UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

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RESEARCH REPORT 10

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Harold L. Ickes, Secretary
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BY

LAWRENCE J. PALMER and CHARLES H. ROUSE

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

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By LAWRENCE J. PALMER and CHARLES H. ROUSE, formerly *biologists, Section of Biological Surveys, Division of Wildlife Research, Fish and Wildlife Service* [1]

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INTRODUCTION

During an investigation of the reindeer in Alaska by the Bureau of Biological Survey (now the Fish and Wildlife Service), begun in 1920 and continued to 1935, a study was made of the tundra because it constitutes the principal range of the reindeer. Numerous permanent and temporary quadrats were established for the observation of plant succession and reaction to grazing. This report summarizes the results of the study and considers the problem of reindeer-musk ox range use for the period subsequent to 1944.

In a general way Alaska may be said to possess three main classes of vegetative cover: (1) Coast forest; (2) woodland, or boreal forest; and (3) tundra.[2] The coast forest is confined to, and is the prevailing type in, southeastern Alaska and the Prince William Sound region. The boreal forest covers much of the interior of northern and western Alaska. The tundra is a treeless, prairielike region characteristic of the Arctic and Subarctic

[1] The writers wish to acknowledge the valued assistance of William Byron Miller, formerly in the Alaska work of the Bureau of Biological Survey, who carried on much of the field work between the years 1925 and 1930. [The senior author, Lawrence J. Palmer, died at Anchorage, Alaska, June 20, 1945, while this publication was in press.]

[2] Plant Ecology, by Weaver and Clements. Second edition, pp. 482-491, 1938.

Zones. It occurs chiefly in a broad belt bordering the Bering Sea and Arctic Ocean and extends from the Aleutian Islands northward to Point Barrow and thence eastward along the Arctic coast into Canada.

The tundra belt, of flat to rolling topography, varies in width from a few miles to approximately 200 miles along the Bering Sea. On the Arctic coast it reaches inland to include the foothills of the Brooks Range, a distance varying between 100 and 150 miles. Extensive patches of tundra also occur in the mountain valleys and uplands of the central interior. The interior tundra is similar in composition to that of the coast although in many places it contains a greater proportion of lichens, grasses, and shrubs. It is also generally drier. In the heavily forested southeastern part of Alaska are many small, semiswamp areas that are tundralike in appearance. These are called "muskegs" and differ from the true tundra in having a flat rather than a hummocky surface and a greater proportion of mosses, grasses, and sedges. This use of the term "muskeg" is local; elsewhere hummocks are considered typical of muskeg.

The tundra merges gradually into the boreal forest so there occurs a transition type of cover composed of open tree growth with an undercover of tundra vegetation. This overlapping zone, essentially tundra in forage values, is included in the tundra belt as here treated (fig. 1). It has been recognized that the forest is slowly advancing onto the tundra.[3]

At a number of places on the Bering Sea and Arctic coasts the spruce is now on, or within a few miles of, salt water. At Unalakleet, on Norton Sound, for example, the trees are within 7 miles of the beach. At Foothill, Bonanza, and Isaac's Point on Norton Bay the spruce comes to the water's edge; and in Kotzebue Sound at the mouths of the Buckland, Selawik, Kobuk, and Noatak Rivers the forest cover reaches within about 25 miles of tidewater.

A characteristic of the major part of the tundra is its hummocky surface, not unlike that of a wet meadow much trampled by livestock. Locally the hummocks are called "niggerheads." They vary in size and shape, but are often so uniform in a locality that when viewed from a distance the ground has a level appearance. Furthermore, on account of the heavy cover of vegetation, the irregular surface may not be apparent until one enters the area. Hummocks may be from a few inches to knee high, often so closely spaced as to make walking difficult. Circular in form, the hummocks vary in diameter from 8 inches or less to a foot or more.

[3] The Edge of the Forest in Alaska and the Reason for its Position, by Robert F. Griggs. Ecology 15 (2): 80-96, April 1934.

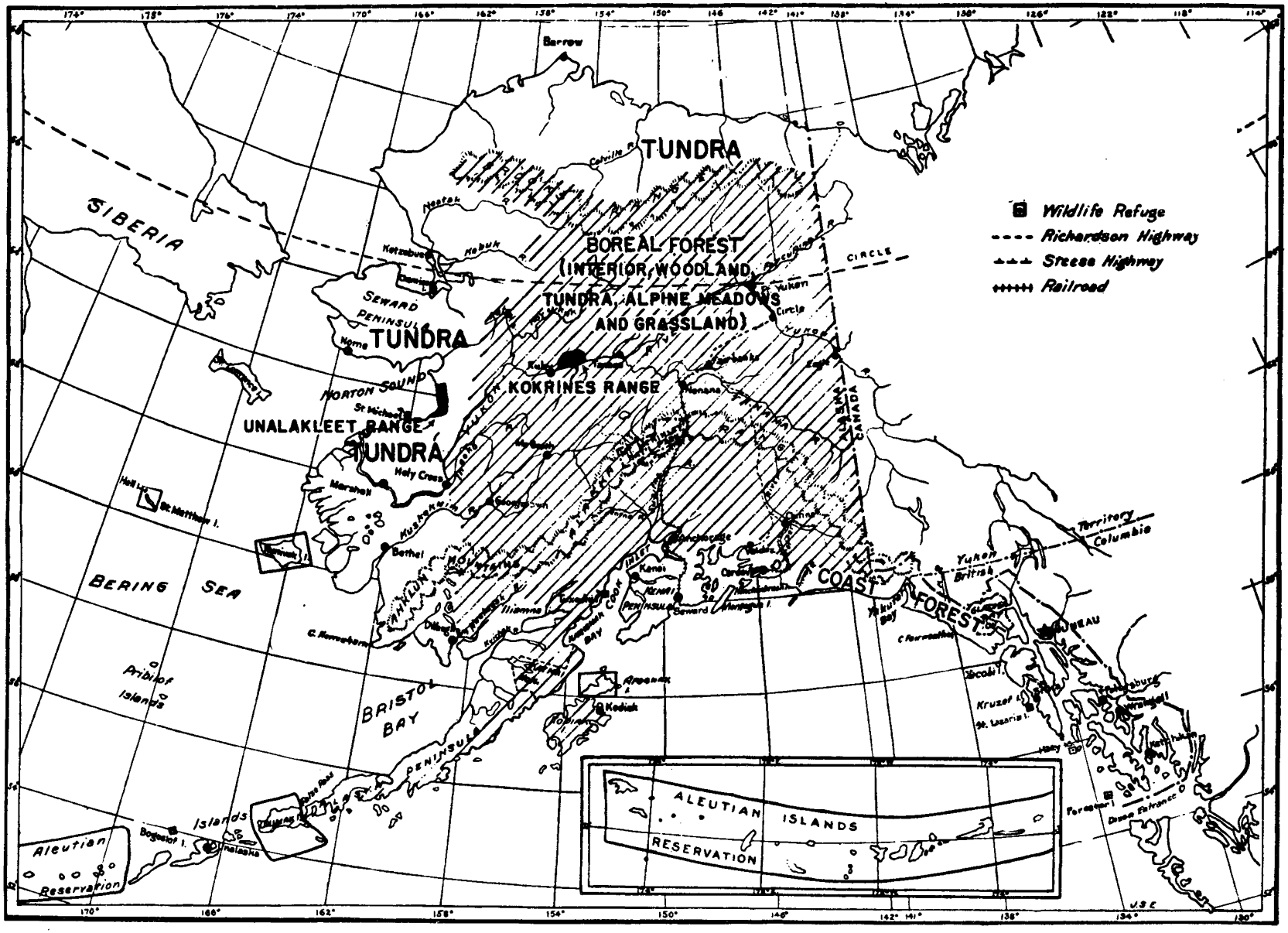

Figure 1.—Distribution of Alaskan vegetative type-cover in general and approximate location of the tundra.

On the lower elevations, especially near the coast, the soil of the tundra is often wet or moist. Puddles of water frequently are found in the interstices between the niggerheads, and numerous small ponds and lakes break the otherwise uniform expanse of deep green cover. Even on as much as a 30-degree slope this condition of wet ground with puddles between the hummocks may sometimes be noted. Flat bogs often are found in the valley bottoms. On better drained areas, away from the coast, a drier condition prevails and the ground is less hummocky. Thus a dry and a wet tundra type are recognized.

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 peatlike in texture. 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, and in some sections, as at Kotzebue Sound, Wainwright, and Barrow, solid ice is found under the soil at a depth of 2 to 3 feet. Moisture furnished by standing water, frost and ice below the surface, prevailing fogs along the coast, and frequent rainfall during the growing season favor luxuriant vegetation throughout the tundra.

Ordinarily, except for water areas and rocky ridge tops, the surface is completely covered with vegetation. The plant composition includes a mixture of lichens, mosses, grasses, forbs (any herbs other than grass), and shrubs, the immediate coast range having a predominance of sedges (*Carex* and *Eriophorum*) and shrubs, and the inland areas a preponderance of lichens and shrubs. Because of differing conditions of exposure, soil, moisture, and the physical nature of the ground, the plant mixture varies greatly. Innumerable combinations occur, presenting a complexity of pattern; and while one may recognize the dry tundra of the interior and the wet tundra of the coastal region, there is a considerable intermixture of minor types in response to varying soil and moisture within each of those major divisions of the formation.

LIST OF TUNDRA PLANTS

The plants[4] most frequently found on the tundra include the following:

GRASSES

Agropyron sericeum (wheatgrass)
Agrostis aequivalvis (bentgrass)
Agrostis borealis (bentgrass)
Alopecurus alpinus (alpine foxtail)
Arctagrostis latifolia
Calamagrostis canadensis scabra (coast bluejoint)
Deschampsia caespitosa (tufted hairgrass)
Elymus mollis (American dunegrass)
Festuca rubra (red fescue)
Festuca rubra lanuginosa (fescue)
Hierochloe alpina (sweetgrass)
Phleum alpinum (alpine timothy)
Poa arctica (Arctic bluegrass)
Poa eminens (giant bluegrass)
Poa hispidula (bluegrass)
Trisetum spicatum (spike trisetum)

GRASSLIKE PLANTS

Carex aquatilis (sedge)
Carex atrofusca (sedge)
Carex canescens (sedge)
Carex compacta (sedge)
Carex concolor (sedge)
Carex heleonastes (sedge)
Carex lachenali (sedge)
Carex macrochaeta (sedge)
Carex membranacea (sedge)
Carex rotundata (sedge)
Carex scirpoidea (sedge)
Equisetum arvense (horsetail)
Equisetum palustre (horsetail)
Equisetum sylvaticum (horsetail)
Eriophorum angustifolium (large cotton-sedge)
Eriophorum callithrix (small cotton-sedge)
Eriophorum vaginatum (cotton-sedge)
Juncus castaneus (rush)
Juncus haenkei (rush)
Luzula arcuata (woodrush)
Luzula kjellmanniana (woodrush)
Luzula multiflora (woodrush)
Sparganium hyperboreum (burreed)

FORBS (HERBACEOUS PLANTS)

Achillea borealis (yarrow)
Aconitum delphinifolium (monkshood)
Allium sibiricum (onion)
Amsinckia menziesi (fiddleneck)
Androsace chamaejasme
Anemone multiceps (anemone)
Anemone narcissiflora (anemone)
Anemone parviflora (anemone)
Anemone richardsoni (anemone)
Antennaria borealis (everlasting)
Antennaria monocephala (everlasting)
Arenaria arctica (sandwort)
Arenaria macrocarpa (sandwort)
Arenaria physodes (water starwort)
Arenaria verna (sandwort)
Arnica alpina (arnica)
Arnica nutans (arnica)
Arnica obtusifolia (arnica)
Arnica unalaschensis (arnica)
Artemisia arctica (wormwood)
Artemisia semavinensis (wormwood)
Artemisia tilesii (wormwood)
Aster sibiricus (aster)
Astragalus alpinus (loco)
Astragalus littoralis (loco)
Barbarea orthoceras (wintercress)
Barbarea vulgaris (wintercress)
Bupleurum americanum (hares-ear)
Caltha natans (marshmarigold)
Caltha palustris arctica (marshmarigold)
Campanula lasiocarpa (bellflower)
Campanula rotundifolia (bellflower)
Campanula uniflora (bellflower)
Capsella bursa-pastoris (shepherds-purse)
Cardamine bellidifolia (bittercress)
Cardamine blaisdellii (bittercress)
Cardamine pratensis (bittercress)
Cardamine purpurea (bittercress)
Cardamine umbellata (bittercress)
Castilleja tristis (paintbrush)
Cerastium alpinum (chickweed)
Cerastium arcticum (chickweed)
Cerastium minimum (chickweed)
Cheirinia cheiranthoides (wallflower)
Chrysanthemum arcticum (daisy)
Chrysanthemum integrifolium (daisy)
Chrysosplenium beringianum (golden saxifrage)
Chrysosplenium tetrandrum (golden saxifrage)
Cicuta douglasi (waterhemlock)
Claytonia eschscholtzi (springbeauty)

[4] Grateful acknowledgment is made to Dr. Sidney F. Blake and Jason R. Swallen, of the Bureau of Plant Industry, United States Department of Agriculture, and to Emery C. Leonard, of the Division of Plants, United States National Museum, for checking the names of plants.

