORT. Annesley House, 1A Union Road, Cambridge, England. 6 pp. ACWRU.

A report of the formation of the Council, negotiations with H. M. Government concerning the importation of reindeer from Scandinavia to Scotland.

64. _____. 1950-1951. SECOND ANNUAL REPORT. 6 pp. ACWRU.

Reports on progress of negotiations, etc.

65. _____. 1951-1952. THIRD ANNUAL REPORT. 14 pp. ACWRU.

Reports on first introduction of animals to Scotland. Mentions "indispensable 'reindeer moss'" gathered as food for animals being shipped from Scandinavia.

66. _____. 1952-1953. FOURTH ANNUAL REPORT. 18 pp. ACWRU.

Describes the results of first importation of animals and the importation of a second group.

67. Reindeer Council of the United Kingdom, The. 1953-1954. FIFTH ANNUAL REPORT. 22 pp. ACWRU.

Describes a third importation of reindeer and results of the first two years of residency of the earlier introduction.

68. _____. 1954-1955. SIXTH ANNUAL REPORT. 43 pp. ACWRU.

Describes the third year on the reserve in Scotland, further importations, veterinary treatment and scientific research (including a brief description of grazing habits), and a brief summary of reindeer research and developments abroad. Includes a statement by Technical Adviser M. N. P. Utsi, made in reference to analyses of rumen contents of deceased animals which showed very little lichen present, " . . . lichens digest more rapidly than other vegetable matter . . . "

69. Rouse, Charles H., Charles R. Mountjoy, and Dale M. Belcher, REINDEER SURVEY - 1948. Mimeo. Rept. by U. S. Fish and Wildl. Serv. and Alaska Native Serv. 16 pp. ACWRU.

This is a report of an investigation of 18 government-, private-, and association-owned reindeer herds in western Alaska, made by the authors. The treatment of each herd is brief, and the mention of the range conditions are confined to statements with little or no detail, as "adequate lichen forage for a good winter range." Lichens are invariably the criterion used for evaluation of the winter range.

The authors' recommendations for each herd are included, and a summary and list of general recommendations for the reindeer industry as a whole follow the discussions of individual herds.

70. Salaskin, A. S. 1934. [NATURAL GRAZING LANDS OF THE MURMAN [SK?] CIRCUIT.] U.S.S.R. Inst. of Reindeer Indus., Ser. "The Soviet Reindeer Industry." 1:9-62. Eng. sum. pp. 57-62. 51 refs. ACWRU. (Eng. sum.)

Contents:

General geographical and economic information about the circuit.

Geology, geomorphology, and soils.

General characteristics of the vegetation cover.

Typology of the vegetation.

Natural grazing regions.

Characteristics of the grazing lands according to the districts.

Conclusions.

71. Salaskin, A. S. 1937. [THE SPEED OF GROWTH OF FORAGE LICHENS.] U.S.S.R. Inst. of Reindeer Indus.,Ser. "The Soviet Reindeer Industry." 11:43-54. Eng. Sum. p. 54. A few Bibliographical footnotes. ACWRU.

The following is a abstract of the English summary.

This is a report of a five-year investigation at the Murman Experimental Reindeer Farm of the Arctic Institute of the U.S.S.R. The methods used to determine growth were those proposed by B. N. Gorodkov, and the conclusions are based on the final two years of experiments (1935-36).

Marks were made on selected lichen plants with india ink, and measurements were made from these marks to the top of the plants. It was concluded that:

Cladonia alpestris grows from 0.6 to 1 cm. per year, depending on habitat. Growth is clearly dependent on habitat, being greater on moist soils and less on dry ones. For example, Cladonia rangiferina grew 9.1 mm. on the border of a marsh, 8.1 mm. on low ground near a stream covered by spruce, and

7.3 mm. in spruce and birch forests. [Measurements are per year]. Although most growth takes place during snow-free periods, lichens also grow in the winter. From the middle of October to the beginning of May, Cladonia alpestris grew an average of 1.5 mm., Cladonia rangiferina 1.2 to 1.7 mm., and Cladonia silvatica 0.4 to 2.0 mm. Growth takes place principally in the top of the plant in the gonidial layer, and does not extend more than 4 cm. from the top of the plant. There is a correlation between the distance between branchings of Cladonia alpestris and the amount of yearly growth. The average distance between branches is equal to the amount of annual growth. Further testing, however, is necessary before this factor is generally applied.

72. Sambuk. F. V. 1934. [NATURAL GRAZING LANDS OF THE TUNDRAS OF THE NENETZKY CIRCUIT (NORTHERN REGION).] U.S.S.R. Inst. of Reindeer Indus., Ser. "The Soviet Reindeer Industry." 1:67-97. Eng. sum. pp. 94-97. ACWRU (Eng. sum.).

Contents:

History of investigation.

Climate.

Geomorphology and Soils.

Natural regions.

Types of tundra.

Grazing economy.

73. Scheffer, Victor B. 1951. THE RISE AND FALL OF A REINDEER HERD. The Scientific Monthly, 83(6):357-362. 6 refs.

The following is a review.

The U. S. Government, in 1911, placed 40 reindeer on the Pribilof Islands. By 1922 the St. George herd had reached its peak of 222 animals, and soon thereafter subsided to a small stable herd of 40 to 60 animals. The St. Paul herd, in contrast, erupted in the 1930's and by 1938 numbered 2,000 animals--12 years later there were only 8 left. The author states that the lichen flora of the island is the key to this population behavior; that this conclusion is inescapable. At the time of writing, the author found that lichens were extremely rare on the island, and quotes a biologist to the effect that no lichens were found in the two stomachs of reindeer examined.

The author also discusses some other factors which have been mentioned by hunters and others as causes of the die-off; among these are hunting (by the military during World War II), disease, inbreeding, and weather. "These factors undoubtedly contributed to the decline, but were not the primary cause."

The author confesses that he is puzzled by the lack of a similar eruption on St. George.

74. Sdobnikov, V. M. 1935a. [THE COMPOSITION OF THE REINDEER FORAGE IN AUTUMN.] Trans. Arctic Inst. U.S.S.R., 24: 128-136. Eng. sum. pp. 135-136. ACWRU (Eng. sum.).

The English summary contains a rather general account of the proportions, especially of lichens, of foods contained in the reindeer rumen in the autumn.

The following is an abstract of the English summary.

It was shown that in a previous investigation in 1931 in the Malozemelskaya tundra lichens made up 25 to 30 per

cent of the food of reindeer fawns in the summer and part of the autumn. Analagous investigations were made in the same region on adult reindeer in August and September, 1932. Lichens, in this analysis, made up, on the average, from 25 to 27.5 per cent of the food. The data is based on the analysis of the contents of the rumina of 13 adult reindeer. "It is to be noted that most of the reindeer from which the samples were taken, were suffering from foot rot. This disease, in any serious form, evidently has some effect on the composition of the food taken." A sample of about 150-200 gm. of the contents of each rumen was divided by means of three metal sieves into three parts. The lichens of the first part, in which the pieces were more than 2 mm. in length, were directly separated; the other divisions, consisting of pieces between 0.5 and 2 mm. in length, were judged optically as to their lichen content. Then all parts of the samples were dried and weighed and the average values taken. "Simultaneously the systematic composition of the lichens and green growths was determined." Lichens were found to be present in all the rumina. The amount of lichens in the individual rumina ranged from 3.2 to 42.5 per cent. The nature of the food taken "is influenced not only by diseases, but also by the quality of the pastures, the duration of grazing, the condition of the weather, etc." The lichens which appeared most frequently were: Cetraria islandica, Sphaerophorus globosus, Stereocaulon spp., Cladonia uncialis, and Cladonia silvatica. Of the green growths consumed, the leaves of Salix (many species) and Betula

nana are important.

> In general it may be considered that at the end of the summer and beginning of autumn the leaves of Salix and Betula nana constitute not less than 35-40 per cent of the entire quantity of green growths consumed, other plants amounting to the same percentage and 20-30 per cent being taken up by the lichen.

The rumen contents of six fawns were also analyzed in 1932. Lichens made up 22.2 to 24.2 per cent of these contents.

> This decrease in the consumption of lichen in comparison with 1931, obviously, is due to the better quality of the pastures in 1932, when there was no scarcity in green growths, as that [sic] observed in 1931.

75. Sdobnikov, V. M. 1935b. [MATERIALS TO [sic] THE PROBLEM OF WINTER FOOD FOR THE REINDEER.] Trans. Arctic Inst. U.S.S.R., 24:137-141. Eng. sum. p. 141. ACWRU (Eng. sum.).

The following is an abstract of the English summary.

Eight reindeer paunches taken in the Malozemelskaya tundra in January and February served as the basis for this study. The samples were subjected to a treatment in which the lichens were separated from the flowering plants and mosses, after which they were dried and weighed. The data obtained by this treatment were summarized, and the mean figures obtained showed that the winter food "contains nearly" as many flowering plants as the lichens. Grasses and sedges are the predominant flowering plants in the diet at this time of year, and leaves and small branches of Vaccinum [sic] vitis-idaea, Vaccinum uliginstum [sic], Ledum palustre, Empetrum nigrum, Arctous [Arctostaphylos] alpina, Rubus chamaemorus, Betula nana, and Salix were also present. The predominant

lichens were found to be Cladonia and Cetraria. Sphaerophorus and Stereocaulon "often occur." Mosses (Hipnum, Sphagnum, and others) were found in every sample in quantities of 3 to 15 per cent of the entire weight of the rumen conterts.

76. Sdobnikov, V. M. 1935c. [RELATIONS BETWEEN THE REINDEER AND ANIMAL LIFE OF THE TUNDRA AND FOREST.] Trans. Arctic Inst. U.S.S.R., 24:5-66. 5 fig. Eng. transl. of Russian Zool. Lit., transl. 125. Transl. by J. D. Jackson, 1943. (Typed, carbon). DI-QL1E8, no. 125.