FORBS (HERBACEOUS PLANTS)—Continued

Claytonia sarmentosa (springbeauty)
Claytonia tuberosa (springbeauty)
Cochlearia fenestrata (spooncress)
Cochlearia oblongifolia (spooncress)
Coelopleurum gmelini (parsnip)
Conioselinum gmelini (hemlock parsley)
Cystopteris fragilis (brittle fern)
Cystopteris montana (brittle fern)
Delphinium blaisdelli (larkspur)
Delphinium browni (larkspur)
Dianthus repens (pink)
Dicentra pauciflora
Dodecatheon frigidum (shootingstar)
Draba alpina (whitlow)
Draba borealis (whitlow)
Dryas octopetala (dryad)
Dryopteris dilatata (shield fern)
Dryopteris fragrans (shield fern)
Epilobium anagallidifolium (willow-weed)
Epilobium angustifolium (common fireweed)
Epilobium bongardi (willow-weed)
Epilobium latifolium (broadleaf willow-weed)
Erigeron hyperboreus (daisy)
Erigeron uniflorus (daisy)
Eritrichium arctioides (Arctic forget-me-not)
Galium boreale (bedstraw)
Gentiana frigida (gentian)
Gentiana glauca (gentian)
Gentiana propinqua (gentian)
Gentiana prostrata (gentian)
Gentiana tenella (gentian)
Habenaria bracteata (orchid)
Habenaria hyperborea (orchid)
Habenaria obtusata (orchid)
Hedysarum americanum (jointpod)
Hedysarum mackenzi (jointpod)
Heracleum lanatum (cow-parsnip)
Hippuris vulgaris (marestail)
Honkeneya peploides (sea-beach sandwort)
Iris setosa (Arctic iris)
Lagotis minor
Lathyrus maritimus (beach pea)
Lesquerella arctica (bladderpod)
Ligusticum macouni
Ligusticum scoticum (Scotch lovage)
Linnaea borealis (twinflower)
Lloydia serotina
Lomatogonium rotatum
Lupinus (lupine)
Lychnis apetala (campion)
Lycopodium alpinum (clubmoss)
Lycopodium annotinum (clubmoss)
Lycopodium selago (clubmoss)
Matricaria hookeri (camomile)
Matricaria matricarioides (camomile)
Menyanthes trifoliata (buckbean)
Mertensia eastwoodae (bluebells)
Mertensia maritima (beach bluebells)
Mertensia paniculata (timber bluebells)
Moehringia lateriflora (trailing sandwort)
Montia rivularis (springbeauty)
Myosotis alpestris (forget-me-not)
Oxyria digyna (mountain sorrel)
Oxytropis campestris (oxytrope)
Oxytropis mertensiana (oxytrope)
Oxytropis nigrescens (oxytrope)
Oxytropis podocarpa (oxytrope)
Oxytropis sewardensis (oxytrope)
Papaver nudicaule (Iceland poppy)
Papaver nudicaule multiceps (Iceland poppy)
Parnassia kotzebuei
Parrya nudicaulis (Parry mustard)
Pedicularis arctica (fernweed)
Pedicularis capitata (fernweed)
Pedicularis labradorica (fernweed)
Pedicularis langsdorfi (fernweed)
Pedicularis parviflora (fernweed)
Pedicularis sudetica (fernweed)
Pedicularis versicolor (fernweed)
Pedicularis verticillata (fernweed)
Pentstemon procerus
Petasites frigida (butterbur)
Phlox sibirica (phlox)
Pinguicula vulgaris (butterwort)
Polemonium acutiflorum
Polemonium humile
Polygonum alaskanum (smartweed)
Polygonum aviculare (knotweed)
Polygonum bistorta (smartweed)
Polygonum plumosum (smartweed)
Polygonum viviparum (smartweed)
Potentilla biflora
Potentilla egedii (fivefinger)
Potentilla elegans (showy fivefinger)
Potentilla emarginata (fivefinger)
Potentilla fruticosa (shrubby cinquefoil)
Potentilla nivea (small woolly cinquefoil)
Potentilla palustris (marsh fivefinger)
Potentilla uniflora (fivefinger)
Primula borealis (primrose)
Primula egaliksensis (primrose)
Primula eximia (primrose)
Primula sibirica (primrose)
Pyrola grandiflora
Ranunculus chamissonis (buttercup)
Ranunculus hyperboreus (buttercup)
Ranunculus nivalis (buttercup)
Ranunculus pallasii (water buttercup)
Ranunculus pygmaeus (buttercup)
Ranunculus sceleratus (buttercup)
Ranunculus sulphureus (buttercup)
Ranunculus verticillatus (buttercup)
Rhinanthus crista-galli (yellow rattle)
Roripa palustris (marshcress)
Rumex acetosa (sour dock)
Rumex occidentalis (dock)
Rumex occidentalis nanus (dock)
Sagina saginoides (pearlwort)

FORBS (HERBACEOUS PLANTS)—Continued

Sanguisorba microcephala (burnet)
Sanguisorba sitchensis (Alaska burnet)
Saussurea monticola (sawwort)
Saussurea subsinuata (purple aster)
Saxifraga bracteata (saxifrage)
Saxifraga bronchialis (saxifrage)
Saxifraga cernua (saxifrage)
Saxifraga eschscholtzii (saxifrage)
Saxifraga flagellaris (saxifrage)
Saxifraga foliolosa (saxifrage)
Saxifraga hieracifolia (saxifrage)
Saxifraga hirculus (saxifrage)
Saxifraga neglecta (saxifrage)
Saxifraga nelsoniana (saxifrage)
Saxifraga oppositifolia (saxifrage)
Saxifraga radiata (saxifrage)
Saxifraga rivularis (saxifrage)
Saxifraga serpyllifolia (saxifrage)
Saxifraga unalaschensis (saxifrage)
Sedum integrifolium (stonecrop)
Selaginella schmidti (selaginella)
Senecio atropurpureus (senecio)
Senecio frigidus (senecio)
Senecio lugens (senecio)
Senecio palustris (senecio)
Senecio pseudo-arnica (senecio)
Senecio resedifolius (senecio)
Senecio walpolei (senecio)
Sieversia glacialis
Sieversia rossi
Silene acaulis (moss campion)
Smelowskia calycina
Solidago multiradiata (goldenrod)
Sophia sophioides (tansymustard)
Statice arctica (thrift)
Stellaria longipes (starwort)
Stellaria media (starwort)
Taraxacum lyratum (dandelion)
Taraxacum officinale (dandelion)
Thalictrum alpinum (meadowrue)
Tofieldia coccinea (false asphodel)
Tofieldia palustris (false asphodel)
Trientalis europaea arctica (starflower)
Valeriana capitata (valerian)
Veratrum spicatum (false-hellebore)
Veronica stelleri (speedwell)
Vicia (vetch)
Viola biflora (violet)
Viola palustris (violet)
Woodsia glabella
Zygadenus elegans (deathcamas)

SHRUBS (WOODY PLANTS)

Alnus alnobetula (alder)
Andromeda polifolia (bog-rosemary)
Arctous alpina (alpine bearberry)
Betula kenaica (birch)
Betula rotundifolia (ground birch)
Cassiope tetragona (moss heather)
Cornus suecica (herb dogwood)
Diapensia lapponica (diapensia)
Empetrum nigrum (crowberry)
Ledum decumbens (Alaska tea)
Ledum groenlandicum (Alaska tea)
Ledum palustre (Alaska tea)
Rhododendron lapponicum (rhododendron)
Ribes triste (red currant)
Rosa acicularis (rose)
Rubus arcticus (Arctic raspberry)
Rubus chamaemorus (salmonberry)
Salix arctica (Arctic willow)
Salix fuscescens (bog willow)
Salix glauca (grayleaf willow)
Salix glauca aliceae
Salix phlebophylla (skeleton willow)
Salix pulchra (diamondleaf willow)
Salix reticulata (netleaf willow)
Salix richardsoni (Richardson willow)
Salix rotundifolia (roundleaf willow)
Spiraea steveni (spiraea)
Vaccinium oxycoccos (small cranberry)
Vaccinium uliginosum (blueberry)
Vaccinium vitis-idaea (mountain cranberry)
Viburnum pauciflorum (highbush cranberry)

MOSSES

Aulacomnium palustre (bunch moss)
Aulacomnium turgidum (bunch moss)
Brachythecium rivulare
Bryum albicans (common moss)
Bryum bimum (common moss)
Calliergon alaskanum
Calliergonella cuspidata
Climacium americanum
Dicranum bonjeani (pad moss)
Dicranum elongatum (pad moss)
Dicranum groenlandicum (pad moss)
Dicranum scoparium (pad moss)
Dicranum spadiceum (pad moss)
Drepanocladus fluitans (fern moss)
Drepanocladus uncinatus (fern moss)
Funaria hygrometrica
Hypnum schreberi
Leptobryum pyriforme
Mnium glabrescens
Oligotrichum laevigatum
Paludella squarrosa
Philonotis fontana
Polytrichum commune commune (heath moss)
Polytrichum commune yukonense (heath moss)
Polytrichum juniperinum (heath moss)
Polytrichum piliferum hyperboreum (heath moss)

MOSSES—Continued

Polytrichum piliferum piliferum (heath moss)
Polytrichum strictum (heath moss)
Ptilidium ciliare
Rhacomitrium lanuginosum
Sphagnum angstroemii (sphagnum moss)
Sphagnum capillacexum tenellum (sphagnum moss)
Sphagnum fimbriatum (sphagnum moss)
Sphagnum girgensohni (sphagnum moss)
Sphagnum lindbergi (sphagnum moss)
Sphagnum magellanicum (sphagnum moss)
Sphagnum plumosum (sphagnum moss)
Sphagnum riparium (sphagnum moss)
Sphagnum squarrosum (sphagnum moss)
Tetraplodon mnioides

LICHENS

Alectoria nigricans
Alectoria ochroleuca
Cetraria chrysantha
Cetraria cucullata
Cetraria islandica
Cetraria islandica crispa
Cetraria islandica platyna
Cetraria nivalis
Cladonia amaurocraea
Cladonia amaurocraea celotea
Cladonia amaurocraea oxyceras
Cladonia bellidiflora
Cladonia coccifera
Cladonia crispata
Cladonia decorticata
Cladonia degenerans
Cladonia delessertii
Cladonia furcata
Cladonia gracilis
Cladonia gracilis dilatata
Cladonia gracilis ecmocyna
Cladonia gracilis elongata
Cladonia rangiferina
Cladonia squamosa muricella
Cladonia sylvatica
Cladonia sylvatica sylvestris
Cladonia uncialis
Cladonia uncialis obtusata
Cladonia uncialis turgescens
Dactylina arctica
Nephroma arcticum
Ochrolechia spp.
Parmelia spp.
Sphaerophorus coralloides
Stereocaulon alpinum
Stereocaulon coralloides
Stereocaulon tomentosum
Sticta linita
Thamnolia vermicularis

Of the plants listed, the *Carex* and *Cladonia* species are dominants in the tundra climax. Subdominants include species of *Eriophorum, Ledum, Salix* and *Betula* (low-growing forms), *Vaccinium, Empetrum nigrum, Arctous 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, Saxifraga, Senecio, Polemonium, Campanula,* and the Arctic coltsfoot (*Petasites frigida*).

METHOD OF STUDY

In study of the tundra by the quadrat method, 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 all the plant cover to simulate extreme overgrazing, trampling and grazing by livestock, and protecting from disturbance as a check. Recording included listing and charting or estimating the plant density and composition.

TYPES OF TUNDRA VEGETATION

Quadrats were established on several types of tundra vegetation and observations were made on them.

BEACH-TRANSITION TYPE

CAPE ETOLIN

Two beach-transition types are being studied. The first of these is located at Cape Etolin, north side of Nunivak Island, near latitude 60° 15′ N., and longitude 166° 5′ W., in Bering Sea. The soil is of fine, deep, well drained, wind-blown sand with very little humus. Moisture conditions, on account of frequent rains and fogs during the summer, are extremely favorable for plant growth. The vegetation is composed of *Elymus mollis, Epilobium latifolium, Artemisia arctica, Achillea borealis, Coelopleurum gmelini, Empetrum nigrum, Stereocaulon tomentosum,* and the mosses, *Polytrichum* and *Bryum.* These make vegetative cover of 0.9 to 1.0 density.[5]

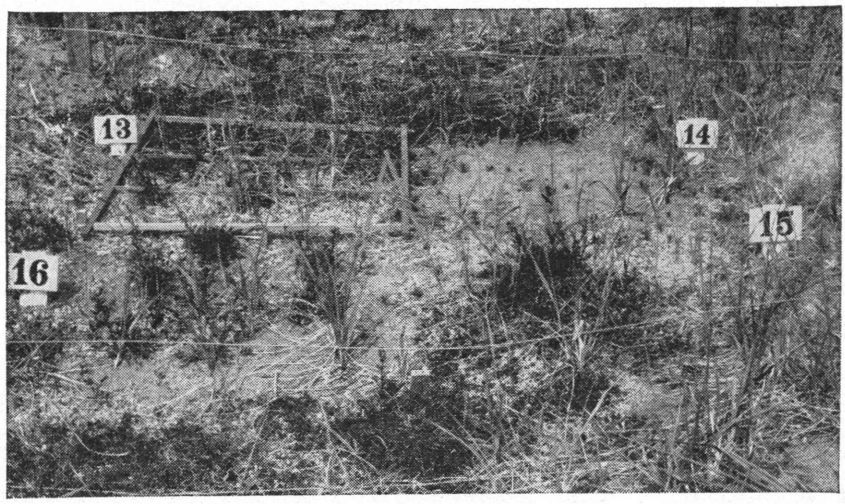

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Figure 2.—Beach-transition type exclosure on Nunivak Island. July 4, 1929.

A fenced exclosure (fig. 2) containing four 1-meter-square quadrats was erected in this type in 1927. Two of the quadrats were undisturbed, on the third the vegetation was removed by cutting it at the ground surface with a sharp knife, and the fourth was denuded by spading.

Denuded quadrat.—Observations indicate that the initial phase of plant succession on the denuded quadrat is an association of *Elymus mollis, Epilobium latifolium,* and *Artemisia arctica.* A few plants of *Achillea, Mertensia,* and *Coelopleurum* also were present. *Empetrum* and *Stereocaulon* were early invaders, spread-

[5] Throughout the report, density of vegetation is expressed by the decimal system, 1.0 representing complete coverage.

ing onto the denuded area from adjacent ground, *E. nigrum* being a prominent species in the nearby tundra association.[6] Nine years after denudation of the quadrat the vegetative cover was found to be of 0.7 density, half of it *Empetrum nigrum*. *Elymus mollis* was proportionately as abundant as on the undisturbed areas, but did not appear so thrifty, as no seed heads were being produced. Sphagnum moss appeared in the later stage of the succession, and lichens receded as *Sphagnum* and *Empetrum* increased. The herbaceous weed species retained their subdominant position.

Cut quadrat.—The revegetation of the quadrat from which all vegetation had been removed by cutting was very similar to that of the spaded quadrat, although the growths of *Elymus* and *Artemisia* were more abundant and the invasion by *Empetrum* and *Stereocaulon* was less marked. Between the fifth and the ninth years after cutting there was a decrease in the proportion of weed species, and sphagnum moss appeared and increased rapidly. *Empetrum* showed little increase in the area occupied, and *Stereocaulon* suffered a definite recession. The density of the plant cover was estimated to be 0.8 at the end of 9 years.

Check quadrats.—During the 9-year period there was a definite change in the vegetation on the check quadrats. *Stereocaulon,* the dominant species when the quadrats were established, had nearly disappeared when the latest observation was made. *Empetrum nigrum* spread to cover about 70 percent of the total area of the quadrats. There was a general decline in the weed species but the grasses showed little change.

Conclusion.—The initial phase of vegetative succession in the beach-transition type appears to be an association of *Elymus mollis, Epilobium latifolium,* and *Artemisia arctica,* with a few such minor weeds as *Achillea borealis, Mertensia maritima,* and *Coelopleurum gmelini.* These species are gradually replaced by invasions of *Empetrum nigrum* and lichens, principally *Stereocaulon tomentosum.* With the development of a more luxuriant plant growth, *Stereocaulon* is replaced by the more tolerant mosses, especially *Sphagnum.* The trend of the succession is apparently towards the association found on the surrounding tundra.

It appears that the beach-transition type could be quite closely grazed without reducing its forage production, and it is probable that grazing would tend to prolong the *Elymus-Artemisia* stage of the succession by retarding the development of the *Empetrum-Stereocaulon* phase.