The following quotations are from [Ch.] V, p. 75 (47 of Orig. Russ.)

> The uniformity and chemical deficiency of the reindeer's vegetable foods make it necessary for the animal to supplement them from other sources. The substances in which they are deficient are apparently albumens and mineral salts. Albumen and mineral starvation is particularly acute in the autumn, winter, and spring, when the reindeer's main food is lichens. During the summer on the other hand the reindeer seems to get all it requires from green food.
>
> At the end of August many reindeer begin to conceive a passion for fungi . . . the passion spreads to more and more of them.

77. Sergeev. M. A. 1950. [THE DEVELOPMENT OF REINDEER FARMING IN THE NORTH.] Sotzial. Zhiv., 12(7):61-70 Abst. in Nutrition Abs. and Reviews, Vol. 21, July 1951 - April 1952, p. 768, Abst. No. 4342.

> . . . green plants, including those under the snow, form 5 to 50 per cent of their (the reindeers') food according to the season of the year and the quality of the grazing grounds. Lichen, though highly digestible, (78 per cent) is poor in protein (about 3 per cent) and minerals (2 to 3 per cent).

78. Skoog, Ronald O. 1955. STEESE-FORTYMILE CARIBOU HERD. Quarterly Progress Report, Surveys and Investigations, U. S. Fish and Wildl. Serv. and Alaska Game Comm. 9 (4):16-23. Juneau, Alaska. ACWRU. Also appears as

MS thesis, University of Alaska, under the title "Range, Movements, Population, and Food Habits of the Steese-Fortymile Caribou Herd." May 1956.

The following abstract is of the section entitled "Fall food habits," pp. 18-23.

During the fall of 1954 seventy stomach samples, ranging in size from 9 to 178 cc., were collected from hunters' kills. The author separated the material in the samples into three classes--coarse, medium, and fine--and separated the plants in the first two classes into plant type groups: lichens, woody, grass-sedge, fungi, moss, forbs, and "other." Individual plants were identified to genus or species when possible. After separation, each group was measured volumetrically. All of the material in the "coarse" class was separated, while only a random sample of the "medium" class was thus analysed. The method used for separation was arrived at after running six trials with three samples. Each sample was washed to remove the "fine" material (which was retained by a cheese-cloth under the washing screen for later measurement): the author estimates that an average of 20.1 per cent of each sample was analysed. Tables included in the report are: Number of caribou stomach samples collected by date; Numbers of plant species found in caribou stomach-samples collected 8/20-9/24/54 [75 per cent of the samples contained a minimum of 9-11 species of plants]; Plants found in caribou stomach-samples collected 8/20-9/24/54; and Average plant composition of caribou stomach-samples collected 8/20-9/24/54. [See Table 7, Section III].

The Cladonia type dominated the lichen group found in the stomachs; Salix and Betula were the most important of the woody plants. Both of these groups appeared in every sample, while fungi appeared in all but one.

The samples were divided into three groups by dates, and by this means it was determined that the Steese-Fortymile caribou feed largely on woody plants and fungi during early fall, with a switch toward lichens and grass-sedge in late fall and probably winter.

79. Skoog, Ronald O. 1958. WINTER RANGE UTILIZATION - NELCHINA HERD. Job Completion Reports, [former Quart. Rept. series] U. S. Fish and Wildl. Serv., Fed. Aid in Wildl. Rest., Alaska, 12(3):109-118. Proj. W-3-R-12. Caribou Mgmt. Studies. Jobs 1a, b; 2a, b, c; 3a, b; 4a, b; 5; 7. Juneau, Alaska. ACWRU.

The following is an abbreviated version of the author's abstract.

Two areas were examined in the winter of 1957-58; the main food plants utilized in these areas were lichens and sedges, with buds and twigs of willow also showing some use. In an area of moderate use, it was found that there was one pawed-out plot for approximately 40 square meters of ground, while there was one such plot for every 11 square meters of ground in an area of heavy use. Only 0.7 and 2.2 per cent of the total areas, respectively, were found to be disturbed by grazing; about 95 per cent of the plots examined completely contained broken or uprooted portions of plants with lichens showing the most damage.

80 Socava, V. B. 1933 [FEEDING VALUE OF PLANTS FROM THE EXTREME NORTH.] Sovetskaja Botanika, 3,4:257-266. Abst. in Nutrition Abst. and Reviews 4:248. July 1934 - April 1935. Abst. No. 1045.

The following quotations are from this abstract.

> Chemical analyses of some more typical species of the arctic have indicated more than a sufficiency of carbohydrates and nitrogenous compounds, but ash studied for P_2O_5, Fe_2O_3, CaO, MgO, and K_2O showed somewhat unsatisfactory results, such as excessive content of K_2O or CaO.
>
> In the lichens, proteins, lichenins, and nigrogenous substances were deficient, fiber content was reduced, while acidity was considerably increased. . . . . If no other plants rich in P are available, lichens must be fed to animals in order to improve the somewhat unilateral mineral content of arctic herbage plants during summer and spring.

81. Spencer, G. C., and O. F. Krumbolta. 1929. CHEMICAL COMPOSITION OF ALASKAN LICHENS.. Journal of the Association of Official Agriculture Chemists. 12(3):317-318. ACWRU.

The moisture, fat, fiber, protein, ash, and nitrogen-free extract of 21 species of Alaskan lichens are given [See Table 1, Section III.]

The analytical work recorded in this paper was conducted according to the official methods for feeding stuffs. The "crude fiber," however, gave considerable trouble when filtered, the gummy nature of the residue after the acid and alkaline digestions being such that the usual procedure could not be closely followed.

82. Spigul, E. M. 1937. [DIGESTION OF SOME FALL PASTURE FORAGES BY REINDEER.] U.S.S.R. Inst. of Reindeer Indus., Ser. "The Soviet Reindeer Industry, 11:31-42. Eng. sum. pp. 41-42. 11 tables. ACWRU.

The following is an abstract of the English summary.

During August 2 to September 12, 1936, the author carried out experiments on digestion of some fall green forages by reindeer. The forages used were: "March trifoil" (Menyanthes trifoliata) and sedge mixture, and water sedge and turfsedge (Carex aquatilis and C. caespitosa). The investigation of this type of forage is important due to the fact that lichens "lack some mineral and azote properties." In the fall, when the majority of fresh green forages lose their nutritive value, Menyanthes trifoliata is vigorously eaten by reindeer. The chemical composition of the plant at this time of year explains this, and the nutritive properties are confirmed by the high coefficient of digestion as determined in the experiments. This plant also "provides the normal azote balance," and another advantage is the high digestibility of mineral properties.

Sedge forage, in contrast, is rather poorly digested and does not represent a very valuable fall forage. Its nutritive properties are "poor," and reindeer fed on these plants decrease in weight, show symptoms of azote and ash starvation, and prolonged feeding may lead to disturbances of the oesophagus.

83. Temnoev, N. I. 1939. [THE WINTERING OF ABOVE-GROUND ORGANS OF SOME PLANTS OF THE FAR NORTH.] Trans. Inst. Pol. Agr., Ser. "The Reindeer Industry," 4:67-88. Eng. sum. p. 88. 50 refs. ACWRU (Eng. sum.).

The English summary is here abstracted.

Many plants in the tundra "conserve," in the winter, live organs in the form of buds, shoots, and succulent roots. These represent necessary winter forage for reindeer. Some plants, such as Carex aquatilis, Festica [sic] supina, and

Eriophorum vaginatum, have a "large production of green mass" in the winter, other plants a small production. There are very few plants in the tundra which cannot supply green forage for reindeer in the winter.

84. Terent'ev N. D. 1936. [EXPERIMENTAL STALL-FEEDING OF REINDEER MOSS AND HAY.] Arctic Inst. U.S.S.R., Ser. Soviet Reindeer Indus., 8:69-86. ACWRU. (Eng. sum.).

The following is an abstract of the English summary.

In Ijma village of the autonomous Komi territory the author carried out experimental stall-feeding of reindeer on reindeer moss and hay. Ten animals were used in the experiment; eight pregnant does, one calf, and one buck. The purpose of the experiment was to establish: (1) how much reindeer moss and hay a reindeer eats when the ration is unrestricted; (2) whether the live weight of reindeer is maintained up to the end of the winter season when they are fed reindeer moss exclusively, and (3) the importance of hay in reindeer nutrition. The experiments were begun on January 25, and finished April 18, [1936?]. It was concluded that:

1. In experiments on nutrition reindeer moss must be fed in a thawed condition.

2. Reindeer moss always contains an admixture of undigestible matter, sometimes in large quantities (up to 50 per cent), and the reindeer in selecting the moss inevitably eats some of this matter of no nutritional value. In calculations of the quantities eaten it is, therefore, necessary to consider the [reindeer] mosses only.

3. The greatest consumption of dry moss matter per 100 kg. of live weight is shown by the calves; 2.58 kg. Pregnant does consume a little less; 2.08 kg. per 100 kg. of live weight, and bucks come last with 1.89 kg. "These figures do not represent the limits."

4. In eating hay the reindeer selects the most tender parts; of the fodder groups the mixed grasses and papilionaceous plants are the "best eaten."

5. Reindeer moss alone does not assure maintenance of live weight during the end of the winter season.

6. When fed unlimited quantities of hay and moss, reindeer consume the following quantities of dry matter per 100 kg. of live weight; does, 1.24 kg. of moss and 1.11 kg. of hay; bucks, 1.13 kg. of moss and 0.93 kg. of hay; calves, 1.55 kg. of moss and 0.98 kg. of hay. [No period is given; presumably these are daily intakes].

7. On a hay and reindeer moss ration the animals not only maintain their live weight but "give an increase;" pregnant does show an exceptionally marked rise in live weight on such a ration, evidently due to the growth of the fetus.

8. Winter pastures can only be considered of full nutritional value--especially in respect to the main group of the herd, the pregnant does,--when besides reindeer moss the pastures "abound in areas of snow-covered green grass."

85. Ustinov, V. I., A. A. Pokrovskii, and P. D. Bogdanov. 1954. [ORGANIZATION OF THE REINDEER FODDER SUPPLY IN CHUKOTKA.] Zhivotnovodstvo, 11:62-68. [All Russian].

The following quotation is from an abstract in Arctic Bibl. Vol. 6. Dept. Defense, 1956. Item 38012, p. 871. Article itself is LC-SF1.Z45.

> The amount of reindeer moss available as winter pasture is often regarded as the factor controlling the size of herd in the area. This opinion is refuted by investigation of actual winter grazing sites: in the Chukotsk and Anadyr' Districts reindeer moss represents only 37 and 35 per cent of the winter fodder, the remainder being grass, dry leaves, etc. . .

TABLE 1. CHEMICAL COMPOSITION OF LICHENS, IN PER CENT

Source	Species	Moisture	Ash	Fat	Protein	Starch	Cellulose	Fiber	NFE	Albumen	Hemi-Cellulose	Lichenin	Other	Notes
52	Cladonia rangiferina	15.00	0.90	2.15	2.05	49.40	30.50	--	--	--	--	--	--	(1)
54	" "	12.83	1.78	0.69	1.75	--	--	47.19	35.76	--	--	--	--	(2)
39	" "	14.21	1.89	0.45	1.75	--	5.23[3]	--	--	1.25	82.56	6.14[4]	0.01 CaO, 0.05 P_2O_5	
39	" "	15.00	1.06	2.53	2.42	--	35.87	--	58.12	--	--	--	--	
39	" "	--	2.10	1.92	--	--	36.27	--	--	--	--	--	--	
30	" "	5.00	--	--	4.18	--	--	--	--	--	--	--	--	
4	" "	12.49	1.36	1.45	2.35	--	41.51	--	45.38	2.30	--	--	--	
54	Cl. alpestris	12.35	2.33	1.92	2.13	--	--	43.98	37.29	--	--	--	--	(1)
39	" "	13.45	2.18	1.42	1.56	--	4.08[3]	--	--	1.00	60.06	--	--	
39	" "	11.60	1.33	0.43	2.00	--	42.08	--	53.86	1.63	--	--	--	
39	" "	11.90	--	--	2.66	--	49.00	--	--	--	--	--	--	
39	" "	10.43	2.08	1.94	3.82	--	41.20	--	50.96	--	--	--	--	
4	" "	11.09	1.15	1.80	2.54	--	33.06	--	48.23	--	--	--	--	(6)
30	" "	0.70	3.60[5]	--	4.53	--	--	--	--	--	--	--	0.72% Nitrogen	
54	Cl. sylvatica	12.66	1.81	1.45	1.75	--	--	31.98	50.35	--	--	--	--	(1) (7)
30	" "	5.1	1.00[5]	--	4.14	--	--	--	--	--	--	--	0.61% Nitrogen	
54	" "	13.02	2.05	0.57	1.50	--	--	44.64	38.22	--	--	--	--	(1) (8)
54	Cl. sylvatica sylvestris	12.93	1.59	1.08	1.67	--	--	48.92	33.81	--	--	--	--	(1)
54	Cl. amaurocraea celotea	12.61	1.48	1.55	1.73	--	--	35.68	46.95	--	--	--	--	(1)
54	Cl. a. oxyceras	11.88	1.39	1.78	1.50	--	--	33.56	49.89	--	--	--	--	(1)
54	Cl. uncialis	12.89	1.78	1.23	1.50	--	--	37.26	45.34	--	--	--	--	(1)
54	Cl. gracilis	12.46	1.79	0.85	2.50	--	--	45.72	36.68	--	--	--	--	(1)
54	Cl. g. dilatata and Cl. bellidiflora hookeri	12.15	2.92	0.89	3.50	--	--	33.27	47.27	--	--	--	--	(9)

TABLE 1. (cont.)

Source	Species	Moisture	Ash	Fat	Protein	Starch	Cellulose	Fiber	NFE	Albumen	Hemi-Cellulose	Lichenin	Other	Notes
54	Cladonia graciliscens	13.27	2.64	0.56	3.06	--	--	40.08	40.39	--	--	--	--	(9)
54	Cl. degenerans	12.90	2.21	0.76	3.56	--	--	58.29	22.28	--	--	--	--	(9)
54	Cl. decorticata	13.04	6.27	1.14	4.25	--	--	40.15	35.15	--	--	--	--	(9)
54	Cl. crispata	12.56	1.85	1.34	2.25	--	--	43.70	38.30	--	--	--	--	(9)
39	Cl. mitis	11.43	2.18	1.67	2.54	--	28.00	--	65.62	2.32	--	--	--	
54	Cetraria cucullata	12.22	1.27	8.70	1.75	--	--	9.42	66.64	--	--	--	--	(1)
39	C. cucullata	15.72	1.66	5.67	2.88	--	1.84[3]	--	--	2.31	77.61	36.71[4]	--	
39	" "	12.24	--	--	2.84	--	35.05	--	--	--	--	--	--	
39	" "	9.87	2.21	3.40	4.72	--	90.58[3]	--	--	--	--	--	--	
54	C. islandica	11.85	1.89	2.08	3.13	--	--	8.53	72.52	--	--	--	--	(1)
39	" "	14.50	1.35	2.45	3.27	--	5.33	--	87.60	--	--	--	--	
39	" "	9.30	1.20	6.33	8.30	--	10.80	--	73.37	--	--	--	--	
4	" "	12.52	1.32	2.89	4.03	--	7.11	--	72.13	--	--	--	--	(10)
52	" "	14.50	1.15	2.10	2.80	74.90	4.55	--	--	--	--	--	--	
54	C. nivalis	13.72	2.69	4.27	1.87	--	--	8.26	69.19	--	--	--	--	(9)
39	" "	15.00	1.64	4.18	1.88	--	2.88	--	89.42	--	--	--	--	
39	" "	11.36	2.20	2.50	3.95	--	91.37[3]	--	--	--	--	--	--	
52	" "	15.00	1.40	3.55	1.60	76.00	2.45	--	--	--	--	--	--	
54	C. hiascens	14.13	1.90	5.23	2.94	--	--	11.18	64.62	--	--	--	--	(9)
39	C. delisei	12.23	3.12	0.56	5.06	--	9.78	--	81.48	4.88	--	--	--	
54	Stereocaulon tomentosum	12.66	2.09	1.94	5.44	--	--	27.32	50.55	--	--	--	--	(9)
52	S. paschale	15.00	1.85	1.75	6.35	56.60	18.45	--	--	--	--	--	--	
39	" "	15.00	2.17	2.06	7.47	--	21.70	--	66.60	--	--	--	--	
39	" "	13.84	3.48	0.77	10.92	--	23.62	--	61.21	--	--	--	--	

TABLE 1. (cont.)

Source	Species	Moisture	Ash	Fat	Protein	Starch	Cellulose	Fiber	NFE	Albumen	Hemi-Cellulose	Lichenin	Other	Notes
39	*Alectoria ochroleuca*	12.30	6.18	10.05	1.87	--	0.83[3]	--	--	--	72.97	67.02[4]	--	
4	" "	11.20	2.96	10.19	2.30	--	--	--	72.71	--	--	67.02[11]	--	(12) (13)
52	*Parmelia encausta*	15.00	8.05	2.25	6.10	51.25	17.35	--	--	--	--	--	--	
39	" "	15.00	9.47	2.64	7.18	--	20.41	--	60.90	--	--	--	--	
52	*P. saxatilis*	15.00	10.70	14.75	5.30	47.15	7.10	--	--	--	--	--	--	
39	" "	15.00	12.58	17.30	6.30	--	8.32	--	55.45	--	--	--	--	
39	*Bryopogon jubatum*	9.85	1.01	1.27	7.31	--	4.51	--	85.90	--	--	--	--	
54	*Dactylina arctica*	13.12	2.54	5.94	2.81	--	--	8.52	67.07	--	--	--	--	(9)
54	*Peltigera* spp.	13.41	7.91	1.12	17.12	--	--	21.93	38.51	--	--	--	--	(9)
39	*Aspicilia* spp.	6.24	50.26	0.27	3.50	--	2.13	--	43.84	--	--	--	--	
4	Average, 8 spp. *Cladonia*	--	--	--	2.62									
39	"Lichenes"	--	2.9	3.30	4.18	--	--	23.51	63.91	--	--	--	--	23 analyses
42	"	--	2.4	3.6	4.0	--	34.7	--	55.3	--	--	--	--	100 analyses

(1) Listed by Palmer as a "Tall Growth" or "Moist-site" lichen.
(2) All figures listed in Palmer (1934) are originally from Spencer and Krumboltz (1929): Palmer makes a division into "Tall and Short Growth."
(3) Low figures (below 6 per cent) here include footnote indicating that these are "More probably correct" (?) percentages. The high (above 90 per cent) figures are combinations of cellulose and nitrogen-free extract ("NFE").
(4) Included in Hemicellulose.
(5) Listed as "minerals".
(6) Average of 10 analyses.
(7) "Light form."
(8) "Dark form."
(9) Listed by Palmer as a "Short Growth type" or "Dry-site" lichen.
(10) Average of 4 analyses.
(11) In per cent of dry matter.
(12) Average of 2 analyses.
(13) Ash is 84.12 per cent SiO_2.