[6] The term "association" as used here has a slightly different meaning than is generally given it in ecological literature. Because of the peculiar adaptations of Arctic plants there does not seem to be the more or less characteristic association of species confined to definite sites as is usually the case in more temperate climates. In the Arctic the same species are found over widely varying site conditions and the variations in the plant cover, instead of being characterized by definite groups or associations of species, are marked by variations in the relative abundance or proportions of the common species.

PASTOLIK

The beach-transition type (fig. 3) studied at Pastolik near lati-

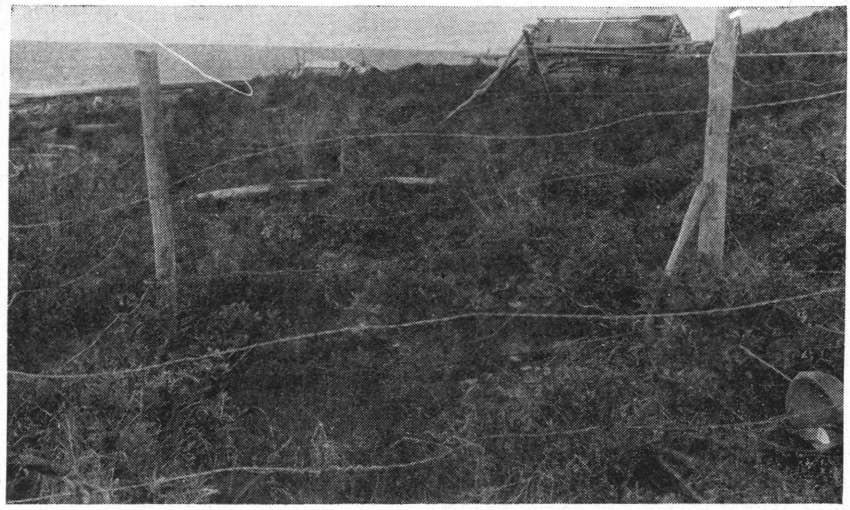

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Figure 3.—Beach-transition type exclosure at Pastolik. July 5, 1928.

tude 63° N., longitude 163° W., is on a soil composed of smooth, fine gravel and sand with a fair amount of humus. Soil moisture is plentiful throughout the growing season. There is a dense growth of vegetation, composed of approximately 20 percent *Arctagrostis,* 20 percent *Poa,* 20 percent *Agrostis,* 30 percent weeds, and 10 percent willows. The study was conducted in the same manner as that at Cape Etolin (p. 8).

Cut quadrat.—Four years after establishment the cut quadrat had a full cover of vegetation, composed of 50 percent grasses, 30 percent weeds, 10 percent willows, and 10 percent mosses. *Poa* made up 90 percent of the grasses. The rate of recovery manifested would indicate that the type has the ability to withstand moderately heavy grazing and still maintain a good stand of palatable forage.

Denuded quadrat.—The denuded quadrat made a much slower recovery. At the end of 4 years the plant density was 0.675, the vegetation comprising 50 percent mosses, 40 percent weeds, and 10 percent grasses. The mosses were very short and had no forage value. *Equisetum* and *Epilobium* formed the initial phase of the succession and were followed by the rapidly spreading mosses. Grasses were much slower in making their appearance. Further study is necessary in order to determine the trend and rate of succession.

Check quadrats.—The undisturbed or check quadrats also have changed in composition. Willows and mosses made substantial increases while grasses decreased. The percentage of weeds remained the same. It appears that, if undisturbed, the beach-transition type will develop into the browse-moss-weed association

of the adjoining tundra. It also appears that grazing tends to retard succession and that under use the grass-weed type would persist.

SAND-DUNE TYPE

NUNIVAK ISLAND

Because of its limited occurrence, the sand-dune type is not of great economic importance as reindeer range, but it is significant ecologically, in that it affords opportunity to observe the development of vegetation on a primary area. The study of the vegetation on sand dunes, begun in 1927, was conducted at Cape Etolin on Nunivak Island. The experimental area was a fenced exclosure (fig. 4) containing three 1-meter-square quadrats located

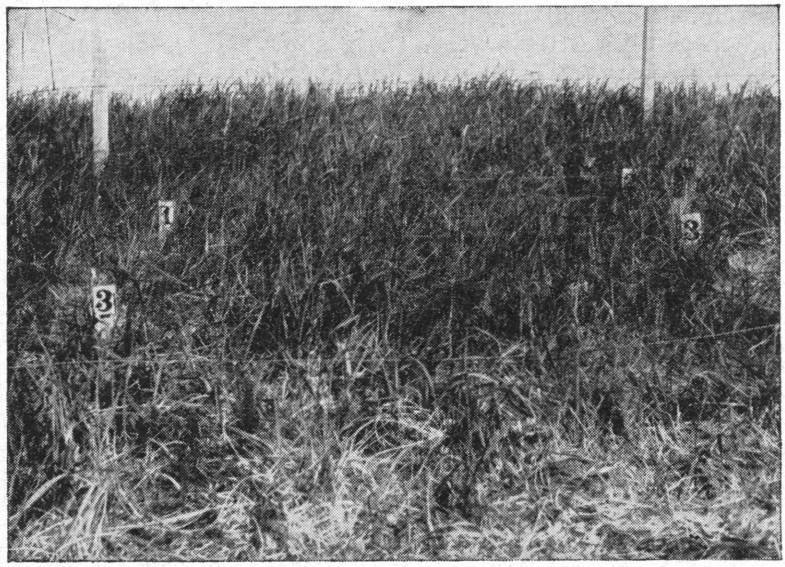

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Figure 4.—The study exclosure in the sand-dune type, Cape Etolin, Nunivak Island. July 4, 1929.

on the south or leeward side of a ridge of sand dunes at about 40 feet elevation. The soil is deep and is composed of fine sand with very little humus. A small amount of wind-borne deposition is still taking place. The soil is well drained but comparatively heavy precipitation during the summer furnished ample moisture for abundant plant growth.

The vegetation on this area is composed principally of grasses with a small percentage of weeds and mosses. The grasses, mainly *Elymus mollis* and *Arctagrostis latifolia,* with smaller amounts of *Poa arctica* and *Festuca rubra,* constitute about 85 percent of the total vegetation. The weeds *Epilobium latifolium, Lathyrus maritimus, Achillea borealis, Petasites* sp., *Solidago, Aconitum, Cerastium, Arenaria,* and *Cornus* make up about 8

percent of the plant cover. The remaining 7 percent consists of small mosses. The plant cover has a density of 1.0.

Denuded quadrat.—One of the quadrats within this exclosure was denuded by spading up all the vegetation. Five years later the vegetation had recovered sufficiently to make a cover density of 0.12, composed of 70 percent grasses and 30 percent weeds. A fine moss also was distributed evenly over the entire area. Nine years after denudation of the quadrat, the density of the plant cover was estimated to be 0.65, and the composition was 60 percent grasses, 20 percent weeds, and 20 percent sphagnum moss. Apparently the grass-weed association is the primary stage of the succession on this site. It is slow to reestablish itself following removal or severe disturbance.

Cut quadrat.—A similar quadrat from which the vegetation was removed by cutting it at the ground surface made a more rapid recovery. After 5 years the grasses and weeds were found to have a density of 0.22. In addition there was an even cover of fine mosses. Nine years after treatment the cover was estimated to have a density of 0.8. Grasses made up 50 percent of the vegetation, weeds 25 percent, and mosses and lichens 25 percent. Although the recovery was more rapid on the cut quadrat than on the spaded quadrat, the ratios of the components were essentially the same.

Check quadrat.—Changes were noted in the composition of the vegetation on the check quadrat, which was undisturbed during the course of this study. *Elymus* decreased from dominance until it made up only 10 percent of the cover, while *Arctagrostis* increased until it dominated all other species. The fine grasses *Poa arctica* and *Festuca rubra* also made definite increases. The weeds showed little change either in species or abundance, but *Sphagnum* increased from 7 percent to 20 percent of the total cover.

During the years of protection afforded by the exclosure there was a gradual accumulation of dead culms and leaves, forming a loose mulch over the ground, which apparently created favorable growing conditions for the mosses. The increase of mosses, with their ability to form humus and retain moisture, helps to alter site conditions in favor of the lichen and browse species that characterize the nearby tundra. It was noted at the latest examination of this type that *Elymus* was the dominant grass on the windward side of the dunes and that *Arctagrostis* prevailed on the leeward side.

Conclusion.—The reaction of the treated quadrats indicates that moderate utilization by grazing animals would tend to stabilize the sand-dune type by prolonging the grass-weed stage of the succession. Close utilization would open the cover and expose the soil to erosion by rain and wind. When undisturbed there is a rather rapid development toward the association of species characteristic of the adjacent tundra.

COAST-SANDSPIT GRASS-WEED TYPE

UNALAKLEET

The coast-sandspit grass-weed type occupies a narrow strip along the coast between the beach and the tundra. The soil is well drained, gravelly loam with a fair amount of humus. Moisture conditions, because of frequent summer rains, are favorable. The vegetation is a mixture of grasses, sedges, and weeds. The grasses *Poa* and *Elymus mollis* make up about 30 percent of the total plant cover; sedges constitute 40 percent; and the weed species *Artemisia, Lathyrus, Polemonium, Conioselinum,* and *Arenaria* contribute the remaining 30 percent. The density of the cover is complete (1.0).

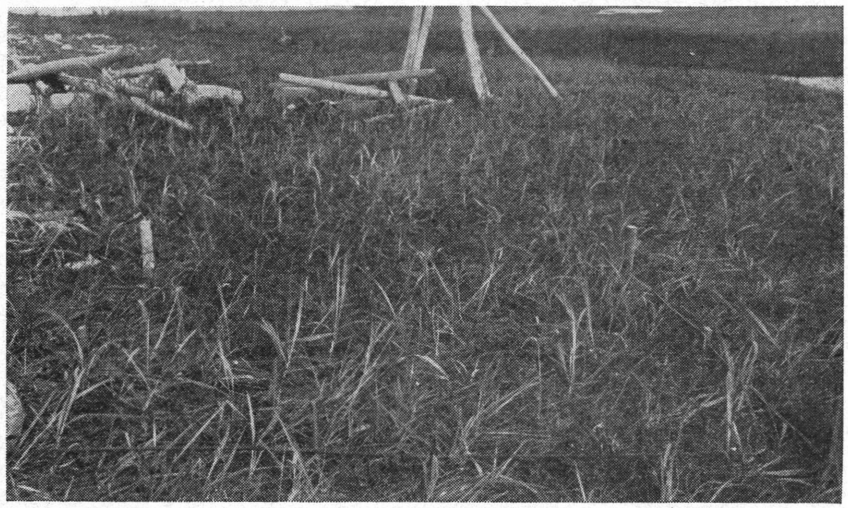

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Figure 5.—The grass-weed type exclosure on the coast sandspit, Unalakleet. August 11, 1927.

Denuded quadrat.—A fenced exclosure containing four 1-meter-square quadrats was established in this type near Unalakleet in 1927 (fig. 5). One of these quadrats was completely denuded by spading up and removing all the vegetation. The invasion of this area by vegetation has been very slow. At the end of 4 years the invading plants had not attained a 0.1 density. The species were the same as those found originally on the area and were in approximately the same proportions. A small moss was spreading evenly over the entire area.

Cut quadrat.—A similar quadrat from which the vegetation had been removed by cutting it off at the ground surface made a much more rapid recovery. At the end of 4 years the vegetative cover had attained an estimated 0.85 density and was composed of 35 percent grasses, 30 percent sedges, 25 percent weeds, and 10 percent mosses. At that time there was evidence that the mosses were being displaced by the other classes of vegetation.

Check quadrats.—There was no noticeable change in the vege-

tation on the check quadrats during the 4 years of observation.

Conclusion.—Although the study was not complete enough to be conclusive, it indicated that the coast-sandspit grass-weed type is comparatively stable, and that moderate grazing during the summer would not appreciably affect the forage production or the trend of the plant succession. Heavy grazing and trampling such as would expose the ground surface would decrease the forage production considerably and alter the plant composition; the more palatable weeds and grasses would be eliminated and mosses would increase.

COAST-SANDSPIT LICHEN-BROWSE TYPE

UNALAKLEET

The coast-sandspit lichen-browse type is found on a slight ridge back from the beach. The soil is fine gravel and sand with a fair amount of humus. The vegetation is composed of lichens and browse with a few grasses. Despite frequent rains during the summer, the ground is rather dry and does not produce a luxuriant stand of vegetation. The density is complete (1.0) but the stand is short, the browse species being decumbent and the lichens averaging not more than 4 inches in height.

B35297

Figure 6.—Lichen-browse type on a coast sandspit. Unalakleet. September 24, 1928.

A fenced exclosure containing four 1-meter-square quadrats was established on this type in 1922 just north of the town of Unalakleet, on Norton Sound, near latitude 64° N., longitude 161° W. (fig. 6). Observations were made until 1930, when the area was included in the airport of Unalakleet and the quadrats had to be abandoned.

Three-fourths-cut quadrat.—In order to study the effect of cropping on lichen growth, the vegetation on one of these quadrats

was clipped so as to remove about three-fourths of the above-ground growth. Before the cutting, the area had a complete ground cover composed of about 60 percent lichens, 38 percent browse, and 2 percent grasses. The cutting was done in the spring while the ground was frozen. An examination made after the ground had thawed disclosed a weak lichen cover approximately half an inch high remaining.

After 9 years the vegetation on this area had a density of 0.95 and was composed of 25 percent grasses, 35 percent lichens, 25 percent browse, 10 percent mosses, and 5 percent weeds. The greater part of the lichen cover died during the year after the cutting but new growth was soon in evidence. The stand was opened, however, and this allowed the establishment of grasses and weeds. In 5 years the ground cover had a density of 0.95. In 9 years the lichens had attained a height of 1½ inches but were only slightly more than half as abundant as formerly. This would indicate that lichens are greatly affected by cropping, that they are very slow to recover, and are easily killed. Grazing tends to open the stand in this type and this permits the increase of grasses and weeds. The browse species were reduced by the cutting but they recovered more rapidly than did the lichens.

Denuded quadrat.—A similar quadrat, having a 1.0 density of cover composed of 75 percent lichens, 15 percent browse, and 10 percent grasses, was completely denuded in order to observe the recovery of the lichens. In 5 years the area was largely covered with grasses and browse to a density of 0.8. Lichens had come in rapidly but were of short growth. Nine years after establishment of the quadrat the vegetation had attained a 0.9 density and was estimated to be composed of 35 percent grasses, 25 percent browse, 30 percent lichens, 5 percent weeds, and 5 percent mosses. The lichens averaged about 1 inch in height.

In this instance the grasses were most aggressive in revegetating the area after the lichens were removed. Browse species also were stimulated by the opening up of the stand. Lichens were slow to reestablish themselves but were doing so gradually. The increased growth and spread of lichens was relentlessly crowding out and replacing the grasses, and eventually, during the course of years, would reclaim the area. The browse species tend to be more stable, but evidence indicates that finally they, too, give way to the lichens.