TABLE 2. CHEMICAL COMPOSITION OF FORAGE PLANTS AND SOME CULTIVATED FEEDS, EXCLUDING LICHENS, IN PER CENT

Source	Species	Date	Moisture	Ash	Fat	Proteir	Starch	Cellulose	Fiber	NFE	Albumen	Hemi-Cellulose	Other	Notes
52	Salix hastata	?	15.00	4.40	3.00	14.80	51.10	11.70	--	--	--	--	--	(1)
39	" "	Aug.	12.49	3.74	3.78	13.25	1.45	--	12.23	--	12.06	17.62	9.45% reducing sugars.	
39	" "	?	15.00	4.40	3.00	14.80	--	--	11.70	51.10	--	--	--	(1)
52	S. lapponicum	?	15.00	3.60	2.65	14.00	47.00	17.75	--	--	--	--	--	
39	" "	?	15.00	3.60	2.65	14.00	--	--	17.75	47.00	--	--	--	
4	" "	?	15.00	3.50	2.65	14.00	--	17.75	--	47.33	--	--	--	
52	S. glauca	?	15.00	5.50	4.00	12.85	47.75	14.90	--	--	--	--	--	(1?)
39	" "	?	15.00	3.85	4.00	12.85	--	--	16.25	47.30	--	--	--	(1?)
39	" "	Aug.	7.05	6.71	4.35	19.94	1.91	--	15.80	--	12.25	18.68	5.12% reducing sugars.	
39	" "	?	11.63	7.90	4.40	34.70	--	--	13.20	39.80	--	--	--	
4	" "	?	11.15	6.90	3.98	18.54	--	16.87	--	--	13.79	--	--	(2)
52	S. herbacea	?	15.00	3.85	2.75	14.85	47.30	16.25	--	--	--	--	--	
39	" "	?	15.00	3.90	2.30	11.60	--	--	25.35	41.85	--	--	--	
4	S. rotundifolia	?	8.10	5.83	4.16	19.11	--	17.65	--	--	16.34	--	--	(3)
4	Betula nana	?	7.97	4.51	6.97	18.77	--	13.55	--	51.10	17.28	--	--	(4)
41	" "	July 5	9.40	3.30	7.10	16.60	--	--	14.30	58.70	15.30	--	--	
41	" "	July 6	11.00	4.30	7.80	27.80	2.01	--	8.50	51.60	25.20	5.67	7.40% reducing sugars.	
41	" "	July 9	9.20	3.30	6.50	13.30	--	--	15.00	61.90	13.10	--	--	
41	" "	July 9-29	64.70	4.20	6.80	25.40	--	--	12.10	51.50	21.40	--	--	(5)
41	" "	July 15	7.90	3.40	6.90	16.20	3.82	--	9.90	63.60	16.10	14.76	13.72% reducing sugars.	
41	" "	July 24	5.80	3.30	7.50	18.70	2.40	--	20.30	50.20	18.20	23.02	10.04% "	"
41	" "	Aug. 7	8.80	3.90	8.50	16.60	7.37	--	11.40	59.50	15.50	9.03	10.23% "	"
41	" "	Aug. 15	6.80	3.80	6.70	13.50	3.12	--	10.80	65.10	13.30	13.67	13.07% "	"

TABLE 2. (cont.)

Source	Species	Date	Moisture	Ash	Fat	Protein	Starch	Cellulose	Fiber	NFE	Albumen	Hemi-Cellulose	Other	Notes
41	Betula nana	Aug. 15	9.90	4.00	11.00	21.60	9.56	--	13.10	50.30	20.70	28.28	7.32% reducing sugars.	
41	" "	Aug. 21	6.60	4.10	9.10	13.20	2.39	--	17.20	56.40	10.30	17.55	8.43% "	"
41	" "	Sept. 5	6.70	3.50	8.10	8.20	--	--	26.00	54.20	6.70	27.34	4.85% "	"
4	Arctagrostis latifolia	?	8.47	8.99	3.00	9.52	--	34.21	--	35.81	9.36	--	--	
52	Poa alpina	?	15.00	3.90	2.30	11.60	41.85	25.35	--	--	--	--	--	
52	Aira flexuosa montana	?	15.00	4.70	2.80	10.15	44.00	23.35	--	--	--	--	--	
39	Carex aquatilis	?	--	6.50	4.0	10.54	--	--	37.21	41.74	9.89	--	--	
39	" "	?	--	5.36	3.12	11.62	--	--	39.82	40.08	11.19	--	--	
39	" "	?	7.7	6.00	2.50	9.50	--	--	29.30	52.70	8.50	--	--	
4	Equisetum arvense	?	?	10-15	3.1-3.57	11-20	--	13-23	--	--	9-17	--	12.1% reducing sugars.	
39	" "	?	11.44	15.14	3.56	17.50	1.81	--	13.32	--	16.80	3.04	" " 1.29% P_2O_5.	" ,
39	" "	?	13.24	15.20	3.57	11.02	--	--	17.54	52.67	9.94	--	--	
39	" "	?	8.49	13.97	3.10	12.59	--	--	23.89	46.45	10.91	--	--	
39	" "	?	--	10.50	3.22	20.00	--	--	17.58	48.70	14.24	--	--	
39	E. hiemale	?	10.02	18.11	3.68	5.75	--	--	20.26	52.20	5.00	--	--	
39	E. variegatum	?	9.95	11.09	3.05	10.38	--	--	16.65	58.83	7.94	--	--	
39	" "	?	10.75	12.40	3.27	8.44	--	--	16.91	58.98	6.94	--	--	
39	Epilobium angustifolium	June 2	9.55	9.40	2.26	18.75	--	--	17.57	52.02	17.50	--	--	
39	" "	July 5	8.35	5.90	1.69	8.69	--	--	27.77	55.75	8.19	--	--	(6)
39	" "	June 6	6.31	6.12	3.68	14.94	--	--	24.48	50.78	13.18	--	--	
39	" "	June 6	7.20	5.00	4.75	11.10	--	--	38.50	40.67	--	--	--	
4	Rumex acetosa	?	12.78	4.25	1.11	6.81	--	56.58	--	58.49	--	--	--	(7)
41	" "	July 7	12.80	4.90	1.30	7.80	--	--	42.00	44.00	--	--	--	(8)

TABLE 2. (cont.)

Source	Species	Date	Moisture	Ash	Fat	Protein	Starch	Cellulose	Fiber	NFE	Albumen	Hemi-Cellulose	Other	Notes
41	Rumex acetosa	?	90.4	15.4	--	30.5	--	--	--	48.0	29.7	--	--	(9)
41	" "	?	91.5	12.5	--	--	--	--	--	--	31.5	--	--	(10)
41	" "	?	91.8	--	--	21.3	--	--	--	--	19.1	--	--	(11)
41	" "	?	10.9	10.8	--	27.7	--	--	--	58.6	22.0	--	--	(9)
41	" "	June 6	85.8	10.4	--	--	--	--	27.5	33.1	20.0	--	--	(9)
41	" "	?	88.5	12.2	--	22.7	--	--	14.1	--	18.4	--	--	(12)
41	" "	?	--	12.0	--	23.0	--	--	15.4	--	16.6	--	--	(13)
41	" "	?	88.5	6.9	--	24.5	--	--	--	--	21.4	--	--	(9)
41	" "	?	89.8	9.0	3.3	22.7	--	--	12.8	53.0	16.8	--	--	(9)
42	Menyanthes trifoliata	?	--	5.2	3.0	9.9	--	--	19.6	62.3	7.5	--	--	(14)
42	" "	Aug. 22	--	7.0	11.3[15]	13.4	--	--	12.8	55.5	13.4	--	--	(16)
42	" "	?	--	9.2	3.3	15.7	8.30	--	14.2	57.6	14.5	6.82	5.83% reducing sugars.	
42	" "	?	--	9.3	3.2	13.7	7.84	--	19.3	54.5	12.3	20.84	4.90% " "	
42	" "	?	--	8.2	4.7	13.1	--	--	17.3	56.3	12.6	--	--	
39	Fungi	?	90.0	8.25	4.22	34.03	--	--	9.50	44.0	--	--	--	
42	"	?	--	8.0	5.3	35.5	--	32.1	--	19.1	--	--	--	
17	Alfalfa (dry roughage)	?	9.5	8.2	2.0	14.8	--	--	28.9	36.6	--	--	--	
17	Raw bone meal concentrate	?	6.4	59.1	5.0	26.0	--	--	1.0	2.5	--	--	--	
17	Red clover silage	?	69.1	2.4	0.9	4.0	--	--	10.2	13.4	--	--	--	

(1) Evidently from same original source, with items differing in translation. According to Palmer, his figures obtained from Norwegian "Indstilling fra Fjeldbeitekomiteen om Hardangerviddens utnytelse - Landbruksdepartmentet." Oslo, 1911. Aksenova's figures appear to be third hand, as the reference source given is "Vashkevich."
(2) Average of 5 analyses, except the figure for "Albumen," which appears to be taken from a different source.
(3) Data originally from Sochava (1933).
(4) Average of 16 analyses, except NFE which is average of 4 analyses, possibly from a different source.
(5) Several additional figures appear in this volume, but they cover a lesser range of nutrients.

TABLE 2. (Footnotes cont.)

(6) In bloom.
(7) End of blossoming.
(8) Entire plant.
(9) Leaves.
(10) Leaf blades.
(11) Fruit.
(12) Fresh leaves.
(13) Dry leaves.
(14) Fruiting, marsh plant.
(15) "May be inaccurate."
(16) Fruiting.
(17) Morrison (op. cit.) Entered for purposes of comparison.

TABLE 3. COMPOSITION OF THE ASH OF LICHENS AND OTHER FOOD PLANTS, IN PER CENT

Source	Species	Si	Fe	Fe_2O_3/Al_2O_3	Ca	Mg	K	P	Cl	S	Na	Notes
39[1]	Cetraria cucullata	43.32[2]	0.97[3]	20.90	1.27[4]	3.84[5]	11.02[6]	7.87[7]	1.97	--	--	
39	Cladonia rangiferina	78.37[2]	0.78[3]	9.72	0.55[4]	4.56[5]	3.38[6]	2.81[7]	0.12	--	--	
39	Cl. alpestris	84.10[2]	0.85[3]	7.58	0.47[4]	1.15[5]	1.79[6]	2.91[7]	0.19	--	--	
39	Alectoria ochroleuca	31.54[2]	4.72[3]	25.30	1.68[4]	11.28[5]	10.90[6]	11.51[7]	0.93			
41	Rumex acetosa	3.76	0.87	--	22.48	4.98	28.36	4.85	3.39	0.86	0.54	
41	" "	1.36	2.45	--	13.03	5.70	28.22	2.99	3.14	3.12	4.98	
41	Betula nana	37.9 [2]	4.8	28.6	6.2	7.7	15.9	4.4	3.4	3.0	7.1	
41	" " ("4.1% ash")	1.62[2]	0.20	1.21	0.26	0.33	0.68	0.19	0.15	0.13	0.31	
41	" "	31.14[2]	--	6.41	16.31	4.41	10.59	13.91	0.90	4.28	2.64	
41	Salix glauca	1.45	4.51	--	10.3	2.25	12.3	1.73	4.9	3.16	2.5	Total Ash 7.4%.
41	" "	0.10	0.31	--	0.71	0.15	0.85	0.12	0.34	0.22	0.17	Dry vernal leaves.
41	" "	--	1.72	--	17.78	8.62	5.59	4.71	--	--	--	Total Ash 6.7%.
41	" "	--	0.114	--	1.19	0.576	0.375	0.315	--	--	--	Dry vernal leaves.
8	Alfalfa Hay	--	0.025	--	1.47	0.29	2.05	0.24	0.37	0.32	0.13	
8	Raw bone meal concentrate	--	0.018	--	23.02	0.24	0.23	10.22	0.09	0.17	0.74	
8	Red clover silage	--	--	--	0.50	0.12	0.53	0.07	0.26	0.05	0.07	

(1) Originally "From V. B. Sochava", publication not specified.
(2) As SiO_2.
(3) As Fe_2O_3.
(4) As CaO.
(5) As MgO.
(6) As K_2O_5.
(7) As P_2O_5.
(8) From Morrison, Frank B. Feeds and Feeding. 21st Ed. Morrison Pub. Co., Ithaca, N.Y., 1950. 1207 pp. Entered for purposes of comparison.

TABLE 4. RELATIVE FORAGE VALUE OF LICHENS

From Palmer (1927)

(1) Most important, because of high palatability and greatest abundance:

Cladonia sylvatica sylvestris.
Cladonia rangiferina.
Cladonia sylvatica.
Cladonia alpestris.
Cladonia amaurocraea subspp.
Cladonia amaurocraea celotea.
Cladonia amaurocraea oxyceras.
Cladonia uncialis.
Cladonia uncialis obtusata.
Cladonia uncialis turgescens.
Cladonia gracilis elongata.
Cetraria cucullata.
Cetraria islandica.

(2) Of medium importance, because of lower palatability and only local abundance or of medium palatability:

Cladonia delessertii.
Cladonia decorticata.
Cladonia squamosa subspp.
Cladonia degenerans.
Cladonia amaurocraea celotea.
Cladonia amaurocraea crasipedia.
Cladonia uncialis adunca.
Cladonia gracilis dilatata.
Cladonia gracilis ecmocyma.
Cetraria islandica crispa.
Cetraria islandica platyna.
Cetraria nivalis.
Cetraria richardsonii
Alectoria ochroleuca.
Dactylina arctica.
Nephroma arcticum.
Stereocaulon alpinum.
Stereocaulon coralloides.
Stereocaulon tomentosum.

(3) Of value only as mixed with other species, because of very scattering occurrence:

Cladonia bellidiflora.
Cladonia crispata subspp.
Cladonia deformis extensa.
Cladonia digitata glabrata.
Cladonia furcata.
Cladonia cyanipes.
Cladonia alpicola.
Cladonia cenotea.
Cladonia fimbriata.
Cladonia alaskana.
Cladonia gracilis chordalis.
Cladonia gracilis.
Cladonia gracilis subtilacerata.
Cladonia subsquamosa.
Cladonia sylvatica laxiuscula.
Cladonia uncialis turgescens.
Cladonia alpestris inturgescens.
Alectoria nigricans.
Cetraria aculeata.
Cetraria chrysantha.
Cetraria hiascens.
Centraria islandica crispa.
Centraria islandica platyna.
Sphaerophorus coralloides.
Duforea ramulosa.
Letharia thamnodes.
Thamnolia vermicularis.
Parmelia spp.

TABLE 4. (cont.)

(4) Of little or no value because of diminutive size, infrequent occurrence, mode of growth, or unpalatableness:

Cladonia botrytis
Cladonia coccifera subspp.
Cladonia degenerans euphorea.
Cladonia pumilata subspp.
Lecanora spp.
Lecidea spp.
Lobaria spp.
Ochrolechia spp.
Peltigera spp.
Physcia pulverulenta fuscigena.
Psoroma hypnorum.
Pertusaria bryontha.
Pilophorus cereolus robustus.
Ramalina dilacerata.
Siphula ceratitica.
Xanthoria lychnea pygmaea.
Cyrophora spp.

Cetraria juniperina.
Cetraria juniperina terrestris.
Alectoria jubata.
Icmadolphila ericetorum.

TABLE 5. THE RELATIONSHIP OF LICHEN OCCURRENCE TO SOIL REACTION

From I V. Larin (1937): "According to the observations of T. A. Rabotnoff in South Yakutia"

Species	No. Records	Median pH	Quartiles pH	Extreme Deviations pH	
Cladonia alpestris	20	4.0	3.8-4.2	3.55-5.1	
Cl. rangiferina	7	3.9	3.9-4.1	3.55-4.6	
Cl. mitis	11	4.1	4.0-4.2	3.75-4.55	(1)
Cl. amaurocraea	3	4.15	--	4.0 -4.3	
Cl. uncialis	5	4.1	4.1-4.2	3.85-4.3	
Cl. graciliscens	6	5.2	4.8-5.36	4.5- 5.75	
Cl. cornuta	1	--	--	4.2	
Cl. ecmocyna	5	4.9	--	4.25-5.15	
Cl. deformis	3	3.95	--	3.9 -4.1	
Cl. gracilis	2	--	--	3.95-4.1	
Cl. pyxidata	2	--	--	6.06-6.7	
Cetraria delisei	6	5.5	5.36-6.6	4.15-6.3	(2)
C. nivalis	4	3.9-4.9	--	3.75-5.8	(3)
Stereocaulon paschale	9	5.1	4.85-5.36	4.45-6.1	
S. alpinum	2	--	--	4.2-4.25	
Alectoria ochroleuca	2	--	--	3.9-4.9	
Icmadophila ericetorum	4	3.9-4.0	--	3.75-4.0	
Peltigera erumpens	2	--	--	6.05-7.7	
P. canina	3	6.6	--	6.15-7.25	
P. rufescens	2	--	--	6.24-6.7	

(1) Better developed at pH 4.0-4.5.

(2) At pH 4.15, shows signs of oppression.

(3) Shows signs of oppression at pH 5.8. A pH of 3.75-3.9 favors development.

TABLE 6. LICHEN SUCCESSION

From Palmer (1944).

"Species included in the various stages in lichen succession and the groupings as given in this study are chiefly as follows."

(1) Primary Stage

Crust lichens (Crustose)	Other lichens
Ochrolechia spp.	Stereocaulon tomentosum
Pertusaria spp.	Stereocaulon alpinum
Lepra spp.	Cetraria nivalis
Diploschistos spp.	Sphaerophorus coralloides
Ephebe spp.	Cetraria hiascens
Lecanora spp.	Thamnolia vermicularis
Baeomyses spp.	Letharia spp.
Psoroma spp.	Siphula spp.
Buellia spp.	Gyrophora spp.
Lecedea spp.	

(2) Secondary Stage

Short Growth lichens Genus Cladonia			Leaf lichens
squamosa	coccifera	alpicola	Nephroma spp.
decorticata	bellidiflora	furcata	Lobaris spp.
fimbriata	pyxidata	crispata	Peltigera spp.
verticillata	degenerans		Cetraria chrysantha
cornuta	deformis		Parmelia spp.
cyanipes	gracilescens		Cetraria aculeata
œnotea	ochrochlora		
digitata	subsquamosa		
gracilis dilatata			
cariosa cribosa			

(3) Final Stage

Tall Reindeer lichens Genus Cladonia	Other tall growth forms
sylvatica sylvestris	Cetraria cucullata
sylvatica	Cetraria islandica
rangiferina	Cetraria islandica platyna
alpestris	Cetraria islandica platyphylla
uncialis	Cetraria richardsonii
amaurocraea	Alectoria jubata
gracilis elongata	Alectoria nigricans
delessertii	Alectoria ochroleuca

TABLE 7. ANALYSES OF STOMACH CONTENTS OF THE GENUS RANGIFER, (See also Figure 1.)

A. From Banfield (1954).

"Summer Stomach Analysis" Lake Clinton-Colden, Canada.

Species	Vol. c.c.	Decimal Occurrence	Plant Coverage	Decimal Coverage of Plant Cover	Palatability
Mushrooms	15	0.012	T	T	High
Equisetum spp.	8	0.006	T	T	"
Cladonia rangiferina	44	0.034	T	T	"
Cl. alpestris	10	0.008	T	T	"
Cetraria nivalis	301	0.230	0.014	0.030	7.66
C. islandica	52	0.040	T	T	High
Salix spp.	206	0.157	0.018	0.039	3.98
Grasses and sedges	368	0.281	0.045	0.096	2.92
Betula glandulosa	216	0.165	0.033	0.071	2.36
Vaccinium vitis-idaea	47	0.036	0.024	0.056	0.67
Ledum decumbens	16	0.012	0.084	0.180	0.67
Arctostaphylos alpina	19	0.013	0.041	0.088	0.15
Vaccinium uliginosum	3	0.002	0.040	0.086	0.02
Alectoria ochroleuca	1	0.001	0.022	0.047	0.02
Empetrum nigrum	1	0.001	0.029	0.062	0.02
Loiseluria precumbens	1	0.001	T	T	Low
Dryas integrifolia	T	T	T	T	"
Rhododendron lapponicus	T	T	T	T	"
Phylodoce caerulea	T	T	T	T	"
Mosses	T	T	0.042	0.090	"

TABLE 7. (cont.)