Picked quadrat.—A third quadrat in this group was originally covered with vegetation having a 1.0 density, and composed of 70 percent lichens, 25 percent grasses, and 5 percent browse. To study the effect of pawing and close winter cropping by reindeer on lichen growth, the lichens on this quadrat were picked by hand while the ground was frozen. The air-dry weight of these lichens averaged with that of the lichens removed from the denuded quadrat mentioned above indicated a forage production of 10,117 pounds to an acre. Examination of the area after the ground had thawed showed that no lichens were left. Five years after establishment the quadrat had a complete cover of vegetation estimated to be composed of 50 percent grasses, 25 percent

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browse, and 25 percent lichens. Nine years after its establishment, the vegetation of the quadrat comprised about 40 percent grasses, 27 percent browse, 25 percent lichens, 5 percent weeds, and 3 percent mosses. The density was 1.0. Aside from the appearance of weeds and mosses, the change in the vegetation between the fifth and the ninth years was very slight.

The recovery of this quadrat was more rapid than that of the denuded area but not as rapid as that of the partially cut or cropped quadrats. The proportions of plant species during the process of recovery, however, were in all cases essentially the same.

Check quadrat.—A fourth quadrat in this group was left undisturbed to serve as a check for comparison with the treated areas. Originally it had a complete cover of vegetation, with an estimated composition of 75 percent lichens, 15 percent grasses, and 10 percent browse. The lichen growth stood about 1 inch high above the frozen ground. After the ground had thawed it was noted that the lichens were brittle and had been trampled. Nine years later this quadrat had a cover of vegetation of 0.9 density that was estimated to be composed of 22 percent grasses, 22 percent lichens, 45 percent browse, 5 percent weeds, and 6 percent mosses. The trampling noted the year of establishment appears to have had an effect comparable to the other methods of treatment as the reactions were much the same. The lichen cover was greatly reduced and there was a corresponding increase in the grasses and browse. This emphasizes what has been observed many times, namely, that lichens are easily injured by trampling when in a dry and brittle state, and efforts should be made to protect them when they are in this condition; hence reindeer should be kept away from important lichen areas during the summer.

The recovery of the vegetation subsequent to extremely close cropping or denudation is much slower than that after partial cropping or cutting. While the quantity of forage removed from the partially cropped area was not so great as that from the denuded quadrat, the quicker rate of recovery would indicate an ultimately greater forage production over an extended period. Considering also the action of the forage cover in maintaining site conditions and preventing erosion, it is evident that moderate grazing under a deferred system of use would prove the most desirable practice in utilizing the coast-sandspit lichen-browse type.

COAST-TUNDRA SEDGE-BROWSE TYPE

EGAVIK

The coast-tundra sedge-browse type is found on practically all the lower ground near the coast, occupying the valley floors and poorly drained flats adjacent to the beach. This coastal strip comprises the greater part of the summer range for reindeer herds along the Bering Sea coast of Alaska.

This particular type occurs on a gentle northeast slope about half a mile from the beach. The soil is fine-textured loam with

abundant humus. Soil moisture is abundant during the growing season owing to frequent rains and poor drainage. The vegetation is composed largely of *Eriophorum* and *Carex* with a fair proportion of browse species, as ground birch, Alaska tea, cranberry, *Empetrum,* and blueberry. Grazing by reindeer during the summer has been moderate for the past several years.

A fenced exclosure containing one 1-meter-square quadrat was established in 1927 for the purpose of studying the effect of protection on this type after moderate grazing. A similar quadrat for comparison was located nearby in the open where it was subject to grazing.

Five years of observations of these quadrats disclosed no significant change in the composition of the vegetation. There was an increase in forage production on the protected plot but not enough to be of special importance. Although the data are far too meager to be conclusive, it appears that this type is little affected by moderate summer grazing.

Tundra sedge-browse subtype.—This phase of the coast tundra is characterized by the predominance of *Carex,* with comparatively few "niggerheads" or *Eriophorum* clumps. Generally the vegetative cover is complete and is composed of approximately 45 percent *Carex,* 20 percent *Eriophorum,* and 35 percent browse. The browse species include *Empetrum,* ground birch, cranberry, blueberry, *Arctous,* Alaska tea, and salmonberry. Lichens and mosses appear occasionally but in negligible quantities. The soil is a deep, fine-textured loam with abundant humus, and although it is nearly saturated with moisture throughout the growing season, there is practically no erosion. The type is grazed moderately by reindeer during the summer.

To observe the effect on the vegetation of grazing and protection, an exclosure containing three 1-meter-square quadrats was established in 1927 and two additional quadrats were located in the open nearby.

Denuded quadrat.—One of the quadrats within the exclosure was denuded of vegetation by spading at the time it was established. Originally it had a complete cover composed of 45 percent *Carex,* 20 percent *Eriophorum,* 6 percent *Empetrum,* 5 percent ground birch, 4 percent cranberry, 8 percent blueberry, 5 percent *Arctous,* 5 percent Alaska tea, and 2 percent salmonberry. Five years later the vegetation on this quadrat had grown so as to attain a density of 0.65. The cover was made up of 60 percent *Carex* and *Eriophorum,* in about equal quantities, 20 percent *Polytrichum,* and 20 percent browse. A notable feature was the large number of seedlings of willow, *Empetrum,* Alaska tea, and low cranberry. The area was revegetated mainly by the same species that were found on the area originally and in much the same proportions. The single exception was the moss, *Polytrichum.* These plants made their appearance rapidly on exposed soil in a moist site. The seedlings of the sedges and browse species apparently had little difficulty, however, in establishing themselves in lightly covered, mossy areas.

Check quadrats.—The other two quadrats within the exclosure

were left undisturbed to serve for comparison with the denuded quadrat and to note the effect on the vegetation of protection from grazing. At the time the quadrats were established, the vegetation on them had a complete density (1.0) and was composed of 65 percent *Carex* and *Eriophorum,* and 35 percent browse. After 5 years the density of the vegetative cover was unchanged, and the plant composition was estimated to be 80 to 85 percent *Carex* and *Eriophorum* and 15 to 20 percent browse. Protection from grazing apparently promoted the growth and spread of *Carex* and *Eriophorum* over that of the browse species, at least during the first 5 years.

Denuded open quadrat.—One of the quadrats outside the exclosure was denuded by spading off the vegetation. Before the removal of the plant cover its density was complete (1.0), the vegetation consisting of 55 percent browse and 45 percent *Carex.* Five years later the cover on this area was estimated to be of 0.5 density and was composed of 50 percent mosses and 50 percent sedges and browse. Lichens were first noted during the fifth year when 5 small groups were found.

The recovery of the denuded area that was exposed to grazing was much slower than that of the protected plot. Not only was there less vegetation on the exposed plot, but also a much larger proportion of unpalatable mosses. The sedges and browse species did not exhibit the thrift and vigor displayed by the plants in the protected area. This would indicate that even moderate grazing tends to retard the revegetation of denuded or badly depleted areas.

Check open quadrat.—The vegetation on the undisturbed quadrat established outside the exclosure had an estimated density of 1.0 and was composed of 55 percent browse and 45 percent *Carex.* During the 5 years that this area was under observation the vegetation changed in composition to 40 percent sedges, 50 percent browse, 8 percent mosses, and 2 percent lichens. The density remained unchanged. Although these data are not sufficient to warrant definite conclusions, it appears that under grazing this type is gradually changing from a sedge-browse type to a predominantly browse type. The reverse occurred in the protected plot. Summer grazing apparently tends to reduce the quantity of sedges and thus permit increased growth of the browse species. Just what effect this will have on the ultimate carrying capacity of the type is yet to be determined.

TUNDRA-LICHEN TYPE

The tundra-lichen type is of great economic importance to the reindeer industry. It is found extensively over the lower tundra areas along the Bering Sea and Arctic coasts and constitutes much of the fall and early winter range of the reindeer.

NUNIVAK ISLAND

An exclosure containing four 1-meter-square quadrats was established in the tundra-lichen type near Cape Etolin, on Nunivak Island, in 1922. The site chosen was at about 100-feet elevation

on a gentle northwest slope (fig. 7). The soil is deep, moist loam with much humus. Precipitation is abundant throughout the summer months. Heavy fogs occur frequently, and the moisture thus supplied is extremely favorable to the growth of lichens. These averaged 6 inches in height and made up about 80 percent of the total vegetative cover. Sedges and browse species composed the remainder of the vegetation.

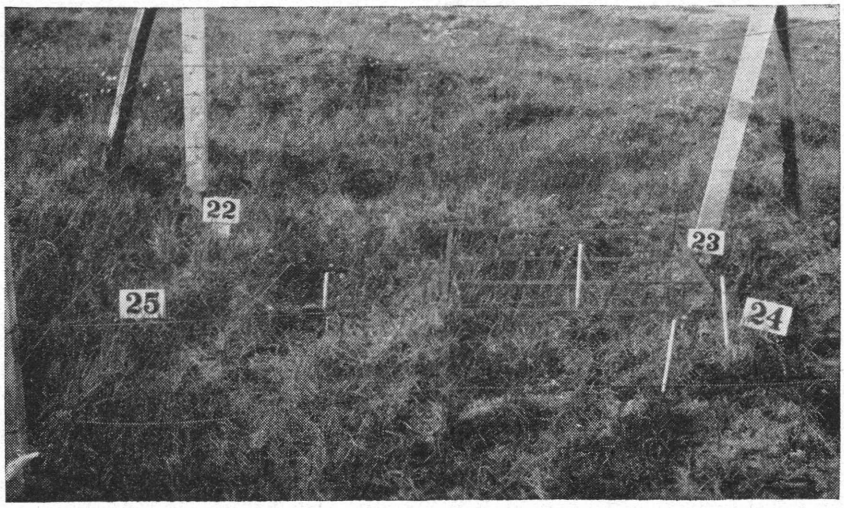

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Figure 7.—The exclosure in the lichen tundra 7 years after establishment, Nunivak Island. July 5, 1929.

Picked quadrat.—On one of the quadrats the lichens were picked by hand, very little of the roots being left with the base stand of 25 percent *Carex, Dicranum, Ledum,* and *Empetrum,* and a scattering of willow, blueberry, cranberry, and salmonberry. The lichens removed had an air-dry weight of 3 pounds 2 ounces; this indicated a forage yield of 12,646 pounds to an acre. Vegetation gradually reclaimed the area, a cover of 0.9 density being attained in the tenth year after the lichens had been picked and a complete cover between the tenth and fourteenth years. Fourteen years after treatment of the quadrat, the lichens averaged 3 inches in height and made up 55 percent of the ground cover. The remainder of the vegetation consisted of 20 percent *Carex* and 25 percent browse, including *Ledum, Empetrum,* willow, salmonberry, and cranberry.

Picked and trampled quadrat.—From a second quadrat, very similar to the first, the lichens were removed by picking, after which the ground was so treated as to simulate the results of intensive grazing and trampling by reindeer. A cover composed of *Carex* and *Dicranum* of about 0.1 density remained on the ground after treatment. During the next 5 years the revegetation consisted largely of sedges with the mosses *Polytrichum* and *Dicranum* making up about one-tenth of the cover. In the following years other species gradually appeared, including *Ledum,*

salmonberry, cranberry, willow, *Empetrum,* and such lichens as *Cladonia* and *Cetraria.* Fourteen years after establishment of the quadrat the vegetative cover was of 0.95 density and was composed of approximately 30 percent sedges, 15 percent browse, 20 percent lichens, and 35 percent mosses. The lichens were most abundant along the edges of the quadrat and averaged about 1½ inches in height.

The reaction of the vegetation to picking and trampling indicates that trampling is an important factor in the rate of recovery in this type. It would appear that moderate to light utilization and a short rotation would cause less disturbance and contribute to greater forage production than intensive grazing with a long rotation period.

Half-cut quadrat.—The third quadrat in this group, which had a complete cover of vegetation (density 1.0) made up of 90 percent lichens and 10 percent sedges, mosses, and browse species, was clipped so as to remove the top half, to simulate light grazing. The air-dry weight of the lichens removed was 2 pounds 14 ounces, which indicated a forage yield of 11,635 pounds to an acre. Revegetation was at first largely by sedges and mosses but later by browse species, including ground birch, *Ledum,* and salmonberry. The greater part of the lichens apparently were killed by the clipping, but new growth appeared, mainly by invasion from the edges. Fourteen years after treatment the vegetative cover was estimated to have a density of 0.9, and to be composed of 20 percent sedges, 40 percent lichens, 16 percent browse (principally ground birch), and 24 percent mosses. The lichens were most abundant along the edges of the quadrat and averaged 2 inches in height.

Cutting appeared to retard the growth of lichens more than did picking, but not so much as did the picking and trampling treatment. Lichens are delicate, and the removal of a very large proportion of the plants seems to be fatal to the lichen range, at least during certain seasons. The vascular plants can withstand a greater degree of disturbance and recover much more rapidly.

Check quadrat.—The fourth quadrat in the group had a complete cover of vegetation (density 1.0) made up of 80 percent lichens and 20 percent sedges, mosses, and browse species. It was left undisturbed for comparison with the treated quadrats. In the first 5 years a definite decrease in lichens and a corresponding increase in sedges were noted. This was likely due to inadvertent trampling when the quadrat was laid out or to disturbance during subsequent chartings. It has been forcibly demonstrated during the course of these studies that when dry, lichens are brittle and very susceptible to injury. During the following years the vegetative development closely corresponded with that on the picked quadrat except that on the check quadrat the lichens were of larger growth and were more evenly distributed. Fourteen years after establishment of the quadrat the vegetative cover was complete and was composed of 35 percent sedges, 5 per-

cent Alaska tea and cranberry, 50 percent lichens, and 10 percent mosses. The lichens averaged 3½ inches in height.

Summary.—From the history of these quadrats it is apparent that lichen range is quick to react to any disturbance. The length of time required for recovery is directly proportional to the degree of disturbance. Revegetation occurs both by invasion from established plants in surrounding areas and by the establishment of new individuals within the area. The reestablishment of lichens is very slow. The picked quadrat made the most rapid and satisfactory recovery, and as this treatment closely simulates the grazing action of reindeer when they are loosely herded, it would seem that open herding, once over, on this type of range and then allowing a lapse of 6 to 8 years for recovery would be the most conservative manner of utilizing it. It appears that trampling has a greater damaging effect upon lichens than has actual grazing or removal of plant parts; open herding would minimize this damage.

The use of 1-meter-square quadrats is important in the study of reindeer ranges in that it has a relation to the feeding habits of the animals. Preferably they graze for a short time on a small area, then move on to another, even though there may remain much forage on the area they leave. This habit results in lighter utilization and permits a shorter period of rotation than would be possible if the reindeer grazed evenly and closely as they moved over the range.

The study of lichen ranges and their reaction to grazing is extremely important. The management of winter ranges, which are largely lichen areas, so as to keep them on a sustained yield basis, is fundamental, as without adequate winter range there can be no reindeer industry. Summer ranges, while equally important, are much less exacting in their management requirements and recover more rapidly after use.