B. From Bonner (1958).

"Analysis of Rumen Contents of Seven South Georgia Reindeer" in Summer (January).

Species	1	2	3	4	5	6	7
Grasses							
All species	++++	++++	-	-	+	+	++++
Poa flabellata	+++	++	+	-	++	+	-
Poa annua	+++	+++	-	+	-	-	+++
Phleum alpinum	-	-	+	+	-	+	-
Deschampsia antarctica	+	-	-	-	-	-	-
Acaena tenera	+	++	+	+++	++	+	++
Rostkovia magellanica	++	-	+++	+++	++	+++	+
Mosses	+	+	++	++	+	+++	+++

"The minus sign does not indicate that the species was absent, but that it was not identified."

TABLE 7. (cont.)

C. From Chatelain (1953).

Species	Per cent Frequency of Occurrence	Per cent Volume
Lichens (fruticose)	100.0	29.8
Grass-Sedge	100.0	23.4
Willow	89.5	17.5
Dwarf birch	94.7	13.3
Unid. browse twigs	73.7	6.1
Blueberry	71.7	2.9
Moss	63.2	1.7
Forbs	28.9	1.2
Cranberry	36.8	1.1
Equisetum spp.	15.8	1.0
Foliose lichens	)	
Ferns	)	
Crowberry	)	2.0
Ledum spp.	)	
Spruce	)	
Arctostaphylos alpina	)	

TABLE 7. (cont.)

D. From A. Murie (1944). (Text).

Mt. McKinley (Alaska) caribou

Species or group	June 14, 1939 (calf)	June 15, 1940 (cow)	July 2, 1941 (cow)
Green grass	99%	40%	99%
Dwarf willow, *Salix* spp.	T	--	--
"Smooth" dwarf willow	--	30%	--
Salix reticulata	--	29%	--
Willow, *Salix* spp.	--	--	T
Lichen	T	--	--
Vaccinium vitis-idaea	T	--	--
Hedysarum spp.	--	--	T
Dwarf Arctic Birch, *Betula* spp.	--	--	T
Other plants	--	1%	--

NOTE: All three animals found dead on range.

TABLE 7. (cont.)

E. From O. Murie (1935).

"Plants eaten by caribou, as shown by contents of 24 stomachs."

Plant	February			April			July - August			September			Year-round Food[1]	
	Stomachs in which found No.	Contents Represented Max. %	Ave. %	Stomachs in which found No.	Contents Represented Max. %	Ave. %	Stomachs in which found No.	Contents Represented Max. %	Ave. %	Stomachs in which found No.	Contents Represented Max. %	Ave. %	Stomachs in which found No.	Contents Represented Average %
Grasses and sedges	4	50	35 3/4	4	65	37 1/2	4	30	16 1/2	9	35	18 1/3	24 (2)	30
Lichens	4	30	18 3/4	4	10	4 1/2	6	40	15	9	65	40 1/2	24 (3)	24
Mosses	4	20	12 1/2	4	30	13 3/4	4	5	3 1/2	9	10	7 1/4	24 (4)	8
Salix spp.	4	10	5	--	--	--	6	80	33 1/3	7	5	4 1/2	23 (5)	9
Betula rotundifolia	1	1	1	3	2	1	4	50	28 3/4	8	10	4 1/4	18	6
Vaccinium vitis-idaea	4	3	2 1/2	4	15	6 3/4	5	1	1	9	10	4	22	3
V. uliginosum	--	--	--	--	--	--	--	--	--	2	2	1/	4	(6)
V. oxycoccus	--	--	--	--	--	--	--	--	--	1	1	1	1	(6)
Ledum decumbens	3	1	1	4	2	1	4	1	1	8	3	1 1/2	19	1
Arctostaphylos uva-ursi	1	1	1	--	--	--	1	1	1	--	--	--	2	(6)
Arctous alpina	--	--	--	--	--	--	1	1	1	--	--	--	3	(6)
Empetrum nigrum	--	--	--	--	--	--	1	1	1	2	1	1-	2	(6)
Cassiope spp.	1	1	1	1	(7)	(7)	--	--	--	--	--	--	--	--
C. mertensiana	--	--	--	--	--	--	--	--	--	--	--	--	2	(6)
C. lycopodiodes	--	--	--	--	--	--	--	--	--	1	1	1	2	(6)
Picea (2 spp.)	4	3	1 3/4	4	2	1	--	--	--	1	1	1	2	(6)
Alnus spp.	--	--	--	--	--	--	2	10	5	7	2	1	23 (8)	1
Lycopodium spp.	--	--	--	--	--	--	--	--	--	1	(7)	(7)	1	(6)
Equisetum spp.	--	--	--	--	--	--	1	1	1	--	--	--	1	(6)
Populus balsamifera	--	--	--	--	--	--	1	(7)	(7)	--	--	--	1	(6)
Phyllodoce empetriformis	--	--	--	1	(7)	(7)	--	--	--	1	1	1	2	(6)

TABLE 7. (E, cont.)

Plant	February			April			July - August			September			Year-round Food[1]	
	Stomachs in which found No.	Contents Represented Max. %	Ave. %	Stomachs in which found No.	Contents Represented Max. %	Ave. %	Stomachs in which found No.	Contents Represented Max. %	Ave. %	Stomachs in which found No.	Contents Represented Max. %	Ave. %	Stomachs in which found No.	Contents Represented Average %
Diapensia lapponica	--	--	--	2	(7)		(7) --	--	--	2	1	1	4	(6)
Dryas octopetala	--	--	--	4	5	2 1/2	--	--	--	2	1	1	11	1
Polygonaceae	--	--	--	1	(7)		(7) --	--	--	--	--	--	1	(6)
Harrimanella stelleriana	1	1	1	--	--	--	--	--	--	--	--	--	1	(6)
Chamaecistus procumbens	1	(7)		(7) --	--	--	1	(7)		(7) 3	1	1	5	(6)
Andromeda	--	--	--	--	--	--	1	1	1	--	--	--	1	(6)
Fungus ("toadstool")	--	--	--	--	--	--	1	(7)		(7) --	--	--	1	(6)
Fabaceae	--	--	--	--	--	--	1	(7)		(7) --	--	--	1	(6)
Triglochin	--	--	--	--	--	--	1	(7)		(7) --	--	--	1	(6)
Pyrola spp.	--	--	--	--	--	--	--	--	--	--	--	--	1	(6)
P. grandiflora	--	--	--	--	--	--	--	--	--	--	--	--	1	(6)

(1) Includes stomachs not represented in preceding columns.
(2) Hierochlea odorata, 2; Bromus spp., 1; Danthonia spicata, 1.
(3) Cladonia spp., 22; Cl. belliflora, 1; Cl. sylvatica, 1; Cetraria cucullata, 1; Thamnolia vermicularis, 2.
(4) Hypnum spp., 10; H. schreberi, 6; Dicranum, spp., 19; D. groenlandicum, 1; D. neglectum, 2; D. scoparium, 1; Polytrichum spp., 20; P. alpinum, 1; P. commune, 3; P. strictum, 3; Hyloconium proliferum, 12.
(5) Salix spp., 23; S. phlebophylla, 1.
(6) Grouped as "miscellaneous," totaling 17 per cent.
(7) Trace.
(8) Picea canadensis, 13; P. mariana, 10.

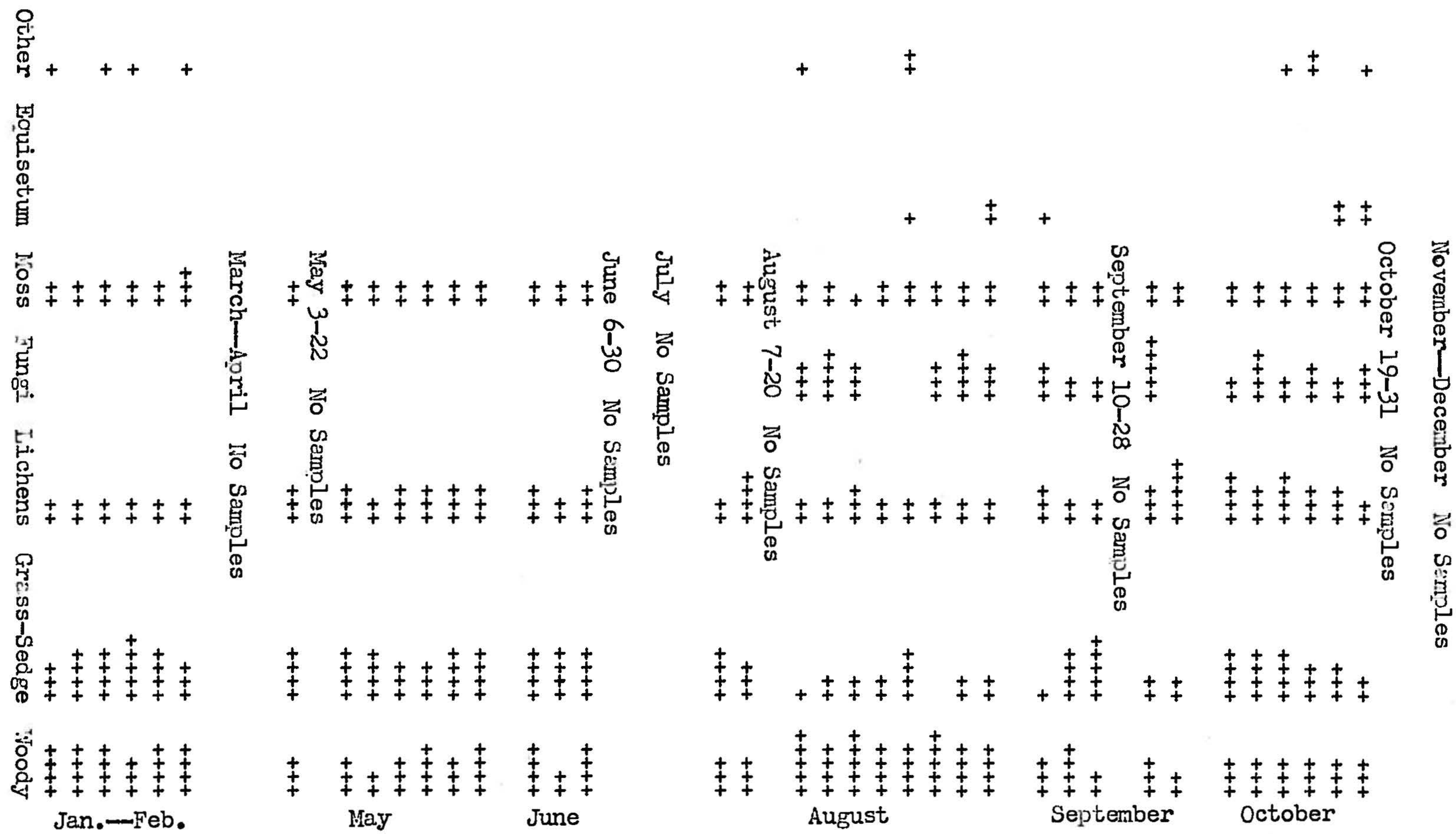
TABLE 7. (cont.)

F. From Skoog (1956). (Various tables).

Steese-Fortymile (Alaska) caribou.

Plant Group	November (1952) 19 samples		July (1955) 4 samples		August 20-31 (1954) 19 samples			September 1-7 (1954) 29 samples			September 12-24 (1954) 22 samples		
	Mean Per cent	Percentage Range	Mean Per cent	Percentage Range	Mean Per cent	Range	Standard Deviation	Mean Per cent	Range	Standard Deviation	Mean Per cent	Range	Standard Deviation
Lichen	55	25-80	6	1-15	15.1	0.5-37.4	10.8	17.8	0.2-45.2	11.1	47.8	5.8-71.2	19.1
Woody	15	5-35	75	62-84	36.0	9.6-75.2	21.1	43.1	7.7-93.6	23.6	12.4	2.6-40.0	8.4
Grass-Sedge	25	10-60	18	7-34	0.7	0.0- 3.4	1.1	4.1	T-20.0	4.3	10.2	0.5-21.0	6.3
Fungi	T	0-T	0	0	45.3	11.5-84.0	22.9	30.3	4.4-66.5	20.0	19.5	0.0-63.2	16.8
Moss	T	0-T	T	0-T	2.3	0.0- 5.7	2.9	4.3	T-10.0	2.6	6.0	T-18.7	6.3
Forbs	0	0	1	0-4	0.7	T- 3.4	1.2	0.2	0.0- 3.2	0.5	0.4	0.0- 2.7	0.6

NOTE: All figures are percentages, based on volumetric measurement.



\+ Enough present to identify

++ More than + but less than 10 per cent

+++ More than 10 per cent but less than 33 per cent

++++ More than 33 per cent but less than 66 per cent

+++++ More than 66 per cent

FIGURE 1. PROPORTIONS OF PLANT GROUPS IN CARIBOU RUMINA ACCORDING TO TIME OF YEAR
Position of + on abscissa indicates approximate date, except for Jan.—Feb. samples, for which no dates were available. Amounts are visual éstimates of volumes. From Courtright (1957).

TABLE 8. RESULTS OF FEEDING EXPERIMENTS WITH REINDEER AND CARIBOU

From Palmer (1942).

"Summary of feeding tests with reindeer and caribou (Feeding trials: 20 days - 1 month)."

No. Animals	Ave. wt. of animals Start lbs.	Ave. wt. of animals End lbs.	Ave. loss or gain lbs.	Feed per head per day Kind	Feed per head per day Amount Given lbs.	Feed per head per day Amount Eaten lbs.	Indicated sustaining feed per day Per animal as fed lbs.	Indicated sustaining feed per day Per animal as eaten lbs.	Indicated sustaining feed per day Per 100 lbs. live wt. as fed lbs.	Indicated sustaining feed per day Per 100 lbs. live wt. as eaten lbs.
2	268.25	273.5	5.25	Lichens/oats	13.0	6.75	11.0	5.71	4.11	2.13
2	271.5	263.5	-8.0	Lichens	14.6	5.41	16.0	5.93	5.80	2.18
2	275.0	274.0	-1.0	Alfalfa	10.0	4.34	10.0	4.34	3.64	1.58
4	150.0	147.4	-2.6	Pea hay	4.0	3.46	--	--	--	--
3	151.33	144.33	-7.0	" "	5.0	2.21	5.5	3.50	3.66	2.33
3	124.0	122.2	-1.8	Vetch/oats	2.0	1.65	--	--	--	--
3	126.0	120.0	-6.0	" "	3.0	2.42	3.5	2.85	2.80	2.28
3	210.66	189.33	-21.33	Pea hay/oats	3.45	--	--	--	--	--
3	189.33	178.66	-10.67	" " "	4.46	--	5.5	--	2.75	--
5	207.2	215.3	8.1	Alfalfa/grain	7.16	--	7.0	--	3.38	--
6	134.2	137.3	3.1	" "	5.0	--	5.0	--	3.73	--
8	176.4	172.3	-4.1	Alfalfa/oats	6.0	--	--	--	--	--
8	172.3	185.3	13.0	" "	6.5	--	6.25	--	3.59	--
8	185.3	193.5	8.2	Alfalfa meal/oats	7.4	--	--	--	--	--
8	193.5	202.9	9.4	Alfalfa meal/oats	7.74	--	--	--	--	--
8	202.5	217.9	15.0	" " "	8.73	--	7.0	--	3.61	--
								AVERAGE	3.70	2.10
				"Feed requirement/250 lb. caribou/day"					9.25	5.25
				Per cent of feed utilized						57%

TABLE 9. DIGESTIBILITY OF NUTRIENTS OF VARIOUS FEEDS IN EXPERIMENTS WITH REINDEER

From Aksenova (1937). Text (English Summary).

	Protein	Cellulose	NFE	Ash	Fat
Lichens	"low"	73.2	71.1	"very low"	68.3
Salix lanata (dry hay)	49.08	56.53	73.00	40-42	66.5
Brown hay of grass, sedge, various herbs	65.43	61.10	73.30	?	?
Lichens - "According to Dmitrochenko"	21.9	78.4	78.3		"poor"

NOTE: All figures are digestibility coefficients in per cent.

TABLE 10. RATINGS AND DESCRIPTIONS OF PALATABILITY, FORAGE VALUE, OR OTHER INDICATIONS OF VALUE OF FORAGE PLANT, FORAGE TYPES, OR AREAS

(A) From Alexandrova (1940) (in text)

Species	
Alectoria ochroleuca	Little eaten; used when fodder is scarce, when growing in combination with other species.
Cetraria islandica	"Much eaten."
Cladonia alpestris	Much eaten, but not as much as Cl. sylvatica or Cl. rangiferina.
Cl. crispata	"Much eaten, together with other species."
Cl. rangiferina	"Much eaten, being in a number of regions one of the principal lichen forages."
Cl. sylvatica	"Very much eaten."
Stereocaulon tomentosum	"Eaten by reindeer when damp."
Equisetum arvense	"Much eaten. . .in green condition, in autumn stays green a long time."
Lycopodium alpinum	Not eaten.
L. pungens	Not eaten.
Arctagrostis latifolia	Much eaten, principally young shoots and top leaves, during growing season.
Populus tremula	Leaves and young shoots eagerly eaten.
Salix glauca	In most regions the most important species of bushy forage, due to abundance and nutritive value.
S. lapponica	Much eaten.
S. rotundifolia	Much eaten by reindeer, especially the young leaves. Eaten also in winter under the snow.

TABLE 10. (A, cont.)

Betula nana	Much eaten, especially in spring and summer. Fallen leaves under snow eaten in absence of better forage.
Rumex acetosa	Much eaten.
Potentilla fruticosa	No information on reindeer use.
Rubus chamaemoris	Much eaten in summer, being one of favorite forages.
Empetrum nigrum	Eaten mainly during forage scarcity. Berries eaten. May furnish green forage in winter, of low value.
Epilobium palustre	Eagerly eaten in summer.
Andromeda polifolia	Not eaten. Contains poison, andromedoforin.
Arctostaphylos uva-ursi	Not eaten.
Arctous alpina	Leaves and fruit occasionally eaten. Use increases in fall.
Ledum palustre	Sometimes grabbed with other plants. Contains harmful substance, ledum camphor. May give lichens an unpleasant odor, causing the latter to be avoided.

TABLE 10. (cont.)

(B) From Banfield (1954). (in text).

"High summer palatability"

("Palatability= $\frac{\text{Relative occurrence of plant in stomach samples}}{\text{Relative occurrence of plant on range}}$"

Species

Lactorius spp.
Hygrosphorus spp.
Russula spp.

Cladonia rangiferina
Cl. alpestris
Cetraria nivalis
C. islandica

Salix pulchra
S. reticulata
S. cordifolia
S. planifolia
S. aretophila

Equisetum spp.

Calamagrostis canadensis
C. purpurascens
C. deschampsioides
Deschampsia caespistosa
Agrostis borealis
Poa glauca
Hierochloe alpina

Carex concolor
C. membranacea
C. rariflora

Eriophorum vaginatum

Betula glandulosa

"Plants thinly distributed on range which were eaten by caribou"

Hedysarum alpinum

Astragalus alpinus

Oxytropis maydelliana

Vaccinium vitis-idaea

"Low summer palatability"

Ledum decumbens

Arctostaphylos alpina

Vaccinium uliginosum

Empetrum nigrum

Loiseluria procumbens

Dryas integrifolia

Rhododendron lapponicum

Phyllodoce caerula

Mosses

TABLE 10. (cont.)