PASTOLIK

The tundra-lichen type at Pastolik is very similar to that on Nunivak Island. It occupies the low rolling hills just back from the beach. The vegetation may be roughly grouped as 75 percent lichens, 15 percent sedges, and 10 percent browse plants. The browse species comprise ground birch, *Ledum,* salmonberry, *Empetrum,* and cranberry. The soil is deep, moist loam with an abundant supply of humus.

An exclosure (fig. 8) containing four 1-meter-square quadrats was established on this type in 1922. The last observations were made in 1931.

Cut quadrat.—One of these quadrats was treated by cutting off the top half of the lichen cover. The vegetation, which was of full density (1.0), was composed of 75 percent lichens, 15 percent sedges, and 10 percent browse. Two years after establishment of the quadrat a very marked invasion of vascular plants was noted. After 9 years the density of the vegetation was again complete, the plant composition being estimated as 65 percent sedges, 5 percent browse, 10 percent mosses, and 20

percent lichens. Disturbance of the lichen cover gave a sharp impetus to the growth of *Eriophorum* and *Carex,* these two genera taking over practically the whole area. If the quadrat is left without further disturbance, the *Eriophorum* and *Carex* doubtless will gradually be replaced by lichens and mosses. Browse species did not show any great response to the treatment. Decline of *Eriophorum* was evident in its lack of vigor. When examined in 1931 the *Eriophorum* outside the exclosure

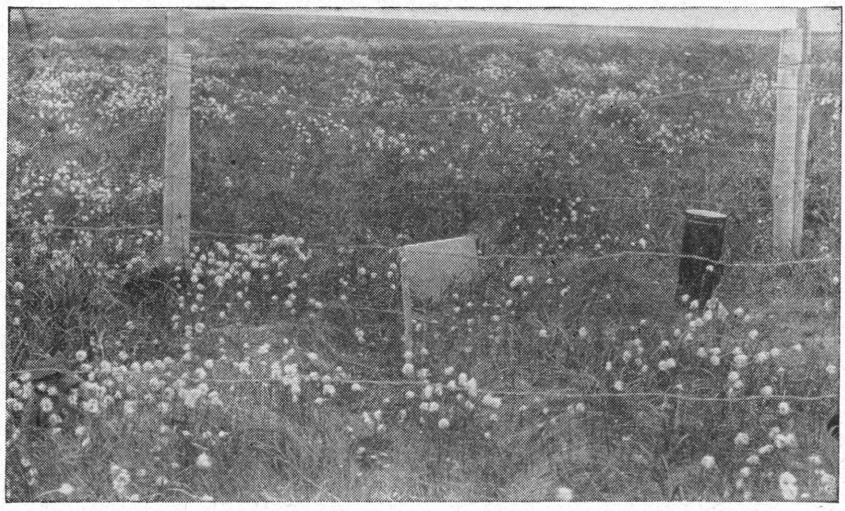

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Figure 8.—The tundra-lichen exclosure at Pastolik 6 years after its establishment. July 4, 1928.

was in full bloom and very abundant, while on the quadrat not a flower stalk was observed.

Denuded quadrat.—The second quadrat in the exclosure, very similar to the first in density and composition, was denuded by cutting the vegetation at the ground surface and then trampling the area. Four years later little lichen growth had appeared, the area being entirely taken by *Eriophorum.* After 9 years the vegetative cover was complete (density 1.0) and had an estimated composition of 80 percent sedges, 5 percent lichens, 10 percent mosses, and 5 percent browse.

After the quadrat was denuded there was an almost immediate establishment of a full vegetative cover of *Eriophorum.* Nine years of protection found the *Eriophorum* beginning to decline, as was evidenced by the quantity of dead leaves and the lack of vigor in producing flower stalks. Sphagnum mosses and lichens were increasing underneath the mat of *Eriophorum* leaves but their progress was slow.

Picked quadrat.—The third quadrat in this series was very similar to the others and from it the lichens were picked by hand; a 25-percent stand of sphagnum moss, sedges, and browse remained. The air-dry weight of the lichens removed from the area indicated a production of 22,764 pounds to an acre. A

heavy invasion of *Eriophorum* followed the treatment, but after 4 years there was noted an abundant reproduction of lichens from 1 to 2 inches in height. After 9 years the vegetation was of complete density (1.0) and was estimated to be composed of 65 percent sedges, 15 percent lichens, 10 percent browse, and 10 percent mosses. *Eriophorum* declined rapidly during the last 4 years of the period. The recovery of the half-cut and the picked quadrats was very nearly equal, indicating that the treatments were practically identical in effect.

Check quadrat.—The check quadrat in this group was very similar to others at the time of establishment but 4 years later, in 1926, it was observed that part of the plants had been killed by trampling. The last examination, made in 1931, showed that the area had a complete vegetative cover composed of 35 percent sedges, 35 percent lichens, 20 percent browse, and 10 percent mosses. The lichens appeared to have made considerable recovery after their being trampled prior to 1926. *Eriophorum* was dying out, and all 4 quadrats were covered with a 6-inch layer of interwoven dead stems and leaves of this plant. Underneath this mat was a good stand of lichens, largely *Cladonia*, and of sphagnum moss. Browse species, with the exception of salmonberry, appeared thrifty.

Summary.—Disturbance of the lichen cover on the moist tundra-lichen type is followed by an almost immediate invasion of vascular plants, chiefly cotton-sedge (*Eriophorum*), that is in direct proportion to the amount of disturbance. Trampling of this type, especially at a time when the lichens are dry and brittle, causes fully as much, if not more, damage than does actual grazing.

UNALAKLEET

An exclosure containing four 1-meter-square quadrats for the study of the tundra-lichen type was established in 1922 on a spur ridge about 3 miles up the Unalakleet River from its mouth. The site chosen was about 150 feet in elevation, nearly level, with a southwest exposure. The soil is a fairly deep loam with abundant humus. Although the soil is well drained, its moisture content is sufficiently high to support a good stand of vegetation (fig. 9). This type is drier than the preceding two tundra-lichen types discussed and contains smaller quantities of sedges and niggerheads. It is more characteristic of the tundra on the hills back from the coast.

Scraped quadrat.—These quadrats were established early in spring while the ground was frozen and there was a light cover of snow. The snow being brushed from the first quadrat, there was revealed a full cover of vegetation composed of 80 percent lichens, 10 percent sedges, and 10 percent browse. The lichens were semi-dry and somewhat brittle and stood about 2 inches above the frozen ground. The vegetation was scraped clean with a hand rake to the frozen ground surface, the lichen base being left intact and protected by the frozen ground and snow. The lichens removed from the area, when air-dry, indicated a forage

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yield of 5,140 pounds to an acre. Later, after the ground had thawed, it was found that the quadrat had a remaining cover of lichens ½ to 1 inch in height. In September of the same year it was determined that half of the vegetation on the quadrat was dead. The next year it was observed that new growth was forming on some of the cut lichen stubs. This was like coppice growth, with the new branches $\frac{1}{16}$ to ⅛ inch in length. It was estimated at that time that two-thirds of the original vegetation was dead. After 10 years the area had a vegetative

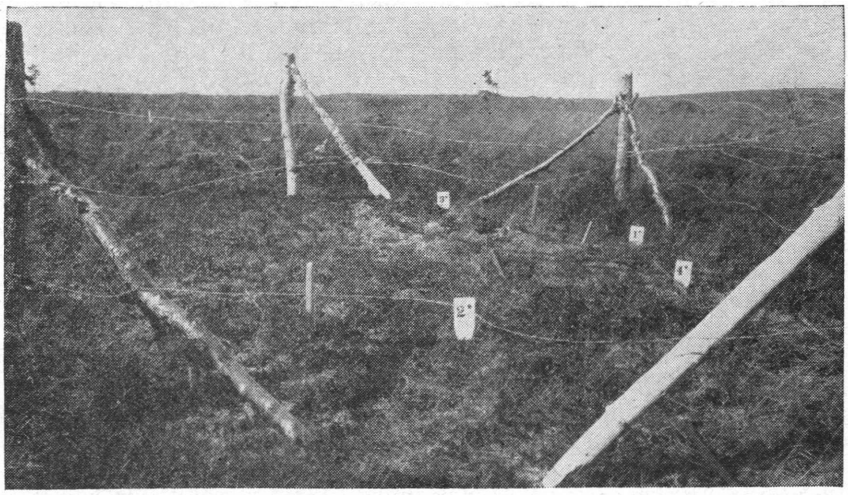

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Figure 9.—The exclosure in the tundra-lichen type. Unalakleet. August 24, 1929.

cover estimated at 0.95 density, composed of 50 percent lichens, 30 percent browse, 15 percent sedges and grasses, and 5 percent mosses. The lichens averaged 2½ inches in height.

Lichens thus have the power to resume growth after a part of the plant has been removed, although frequently it appears that such treatment is fatal. In this instance two-thirds of the plants were killed. Recovery was slow, and in 10 years the lichens had regained only slightly more than half of their former abundance and height growth. Browse species were stimulated by the opening of the lichen stand, but sedges and mosses made little response.

Clipped quadrat.—The second quadrat in this exclosure was very similar in appearance to the first when established. The vegetation was clipped to take off about the top half of the forage exposed above the frozen ground. The lichens removed from the quadrat had an air-dry weight of 0.65 pounds, which indicated a yield of 2,630 pounds to an acre. After the ground had thawed there was a remaining lichen cover 1 to 2 inches in height. Later it was determined that on this quadrat, as on the first, half of the vegetation had been killed. After 10 years the density of the vegetation was complete (1.0). The vegetative cover was estimated to be composed of 50 percent lichens,

45 percent browse, and 5 percent grasses and sedges. The lichens averaged 3 inches in height. Although cutting apparently did not affect the vegetation as much as did scraping, yet it caused great reduction in the lichen stand. It will require several more years for the lichens to regain completely their former abundance and volume. The immediate result of reducing the lichens was to stimulate the growth of browse. Sedges did not seem to be materially affected by the treatment.

Denuded quadrat.—The third quadrat, similar to the others originally, was scraped clean to the frozen ground surface at the time of establishment. Later when the ground had thawed there remained a cover of lichens 1½ to 2 inches in height. This also was removed by scraping, the area being thus completely denuded. The following year considerable lichen reproduction was found, a growth of $\frac{1}{16}$ to ⅛ of an inch being noted on old stumps. The lichens observed at that time were *Cladonia rangiferina, C. sylvatica, C. sylvatica sylvestris, Cetraria cucullata, C. islandica,* and *Stereocaulon tomentosum.* Ten years after establishment the quadrat was covered with vegetation to an estimated density of 0.85 composed of approximately 35 percent lichens, 40 percent browse, 15 percent sedges and grasses, and 10 percent mosses. The lichens averaged about 1 inch in height.

This denuded area made nearly as rapid recovery as did the half-cut and the scraped quadrats. The original species revegetated it, but their proportions were changed. On this drier site the increase of *Carex* and *Eriophorum* following denudation of the area was negligible. On the other hand, the browse species were noticeably stimulated. Lichens, also, made a good recovery, especially where the ground surface remained sufficiently clear.

Check quadrat.—The fourth, or check, quadrat in this type was left undisturbed at the time of establishment. The vegetation formed a complete cover and was estimated to be composed of 80 percent lichens, 10 percent browse, and 10 percent sedges. The lichens averaged between 2 and 3 inches in height above the frozen surface, and later, after the ground had thawed, they measured between 3 and 4 inches in height. The quadrat must have been trampled at the time of establishment or during later examinations, because 5 years after its establishment it was estimated that about half of the lichen stand was dead. At that time the cover was composed of 50 percent lichens, 40 percent browse, and 10 percent sedges. In 1932, 10 years after establishment of the quadrat, the plant composition was estimated to be still the same.

Because of disturbance the quadrat failed to fulfill its purpose but instead yielded further information on the reaction of lichens to trampling. The stand in this case was reduced by approximately 40 percent, presumably from trampling, and did not make any appreciable recovery during the last 5 years of the investigations. This again clearly demonstrates the fragile and delicate nature of these plants and emphasizes the necessity of

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guarding lichen areas against trampling or use during the summer.

Summary.—On the dry tundra-lichen type a reduction in vegetative cover through grazing, as typified by the treated quadrats, is followed by accelerated growth of the browse species. *Carex* and *Eriophorum* show little response to the opportunity for expansion. Lichens recover as readily, if not more so, as on more moist sites, because the ground is left unoccupied by competitors for a longer period. On this type conservative use would not open the ground cover sufficiently to allow damage from erosion due to spring runoff and summer rains, and would permit the use of a fairly short rotation. Intense use, sufficient partially to denude, would cause a severe loss of forage through trampling, would open the vegetative cover and produce an erosion hazard, and finally would necessitate deferring use of the area for a period of 20 to 30 years to allow the vegetation to recover sufficiently to be grazed again.

WET-TUNDRA SEDGE-LICHEN TYPE

NUNIVAK ISLAND

The wet-tundra sedge-lichen type is a typical lowland tundra type and is found extensively along the Alaska coast. It is more

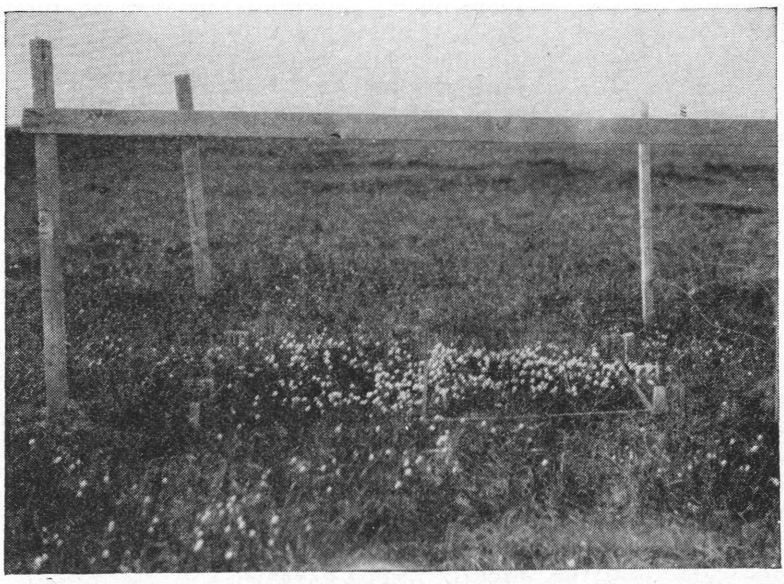

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Figure 10.—Sedge-lichen vegetation in the wet-tundra type, Nunivak Island. July 4, 1929.

boglike than the "niggerhead" tundra, although most of the species found there, except the sphagnum mosses, are also present in the "niggerhead" type. In the wet-tundra sedge-lichen type the soil is deep, spongy, and peatlike. It is saturated with moisture throughout the growing season and drainage is poor.

The vegetation is dominated by the sedges, with lichens (*Cladonia* and *Nephroma*) present in smaller quantities. The browse species are *Ledum,* prostrate willows, ground birch, *Empetrum,* and cranberry.

Study of this type was begun in 1927, when an exclosure was erected about a mile south of the native village at Cape Etolin on Nunivak Island. The site chosen was nearly level and at about 70 feet elevation. Three 1-meter-square quadrats were established within the exclosure for the purpose of determining the effect of grazing, denudation, and trampling on the sedge-lichen vegetation (fig. 10).

Cut quadrat.—The first of these quadrats had a full cover of vegetation estimated to be composed of 45 percent sedges, 32 percent lichens, 12 percent browse species, and 11 percent mosses. This was removed by cutting it at the ground surface with a sharp knife.

A full cover of vegetation was reestablished the third year after the cutting, with *Eriophorum* making up 75 percent of the stand. Mosses were estimated to compose 15 percent and lichens the remaining 10 percent of the growth. Nine years after cutting the vegetative cover consisted principally of sedges, *Carex* forming 40 percent and *Eriophorum* 60 percent. A vigorous growth of sphagnum moss was found underneath the accumulation of dead sedge leaves.

Spaded quadrat.—The second quadrat was similar to the first, having a complete cover of vegetation made up of 45 percent sedges, 31 percent lichens, 12 percent browse species, and 12 percent mosses. The plants, including their roots, were removed by spading. Revegetation occurred rather slowly, a complete cover not being established after a lapse of 9 years. *Eriophorum* was the principal invader, followed by *Carex, Sphagnum,* and willow. When the quadrat was last examined, in 1936, the density of the vegetative cover was estimated to be 0.95. *Eriophorum* composed 40 percent of the stand, *Carex* 35 percent, sphagnum mosses 20 percent, and willows 5 percent. The willows apparently crept in by layering from plants in the check quadrat.

Check quadrat.—This undisturbed quadrat had a complete cover of vegetation made up of 50 percent sedges, 30 percent lichens, 15 percent browse species, and 5 percent mosses. During the period of observation some changes occurred in the vegetative cover. A gradual decrease in lichens and a corresponding increase in sedges and willows were recorded. At the end of 9 years the cover was complete and was made up of 70 percent sedges (*Carex* and *Eriophorum* in about equal quantities), 22 percent browse, mostly willow, and 8 percent lichens and mosses.

Many runways of lemmings were found underneath the accumulation of dead sedge leaves. It is possible that these rodents caused some of the change in vegetation, but observations on this point have not been sufficient to be conclusive.

Summary.—The length of time required for vegetation in the wet tundra type to recover after disturbance seems to be directly proportional to the degree of disturbance. *Eriophorum callithrix*

is the principal species to appear following disturbance and may be considered a reliable indicator of overgrazing in this type.

WET-TUNDRA SEDGE TYPE

UNALAKLEET

The wet-tundra sedge type is of rather common occurrence on the low tundra used as summer range for reindeer. This part of the tundra is dotted with small, shallow, fresh-water ponds and lakes, around the margins of which sedges frequently occur in pure stands. The soil is fine and deep with a high humus content. These areas are usually flooded during the spring, and the soil remains saturated throughout the summer.

The site chosen for the study of this type was 200 yards back from the margin of a small fresh-water lake, and about a mile north of the reindeer corrals at Unalakleet. A fenced exclosure surrounding three 1-meter-square quadrats was erected in 1927 to study the effect of grazing and denudation on this wet-tundra type. The exclosure (fig. 11) was located within the driveway leading to the reindeer corrals and, in 1932, the Lapps removed the exclosure fence and allowed the area to be severely trampled by the reindeer.

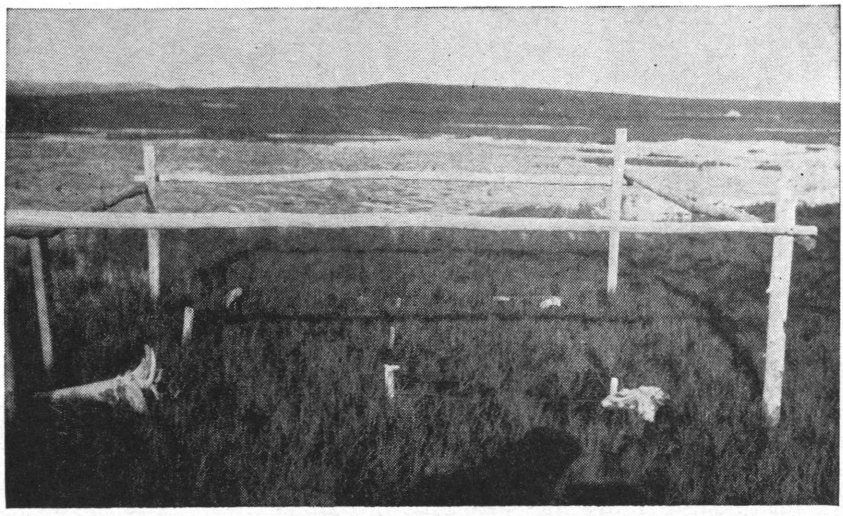

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Figure 11.—The study area in the wet tundra. Unalakleet. September 22, 1928.

Cut quadrat.—When the quadrat was established the vegetation had a density of 0.4 and was made up of a very even stand of sedges and about 10 percent mosses. The area was denuded by cutting the vegetation at the ground surface. The following year the plot was occupied by a stand of sedges having a density of about 0.35. At the end of 5 years, and after being trampled by reindeer during the summer of the fifth year, the vegetation was composed of a pure stand of sedges of 0.5 density.

Spaded quadrat.—The second quadrat in this group was similar in appearance to the first, when established. The vegetation on the area was completely removed by spading it up. At the end of the first year there was a pure stand of sedges with a density of 0.2. After 4 years the plant density had increased to 0.6, the vegetation being composed of 90 percent *Carex* and 10 percent fine grasses of undetermined species but thought to be bluegrass. At the end of the fifth year, after being trampled by reindeer, the vegetation was a pure stand of *Carex* of 0.5 density.

Check quadrat.—Originally the check quadrat was very similar to the others in the group. It had a vegetative cover of approximately 0.4 density composed of 90 percent *Carex* and 10 percent mosses. It was left undisturbed for comparison with the other quadrats and to observe the effect of protection. After 4 years the vegetation was made up of 90 percent *Carex* and 10 percent fine grasses. The density was estimated to be 0.65. A very small moss growing between the sedge clumps, if included, would bring the density up to 0.8. During the fifth year, after being trampled by reindeer, the vegetation was again reduced to 0.5 density and was composed of a pure stand of *Carex.*

Summary.—On this wet-tundra type the vegetation readily recovered after denudation of the area, an almost pure stand of *Carex* coming in. Under protection density increased and an invasion of fine grasses was noted. One season without protection, however, was sufficient to undo the progress of 4 years and render the area substantially the same as when the studies were started. It would be interesting to continue the study to determine the progress and effect of the grass invasion.

GRASS-BROWSE TYPE

NUNIVAK ISLAND

The grass-browse type is of rather limited occurrence and of minor importance compared with the types that make up the greater part of the reindeer ranges. It is confined to shallow gulches and along stream courses and does not extend far to either side. The limiting factors are probably soil and soil moisture, and it is likely that drifting snow exerts an influence. The soil is fine, deep loam, very rich in humus. It is wet, if not saturated, during most of the growing season. The vegetation is predominantly willows and grasses. Other plants found in lesser abundance in this habitat are *Carex, Ranunculus, Potentilla, Petasites, Polemonium, Equisetum,* and *Epilobium. Bryum* and a few lichens, largely species of *Cladonia,* are found occasionally underneath the other plants.

A fenced exclosure containing three 1-meter-square quadrats for studying this type was erected in 1927 about 1½ miles south of the native village at Cape Etolin on Nunivak Island (fig. 12).

Spaded quadrat.—The first quadrat in this group was completely covered with a rank growth of *Arctagrostis* and willows. The willows shaded about 70 percent of the area. This vegeta-

tion was completely removed by spading. Two years later this quadrat again supported a full stand of vegetation. It was composed, however, of 65 percent mosses, 15 percent *Equisetum,* 15 percent grasses, and 5 percent weeds (*Petasites, Viola,* and *Artemisia*). During the next 7 years there was a gradual decrease in mosses and an increase in the number and quantities of weeds. Willows became reestablished and increased slowly. Grasses decreased in the amount of area covered. The final charting made 9 years after spading revealed a cover density of 0.6, the vegetation being composed of 65 percent mosses, 8 percent *Arctagrostis,* 9 percent willow and salmonberry, and 18 percent weeds, including *Artemisia, Petasites, Epilobium, Viola,* and *Polemonium.*

Cut quadrat.—The second quadrat in this group was originally similar to the spaded quadrat, having a full cover of willows and *Arctagrostis.* The vegetation was removed by cutting it at the ground surface and then trampling it. Two years later there was a full cover of vegetation made up of 85 percent grasses, 8 percent mosses, and 7 percent weeds. The vegetation was again

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Figure 12.—The site of the study of the grass-browse type on Nunivak Island. June 27, 1927.

removed by cutting. The following year the plant cover had a density of 0.8 and was composed of 38 percent grasses, 50 percent mosses, and 12 percent weeds. During the next 6 years there was a gradual increase in the number of species and quantities of weeds and browse and a decrease in the mosses. The last charting recorded a cover of 0.9 density made up of 30 percent grasses, 30 percent weeds, 30 percent mosses, and 10 percent browse species. *Petasites, Equisetum, Coelopleurum,* and *Artemisia* were the dominant weeds.

Check quadrat.—The check quadrat was similar in density and composition to the treated quadrats when established. Subse-

quent observations over the 9-year period revealed a gradual decline in the grasses and mosses and a corresponding increase in the quantity of weeds. The final charting recorded a vegetative cover of 0.9 density composed of 25 percent *Arctagrostis,* 48 percent weeds, 17 percent mosses and lichens, and 10 percent thimbleberry (*Rubus arcticus*). The dominant weeds were *Artemisia, Coelopleurum, Honkeneya,* and *Equisetum.*

Summary.—The vegetative cover was rapidly restored to areas in the grass-browse type after denudation. The original *Arctagrostis*-willow association was first replaced by a moss-*Equisetum-Arctagrostis* cover. During the following years the progress of succession was marked by a gradual increase in weed species and a decline in the mosses. Significant changes in the composition of the vegetation on the check quadrat were recorded but are not as yet fully understood. These changes may have resulted from the protection afforded by the exclosure or they may be successional changes by which the type is adjusting itself to the habitat. It appears that the grass-browse type would bear rather intensive grazing without impairing its productivity.

HEATH TYPE

NUNIVAK ISLAND

The heath type is a typical subtype in the better drained browse tundra. The soil is deep, with a top layer of humus that is peatlike in character. The subsoil is fine, gray, and of volcanic origin. Soil moisture is plentiful during the growing season. *Empetrum nigrum* is the dominant species, and associated with it are *Arctous alpina,* cranberry, willows, and salmonberry, as well as sphagnum moss and a few lichens.

The site chosen for the study of this type was about 2 miles south of the native village at Cape Etolin on Nunivak Island on a gentle northerly slope at about 100-feet elevation. A fenced exclosure surrounding three 1-meter-square quadrats was erected there in 1927 (fig. 13).

Spaded quadrat.—When established this quadrat was covered completely with vegetation made up of 80 percent *Empetrum* and 20 percent willow, cranberry, salmonberry, *Arctous alpina, Carex, Cetraria islandica, Cladonia,* and mosses. The plant cover was removed by spading. In 2 years a vegetative cover of 0.8 density was reestablished. It was made up of 70 percent mosses, 26 percent weeds (*Equisetum* and *Petasites*), and 4 percent grasses. During the next 7 years there was a slow increase in the number of weed and browse species. The last charting revealed a cover of 0.6 density composed of 7 percent grasses, 13 percent weeds, 15 percent browse species, and 65 percent mosses. The weeds were dominated by *Equisetum* and *Petasites,* but *Cornus, Artemisia, Arnica,* and *Honkeneya* also were present. The browse species were about equally represented by willows, *Empetrum,* cranberry, salmonberry, and thimbleberry.

Cut quadrat.—The second quadrat in this group had a complete cover of vegetation composed of 85 percent *Empetrum nigrum,*

with scattering willows, *Petasites, Arctous,* cranberry, *Carex,* and lichens making up the remaining 15 percent. This cover was removed by cutting it at the ground surface. Two years after the cutting the vegetation had an estimated density of 0.3 and was composed of 10 percent grasses, 20 percent browse species, 60

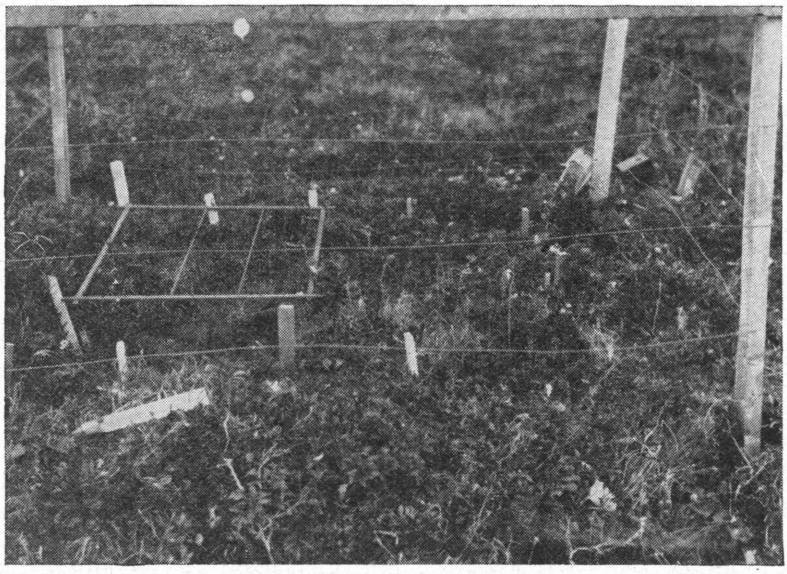

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Figure 13.—The heath type exclosure on Nunivak Island. July 5, 1929.

percent weeds, and 10 percent mosses. Five years after the cutting the density of the cover was 0.9. Mosses were growing over the entire area and salmonberry plants were too numerous to chart individually. Many small lichens ⅛ inch high were noted. After 9 years the salmonberry plants had entirely disappeared. The vegetation had a density of 0.9 and was made up of 40 percent browse species, 35 percent mosses and lichens, 22 percent weeds, and 3 percent grasses and sedges. *Empetrum* was the dominant browse species, but cranberry, *Arctous,* willows, and *Ledum* also were represented. Weed species were about equally represented by *Petasites, Polemonium, Arnica, Honkeneya, Artemisia, Coelopleurum, Gentiana,* and *Aconitum.* The browse species appeared vigorous and spreading.

Check quadrat.—The check quadrat had a complete cover of vegetation composed of 80 percent browse species, 2½ percent grasses and sedges, 3½ percent lichens, 5 percent mosses, and 9 percent weeds (*Petasites* and *Pedicularis*). During the 9-year period over which the observations were made several changes in the composition were noted, but the general ratios of the browse, weeds, grasses, and mosses remained nearly the same. Several new weed species appeared, among them *Arnica, Artemisia, Aconitum, Equisetum,* and *Polemonium,* and willows disappeared. The last charting showed a complete ground cover

of 5 percent grasses, 11 percent weeds, 80 percent browse species, and 4 percent lichens and mosses.