(C) From Palmer (1926).

"Plants grazed during the summer in order of relative forage value."

(1) Most important, because of high palatability and greatest abundance:

Eriophorum callitrix (small cotton sedge).
Eriophorum angustifolium (large cotton sedge).
Salix (willows).
Cladonia (mostly) (lichens).
Betula rotundifolia (ground birch).
Ledum decumbens and L. groenlandicum (Alaska tea).

(2) Of medium importance, because of high palatability and only local abundance or of medium palatability:

Alnus alnobetula (alder).
Vaccinium vitis-idaea (mountain cranberry).
Empetrum nigrum (crowberry).
Vaccinium uliginosum (blueberry).
Dryas octopetala (dryad).
Ranunculus pallasii (water buttercup).
Equisetum (horsetail).
Valeriana capitata (valerian).
Pedicularis spp. (fernweed).
Epilobium angustifolium (fireweed).
Artemisia arctica and A. tilesii (wormwood).
Lupinus arcticus (lupine).
Astragalus alpinus and A. littoralis (vetch).
Polygonum alaskanum (smartweed).
Rumex occidentalis (dock).
Coelopleurum gmelini (parsnip).
Ligusticum scoticum (Scotch lovage).
Carex (sedge).
Poa (grass)
Arctagrostis, Calamagrostis, Festuca, Agrostis, Phleum (grasses).

(3) Of less importance, because of lower palatability:

Rubus chamaemorus (cloudberry).
Ribes triste (currant).
Viburnum pauciflorum (cranberry bush).
Rubus arcticus (raspberry).
Arctous alpina (alpine bearberry).
Betula kenaica (birch).
Conioselinum gmelini (hemlock parsley).
Bupleurum americanum (hare's-ear).
Merckia physodes (beach starwort).
Lathyrus maritimus (beach pea).
Mertensia paniculata (bluebells).

TABLE 10. (cont.)

(D) From Palmer (1926).

"Summary of forage types in the stand on summer and winter ranges showing in percentages the composition, density, palatability, and forage value."(1)

Section	Composition						Palatability	Forage value
	Lichen	Browse	Sedge	Weeds	Moss	Density		
Coast summer range:								
St. Lawrence Island	0	5	91	3	1	90	65	58.5
Kivalina----------	5	15	47	31	2	79	68	53.7
Kotzebue Sound-----	10	26	51	5	8	93	64	59.5
Seward Peninsula---	7	15	53	24	1	68	60	40.8
Norton Sound-------	11	22	50	5	12	92	51	46.9
Yukon-Nunivak Is.--	9	15	57	15	4	90	60	54.0
Kuskokwim----------	6	40	34	17	3	70	67	46.9
Average	7	20	55	14	4	83	62	51.4
Interior summer range:								
Broad Pass---------	18	28	27	12	15	96	70	67.2
Gulkana-Tangle Lakes---	16	34	29	10	11	88	68	59.8
Average	17	31	28	11	13	92	69	63.5
Coast winter range:								
St. Lawrence Island	65	12	2	11	10	40	80	32.0
Kotzebue Sound-----	50	25	15	10	0	60	70	42.0
Seward Peninsula---	50	15	30	5	0	70	75	52.5
Norton Sound-------	50	10	30	4	6	87	67	58.3
Yukon-Nunivak Is.--	50	10	30	2	8	99	66	65.3
Kuskokwim----------	47	30	10	3	10	70	70	49.0
Average	52	17	20	6	6	71	71	50.0
Interior winter range:								
Broad Pass---------	50	20	8	4	18	85	76	64.6
Gulkana-Tangle Lakes---	53	23	11	6	7	85	83	70.5
Average	52	22	10	5	13	85	80	67.5

(1) "Forage value derived by multiplying the percentage of density of forage stand by the percentage of palatability."

TABLE 10. (cont.)

(E) From Palmer (1934a).

"Summary of principal forage types occurring on the coast reindeer range between Nunivak Island and Kotzebue Sound."

Type	Subtype	Average forage value.[1]	Distribution
Lichen--	--------	5.00	Ridges and interior hills; fall and winter range.
"	Sedge---	5.25	" " " " "
"	Browse--	5.50	" " " " "
"	Grass---	4.25	" " " " "
Sedge	--------	6.00	Tundra types--on flats, benches, and lower slopes; summer and fall range.
"	Browse--	5.70	" " " " "
"	Lichen--	6.35	" " " " "
"	Grass---	4.95	" " " " "
Conifer-	--------	3.20	Along rivers and creeks.
"	Grass---	3.20	" " " "
"	Browse--	3.90	" " " "
"	Lichen--	2.50	" " " "
Browse--	--------	4.45	Slopes and ridges; summer range.
"	Grass---	3.50	" " " " "
"	Sedge---	5.40	" " " " "
Grass---	--------	4.00	Over relatively small areas on sandy spits; coast types of summer range.
"	Browse--	5.00	" " " " "
"	Weed----	3.00	" " " " "

[1] Derived by multiplying the percentage of density of forage stand by the percentage of palatable plants.

TABLE 10 (cont.)

(F) From Palmer (1934a).

"Summary of principal forage types occurring on some of the far interior reindeer ranges, particularly over the Broad Pass, Gulkana, and Tangle Lakes region."

Type	Subtype	Average forage value.[1]	Distribution
Lichen--	--------	5.75	
"	Browse--	6.50	Ridges, upper slopes and benches, and glacial canyons.
"	Browse, weed---	4.80	Upper steep slopes.
"	Grass	6.00	Foothills of upper drainages.
Browse--	--------	6.40	
"	Lichen--	6.50	Lower ridges and slopes, and shallow draws of benchlands.
"	Grass---	6.15	Old burns, and in open parks in timber.
"	Weed----	6.65	Lower slopes.
Grass---	Lichen--	6.85	Benchlands.
Conifer-	Browse--	5.40	Along draws and around lakes.

[1]Derived by multiplying the percentage of density of forage stand by the percentage of palatable plants.

TABLE 10. (cont.)

(G) From Palmer (1934a).

"Plants grazed in summer, in the order of their importance."

First series:

Group I--

Small cotton sedge (Eriophorum callitrix).
Large cotton sedge (Eriophorum angustifolium).
Willows (Salix) (several species).
Reindeer moss (lichens) (Cladonia).
Iceland moss (lichens) (Cetraria).

Group II-

Ground birch (Betula rotundifolia).
Alaska tea (Ledum palustre and L. groenlandicum).

Second series:

Group I--

Blueberry (Vaccinium uliginosum).
Mountain cranberry (Vaccinium vitis-idaea).
Crowberry (Empetrum nigrum).
Sedges (Carex).
Grasses (Poa; Arctagrostis; Festuca; Agropyron).
Water buttercup (Ranunculus pallasii).
Valerian (Valeriana capitata).
Fernweed (Pedicularis verticillata).
Wormwood (Artemisia tilesii).
Wormwood (Artemisia arctica).
Fireweed (Epilobium angustifolium).

Group II-

Mushrooms.
Gentian (Gentiana glauca).
Dryad (Dryas octopetala).
Lupine (Lupinus).
Vetch (Vicia).
Polygonum (Polygonum alaskanum).
Dock (Rumex occidentalis).

TABLE 10. (G, cont.)

Third series:

Group I--

Alder (Alnus alnobetula).
Salmonberry (Rubus chamaemorus).
Alpine bearberry (Arctous alpina).
Diapensia (Diapensia lapponica).
Clubmoss (Lycopodium annotinum).
Heath moss (Polytrichum) (several species).
Bunch moss (Aulacommium turgidum).
Fern moss (Hylocomium alaskanum).
Horsetail (Equisetum arvense).

Group II-

Water starwort (Merckia physodes).
Beach pea (Lathyrus maritimus).
Timber bluebells (Mertensia paniculata).
Fernweed (Pedicularis).
Gentian (Gentiana).
Birch (Betula kenaica).
Spiraea (Spiraea steveni).
Parsnip (Coelopleurum gmelini).
Hemlock parsley (Conioselinum gmelini).

"Plants grazed in winter, in the order of their importance."

First series:

Reindeer moss (lichens) (Cladonia) (numerous species).
Iceland moss (lichens) (Cetraria) (numerous species).

Second series:

Group I--

Cotton sedges (Eriophorum).
Sedges (Carex).
Grasses (Arctagrostis; Poa).
Ear lichen (Nephroma arcticum).

Group II-

Heath moss (Polytrichum) (several species).
Bunch moss (Aulacommium turgidum).
Clubmoss (Lycopodium annotinum).
Fern moss (Hylocomium alaskanum).
Sphagnum moss (Sphagnum fimbriatum).
Pad moss (Dicranum) (several species).

TABLE 10. (G, cont.)

Third series:

Willow (*Salix*).
Blueberry (*Vaccinium uliginosum*).
Ground birch (*Betula rotundifolia*).
Crowberry (*Empetrum nigrum*).
Alaska tea (*Ledum palustre*).
Mountain cranberry (*Vaccinium vitis-idaea*).

TABLE 10. (cont.)

(H) From Palmer (1944).

"The per cent of palatability, or the degree of liking by the reindeer, of the more important plants is as follows:"

Species	Per Cent Palatability	Species	Per Cent Palatability
Lichens	100	Cloudberry	10
Mushrooms	100	Mountain heather	10
Grasses generally	50	Bramble	10
Sedge (*Carex* spp.)	75	Tea	15
Cotton sedge (*Eriophorum*)	50	Woodbrush	negligible
Ground birch	50	Ferns	"
Willows	100	Wiregrass or rush	"
Crowberry	25	Mosses	"
Cranberry	50	Clubmoss	"
Blueberry	50	Bearberry	"
Mare's Tail	50	Aspen	"
Weeds generally	25	Cottonwood	"
Horsetail	50	Current	"
Alder	15	*Spiraea* spp.	"