Summary.—On completely denuded areas, as represented by the spaded quadrat, the initial invasion was by mosses and *Equisetum.* Following these were the grasses and weeds, represented by such species as *Calamagrostis, Carex, Petasites, Arenaria, Polemonium,* and *Artemisia.* Browse species were the last to become reestablished.

When the vegetation was removed by cutting a more rapid revegetation occurred. This was likely due, at least in part, to the viable roots left after cutting the aerial portions. Weed species, especially *Equisetum,* were aggressive in recovering the area and browse plants also made rapid progress. Essentially the same species were found in the new vegetative cover as were originally present, but the disturbance caused considerable changes in their specific abundances.

Changes in composition were noted also in the undisturbed check quadrat. Although they were quantitatively of minor importance, it is possible that these changes may reflect an unstabilized condition of the type.

LICHEN-BROWSE TYPE

DEXTER CREEK

The lichen-browse type is typical of the lower hills back from the coast on Seward Peninsula. The soil is well drained, shallow, rocky loam, with a thin humus layer on the surface. Soil moisture is plentiful during the spring and fall, but scant in summer. The vegetation is made up largely of lichens with a small percentage of browse, mosses, and sedges. This type is of major importance, as it furnishes a large part of the winter forage for the reindeer in that section.

The site chosen for the study was about 7 miles north of Nome in the Dexter Creek drainage. The plot, on a 20-percent north slope, was at an elevation of approximately 750 feet. A fenced exclosure containing four 1-meter-square quadrats was established there in 1922 (fig. 14).

Half-cut quadrat.—The first of these quadrats when established had a full cover of vegetation, composed of 92 percent lichens (*Cladonia alpestris, C. sylvatica, C. sylvatica sylvestris, C. rangiferina* and *C. uncialis,* 80 percent; and *Cetraria islandica,* 12 percent); 5 percent browse (*Ledum*); and 3 percent sedges. The lichens averaged 4 inches in height. The top half of the vegetation was removed by cutting to simulate light grazing. Five years after establishment of the quadrat the density of the vegetation was estimated to be 0.3, the plant cover being composed of 38 percent browse (*Empetrum,* 15 percent; blueberry, 10 percent; ground birch, 5 percent; *Ledum,* 4 percent; and cranberry, 4 percent); 42 percent lichens, and 20 percent sedges. The proportion of browse species and sedges had increased markedly, but this was due largely to decrease in density rather than to any great increase in the area covered by these species.

Nine years after establishment of the quadrat the vegetation again had attained a complete cover of 1.0 density. This was composed of 25 percent browse (*Empetrum, Ledum,* cranberry, willow, and ground birch); 67 percent lichens; and 8 percent sedges. The last examination, made in 1932, disclosed little change from the 1931 charting.

Light cropping, as typified by the one-half cutting, greatly reduced the stand of lichens and at the same time appeared to have stimulated the growth of browse and sedges. This stimulation was likely due to the sudden release of these plants from competition with the lichens. Several browse species invaded, among them *Empetrum,* cranberry, ground birch, willow, and blueberry. The sedges did not respond as readily as did the browse species and as the lichens returned were rapidly reduced

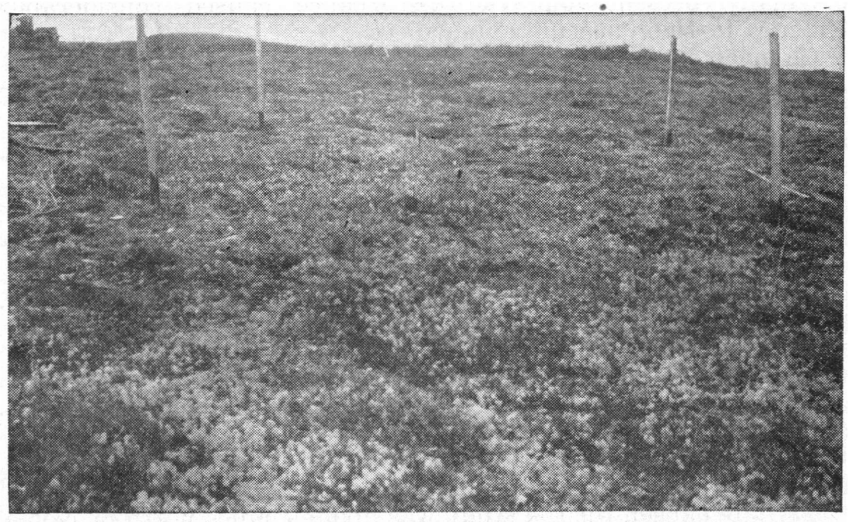

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Figure 14.—The exclosure in the lichen-browse type on Dexter Creek. October 2, 1928.

to their original status. The lichens made little recovery during the first 5 years after cutting, but during the second 5-year period they spread over much of the quadrat and attained a height of about 2 inches.

Denuded and trampled quadrat.—This quadrat had a complete cover composed of 92 percent lichens, 5 percent browse, and 3 percent sedges. The lichens were 3 to 5 inches in height. The area was denuded of vegetation and trampled. Five years later, in 1927, the density of the plant cover was estimated to be 0.1. The vegetation was composed of 45 percent browse, 15 percent sedges, 30 percent lichens, and 10 percent weeds.

In 1932, ten years after denudation of the area, the vegetation had an estimated density of 0.4 and was composed of 45 percent browse, 5 percent sedges, and 50 percent lichens. Most of the lichen growth was around the edges of the quadrat but some new growth was beginning in the center.

In this instance the denuded area was revegetated by the same species that were originally found on the area. The rate of revegetation was very slow, and indicated that it would probably require 25 years for the complete return to original condition of density, composition, and volume. Browse species and sedges recovered more rapidly than did the lichens.

Picked quadrat.—The vegetation on the third quadrat in this group was very similar to that of the others, namely, a complete cover composed of 92 percent lichens, 5 percent browse, and 3 percent sedges. The lichens were picked by hand and the browse and sedges left undisturbed. Five years later, in 1927, the vegetation was estimated to be of 0.25 density and was composed of 33 percent browse, 17 percent lichens, 45 percent sedges, and 5 percent weeds. Ten years after establishment of the quadrat, in 1932, the cover density was estimated to be 0.55, the vegetation consisting of 45 percent browse, 20 percent sedges, and 35 percent lichens. Most of the lichens were creeping in from the edges of the quadrat but a few groups of fair size were found within the interior of the plot. They averaged 2 inches in height.

The removal of the lichens was followed by an increase in browse and sedges. This no doubt resulted from removing competition by the lichens as well as from opening the stand and affording more suitable areas for the establishment of new individuals. The browse species thus established persist, but the sedges are crowded and killed out by the advancing lichens.

Check quadrat.—At the time of establishment of the check quadrat in 1922 it had a complete vegetative cover of approximately 90 percent lichens and 10 percent browse and sedges. The lichens averaged 4 inches in height. The last examination, made in 1932, disclosed complete cover density (1.0), the plant composition being 77 percent lichens, 20 percent browse, and 3 percent sedges. At first glance it would appear that the lichens had decreased and had been replaced by browse species, but this was not actually the case. In charting, the areas occupied by the browse species were outlined, and it is apparent that they have expanded, but lichens were found underneath and intermingled with the prostrate browse forms as abundantly as when the quadrat was established. It is merely a shortcoming of the system of charting that creates the illusion. Actually little change in the vegetation of this check quadrat took place during the 10 years of observation.

Summary.—Light cropping, as exemplified by the half-cut quadrat, was followed by the most rapid recovery that was made in any of the tests in this lichen-browse type. After heavy cropping, as on the picked and on the denuded and trampled quadrats, fully twice as much time was required for recovery, which in all cases was slow. Nine years were required for the half-cut quadrat to reestablish a full cover of vegetation, and the lichens did not occupy as large an area in it, nor were they as tall in growth, as originally.

Open herding, with possibly a 10-year rotation, would seem to be a practical system of utilizing this type. It would afford suffi-

cient time for the lichens to recover and so maintain forage production. Under no consideration should reindeer be allowed on the area during the summer and early fall when the lichens are dry and brittle.

WOODLAND-MOSS TYPE

UNALAKLEET

The woodland-moss type occurs most frequently along the larger drainages in the Norton Sound region, but is found also farther back in the interior. The vegetation is characterized by birches and alders with an understory of lichens, mosses, grasses, weeds, and small browse species. The soil is shallow and rocky, but frequent summer rains furnish sufficient moisture to support a vigorous stand of vegetation.

The site chosen for the study of this type was on the steep south slope of a bluff on the north side of the Unalakleet River, about 7 miles from its mouth, at an elevation of approximately 300 feet. Five open quadrats were established there near the top of the bluff.

Scraped and cut quadrat.—The first of these quadrats, when established in April 1922, had a vegetative cover of 87 percent lichens, 10 percent mosses, and 3 percent grasses. The density of the cover was 1.0. The vegetation was removed by first scraping and then cutting to the frozen ground surface. The purpose of establishing the quadrat was to observe the effect of close cropping of lichens and to determine the quantity of forage in the stand. Later, when the ground had thawed, there remained on the ground a cover of moss (*Polytrichum*) 1½ inches deep. The lichens had been entirely removed. The air-dry weight of the lichens taken from the quadrat was 3.46 pounds, which indicated a forage yield of 14,000 pounds to an acre.

Seven years after establishment of the quadrat the vegetation had recovered to a 0.95 density. It was made up of 25 percent lichens, 65 percent mosses (*Polytrichum*), and 10 percent grasses. The lichens averaged 1½ inches in height.

The quadrat recovered from a denuded condition to one of almost complete density in 7 years. *Polytrichum* was greatly stimulated by the removal of the lichens and was active in revegetating the area. Grasses responded only weakly to the reduction in cover. The reestablishment of lichens on this area was rapid.

Picked quadrat.—The second quadrat in this group had a complete cover of vegetation in 1922, composed of approximately 90 percent lichens, 7 percent mosses, and 3 percent grasses. *Stereocaulon* was the dominant lichen. The vegetation was removed from the quadrat by hand picking. By this method the lichens were readily removed to the frozen surface. The object was to observe the effect of moderately close cropping of lichens to determine the quantity of forage produced. The air-dry weight of the lichens removed from the 1-meter-square quadrat was 3.25 pounds, which indicated a forage production of 13,152

pounds to an acre. Later, when the ground had thawed, it was found that a cover of moss (*Polytrichum*) 1½ inches deep still remained on the area. The lichens had been entirely removed.

The last observation, made in 1932, disclosed a vegetative cover of 0.975 density composed of approximately 70 percent lichens, 28 percent mosses, and 2 percent grasses and weeds. The lichens were 60 percent *Stereocaulon* and 10 percent *Cladonia*. They averaged 3 inches in height. Many small, new lichens also were noted in the more open spaces.

The quadrat recovered from a nearly denuded condition to about the original density in 7 years. The lichens almost completely recovered their density and closely approached their original height in 10 years, much of this growth taking place during the last 3 years of the period. *Equisetum* came in rapidly following the denudation but was as promptly replaced by the spreading lichens and mosses. It is indicated that moderately close cropping, as typified by the picking treatment, is not so severe a treatment as scraping and cutting. The recovery of the vegetation, especially that of the lichens, was much more rapid than that following the scraping treatment. The grasses showed little response to the opening of the stand of vegetation. This quadrat again demonstrated that grazing such as would result under a system of open herding is the most advantageous method of utilizing lichens. It also emphasizes the necessity of employing a long rotation in order that the vegetation may recover after use.

Check quadrat No. 1.—The check quadrat in this group (fig. 15) had a vegetative cover of 90 percent lichens, 9 percent mosses, and

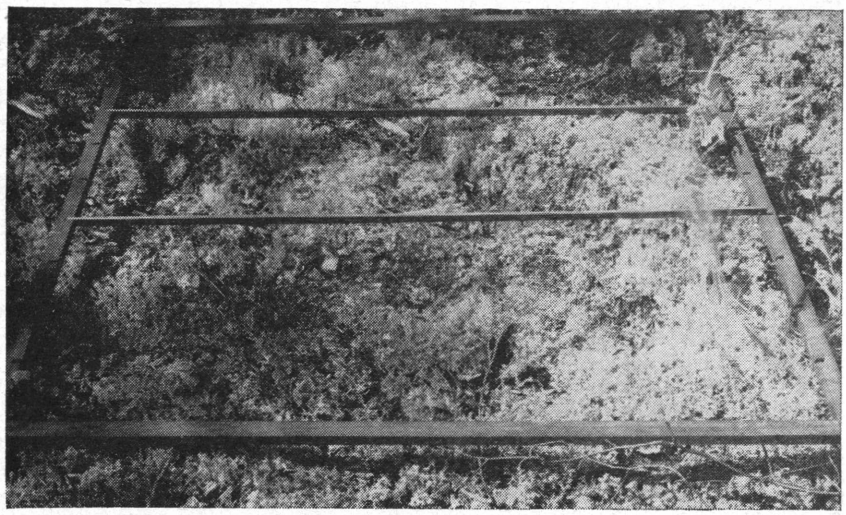

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Figure 15.—The check quadrat in the woodland-moss type near Unalakleet. August 24, 1929.

1 percent grasses. The lichens averaged 2½ inches in height. By 1929, seven years after establishment of the quadrat, the

density of the vegetation had been reduced to 0.9. The composition was estimated to be 80 percent lichens, 15 percent mosses, and 5 percent grasses. Bare areas had developed. When the area was last examined in 1932 the density of the vegetation was estimated to be 0.8. Lichens made up 80 percent of the cover, with mosses the remaining 20 percent. The average height of the lichens was 3½ inches. Some very small new lichen growth was noted in the previously bare areas.

The opening up of the lichen stand on this quadrat allowed the mosses to increase. The lichen growth appeared, but the increase in mosses and lichens was not rapid enough to maintain a complete vegetative cover. The cause of this reduction of the lichen stand is not known and further observations should be made.

Check quadrat No. 2.—The fourth quadrat in this group was established in 1929. The vegetative cover was complete and was composed of 85 percent lichens, 10 percent mosses, and 5 percent weeds (*Epilobium* and *Equisetum*). When the area was last examined in 1932 the density of the vegetation was estimated to be 0.975. The cover was composed of 95 percent lichens, 4 percent mosses, and 1 percent weeds (*Equisetum*). The lichens averaged 4 inches in height. It appears that lichens increased on this quadrat, displacing the mosses and weeds. These observations, however, are not complete enough as yet to warrant definite conclusions.

Quadrat No. 5.—The fifth quadrat in this group was also established in 1929. It appeared to have been badly trampled, and it is thought that the area may have been scraped in 1922. There was a scattering of dead lichens as though the area had been grazed. The density of the vegetation was 0.6 and it was estimated that half of it was dead. *Stereocaulon* made up 65 percent of the total cover. In 1932 the plant density was 0.8, and it was estimated that the vegetation was composed of 90 percent lichens, 6 percent mosses, and 4 percent birch, *Carex, Equisetum,* and *Epilobium.* The vegetation on this area appeared to be changing rapidly, but these observations are, as yet, too meager to be conclusive.

ALPINE-DRYAS TYPE

EGAVIK

The alpine-dryas type occupies the summits of the higher ridges and hills back from the coast in the Norton Sound region. It is not of much economic importance as forage for reindeer because of its short growth. It is chiefly valuable for holding the soil against erosion, conserving moisture, and serving as forage for such rodents as parka squirrels and marmots. The vegetation is composed largely of low-growing mat forms, of which *Dryas octopetala* is the most important. *Antennaria* and *Phlox* also are found in this type, along with a few sedges and such fine grasses as *Poa* and *Festuca.* The soil is shallow and rocky, with a slight layer of humus. Soil moisture is plentiful during

the spring and fall, owing to melting snow and seasonal rains, but during the summer it is scanty.

In order to study the trend of plant succession in this type, an exclosure (fig. 16) was erected around three quadrats, and two unprotected quadrats were established nearby. These quadrats were marked out in 1929 on top of a high ridge a mile or so north of Egavik, near latitude 64° N., longitude 161° W.

Spaded quadrat.—When established within the exclosure this quadrat had a cover of 0.5 density composed largely of *Dryas* and *Tofieldia.* The plants were completely removed from the quadrat

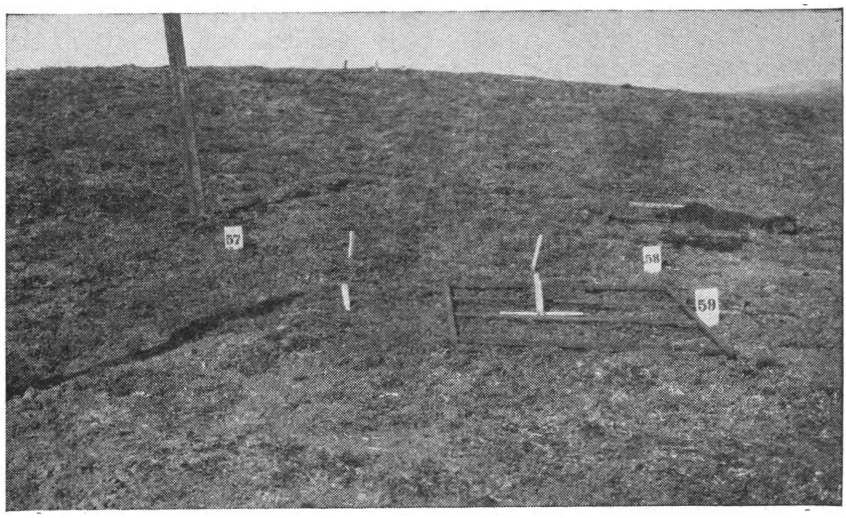

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Figure 16.—The exclosure in the alpine-dryas type near Egavik at the time of establishment. August 23, 1929.

by spading it. After 3 years the total growth on the area consisted of 6 *Carex* clumps, 1 of *Phlox,* 1 *Astragalus,* 1 *Aster,* 2 *Dryas,* 1 willow, and 6 of mosses.

The vegetation had been heavily frosted when the last examination was made, and it is possible that some seedlings of grasses and weeds were overlooked. The *Dryas* and willow appeared during the third year after denudation of the area. These data are far too meager and the study was of insufficient duration to show anything conclusively, but it appears that the same species return to an area following denudation. The recovery of the vegetation was slow.

Cut quadrat.—The vegetation on the second quadrat within the exclosure was removed by cutting it at the ground surface, leaving the roots and soil undisturbed. Before cutting, the vegetation had a density of 0.6 and was composed of *Dryas* and *Tofieldia.* Two years later the vegetation was of 0.3 density and had a high percentage of *Poa* and *Carex. Dryas* had made a strong recovery, undoubtedly by regrowth of viable roots left in the soil by the cutting. *Antennaria, Phlox,* and *Astragalus* also were present and making good growth. The third year after cutting, further

expansion of the mat forms *Dryas, Phlox,* and *Antennaria* was noted. Fewer grasses and sedges were found, but this may have been due to these plants having been frosted and withered, and for that reason overlooked. The same species that made up the original plant cover were active in revegetating the denuded area. Further study is necessary before definite conclusions can be drawn.

Check quadrat.—The third quadrat in this exclosure was left undisturbed. The cover at the time of establishment of the area was of 0.7 density and was composed largely of *Dryas* with a few scattering plants of *Astragalus, Tofieldia,* and *Festuca.* In 1932, three years after establishment of the quadrat, the density of the vegetation was estimated to be 0.85, an increase due to the spread of the *Dryas* mats. Lichens appeared in 6 small areas. It is indicated that this vegetative type is unstable and that it is still in active adjustment to its habitat. Further observations should be made.

Denuded open quadrat.—This quadrat, located outside the exclosure, was denuded of vegetation by grubbing and pulling the plants. Before the area was denuded, the vegetation had a density of 0.7 and was composed of 85 percent *Dryas,* 10 percent *Tofieldia,* and 5 percent *Antennaria, Astragalus,* and *Draba.* Two years later the cover was estimated to have a density of 0.15. *Dryas* was invading from the edges and a few plants had become established within the area. *Phlox, Antennaria,* and *Astragalus* also had reestablished themselves. *Carex* and *Poa* were well represented and a few small patches of lichens were noted. Three years after establishment of the quadrat the mats of *Dryas, Phlox, Antennaria,* and *Astragalus* were found to be much the same as they were the previous year. Sedges and grasses were not seen. They may have been frosted down and thus escaped notice or they may have been grazed by reindeer. Further study should be made of this area.

Check open quadrat.—When the check open quadrat was established, the vegetative cover had a density of 0.7 and was composed of 85 percent *Dryas,* 10 percent *Tofieldia,* and 5 percent *Draba, Astragalus,* and *Antennaria.* During the 3 years the quadrat was observed little change occurred. The area occupied by *Dryas* increased slightly.

OVERGRAZED-TUNDRA BROWSE-LICHEN TYPE

STUART ISLAND

The overgrazed-tundra browse-lichen type is characteristic of the drier tundra in the Norton Sound region. The soil is loam, with heavy humus, and is of unknown depth. It is of volcanic origin. Because of frequent fogs and rains, soil moisture is plentiful throughout the growing season. Reindeer were grazed on Stuart Island during the winter prior to and during 1918, but not after that time. In that comparatively brief period, however, the island was overgrazed.

In 1920 a fenced enclosure (fig. 17), containing one 1-meter-

square quadrat, was established to determine the length of time required for this type of range to recover from overgrazing. At that time young lichens of 1/8 to 1/4 inch in height were beginning to appear. Sedges, *Polytrichum, Empetrum, Arctous* and *Ledum* also were found. From examination of the chart it is assumed that this vegetation had a density of approximately 0.3. Subsequent examinations revealed steady progress up until 1931, when the last examination was made. The vegetation then had an estimated density of 0.95 and was composed of 15 percent lichens (*Cladonia,* 4; *Cetraria,* 3; and others, 8); 50 percent browse (*Empetrum,* 15; *Arctous,* 16; cranberry, 7; and *Ledum,* 12); 8 percent sedges, and 27 percent mosses (*Polytrichum,* 12; and common moss, 15).

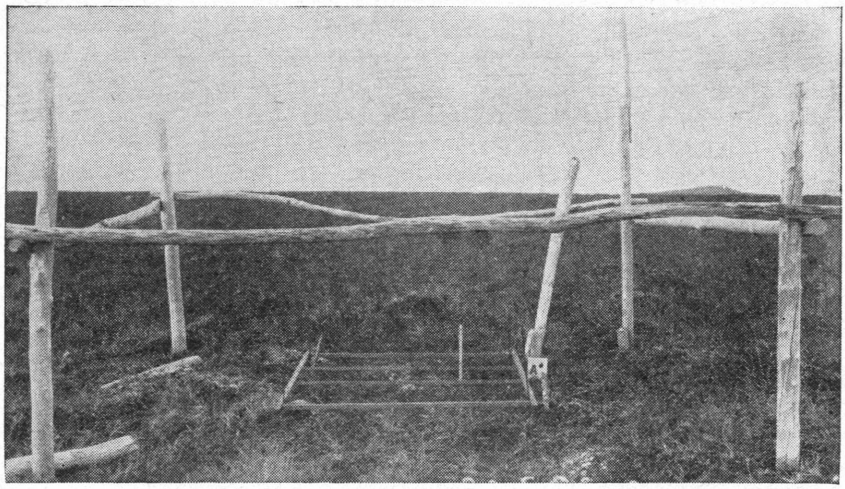

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Figure 17.—The study area on overgrazed browse-lichen tundra on Stuart Island. August 31, 1929.

Lichens increased rapidly at the start but during the later years made slower progress. Browse species, especially *Empetrum* and *Arctous,* were most aggressive in revegetating this overgrazed type. Sedges made little progress and were rapidly replaced by the lichen and browse species. Judging from the observed rate of recovery, it will require 25 or more years for this overgrazed type to be completely restored. It appears that the species originally found on the area are those which revegetate it, and that in time the proportions of the species will become about the same as before.

OVERGRAZED-TUNDRA SEDGE-WEED TYPE

PASTOLIK

The overgrazed-tundra sedge-weed type is common near the coast of lower Norton Sound. The vegetation is characteristically a mixture of sedges, weeds, and small *Eriophorum* clumps or "niggerheads." The soil is rather shallow and rocky, but has a

fair supply of humus. Although the area is well drained, moisture is plentiful owing to frequent local rains.

The type was heavily overgrazed by reindeer when an exclosure containing one 1-meter-square quadrat was erected on it in 1922. The vegetation was made up of sedges and weeds and had an estimated density of 0.1. The plants were in a noticeably weakened condition. The first year of protection brought a noticeable increase in the sedges, *Equisetum* and *Dicranum*. Two invading species of the genera *Saxifraga* and *Thalictrum* also were found. The next year the cover density had increased to 0.35, and *Gentiana* was added to the plant population. Four years after establishment of the quadrat the density appeared to be 0.6, and among the invading species were found *Juncus, Poa, Arctagrostis,* primrose, vetch, clover, *Empetrum,* and *Saussurea.* The quadrat was then abandoned as the site was included within a newly constructed reindeer corral.

During the 4 years that the quadrat was studied the vegetation made substantial recovery. The original sedge-weed cover, which was nearly destroyed by overgrazing, seemed to be returning under protection.

OVERGRAZED BROWSE-GRASS TYPE

CHORIS PENINSULA

The overgrazed browse-grass type occurs on top of the main ridge of Choris Peninsula which partly separates Kotzebue Sound from Eschscholtz Bay, at latitude 66° 15′ N., longitude 162° W.

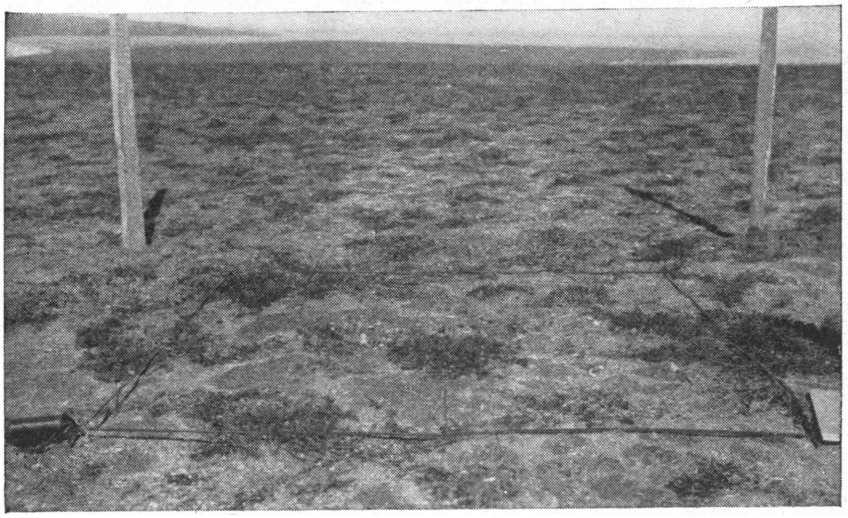

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Figure 18.—The exclosure site in the overgrazed browse-grass type on Choris Peninsula. August 7, 1928.

The vegetation consists mainly of browse, ground birch, willow, *Ledum,* and *Empetrum,* with a small proportion of sedges and

grasses. Weeds are few and lichens are scarce. The soil is shallow and rocky, with scant humus. Soil moisture is plentiful during spring and fall, but because of the sparse vegetation and the lack of humus, the moisture-holding capacity is low, and during the summer the soil becomes dry.

Choris Peninsula in years past was used as a holding pasture for reindeer and as a result it became overgrazed. The vegetative cover was greatly depleted and in places almost completely removed. In 1928 an exclosure containing four 1-meter-square quadrats was located on top of the main ridge of the peninsula to study the effect of overgrazing, denudation, and partial denudation on this vegetative type (fig. 18).

Cut quadrat.—The first quadrat in this group had a vegetative density of 0.4. The cover was made up of 90 percent browse (*Empetrum,* 35; *Ledum,* 35; ground birch, 10; and willow, 10), 5 percent grasses, and 5 percent weeds (*Tofieldia,* 2; *Oxycoccos,* 2; and *Phlox,* 1). The vegetation was removed from the area by cutting it at the ground surface. In 1932, four years after establishment of the quadrat, the total plant population consisted of 6 willows, 3 plants of *Ledum,* 1 of *Phlox,* 1 clump of grass, and 2 small patches of lichens. The lichens were first noted in 1931.

The recovery of the vegetation in this type is very slow, although observations were too few to serve for further conclusions.

Spaded quadrat.—The second quadrat in this group had in 1928 a cover density of 0.25. The vegetation was composed of approximately 90 percent browse (*Empetrum,* 42; *Ledum,* 42; and willow, 6), 5 percent grasses, and 5 percent weeds (*Tofieldia*). The plot was denuded by spading. In 1931 plant growth consisted of 5 small clumps of grass, 3 of *Carex,* 2 willows, 1 plant of *Ledum,* 1 of *Phlox,* and 2 small patches of lichens. In 1932 the vegetation had increased to 5 small grass clumps, 12 of *Carex,* 1 *Eriophorum* seedling, 2 willows, 1 plant of *Ledum,* 1 of *Phlox,* and 12 small lichen patches. The largest *Carex* clump found in 1931 appeared to be dead in 1932. The willows were sprouts from roots left after spading. Lichens, largely *Alectoria,* were increasing rapidly. Mosses were thinly scattered over the area.

The recovery of the vegetation on this spaded quadrat was very slow, although it was more rapid than that on the cut quadrat.

Check quadrats.—The third quadrat in this group was left undisturbed to serve as a check for comparison with the treated quadrats. When established in 1928 the plot had a vegetative cover of 0.3 density, and was composed of 98 percent browse (ground birch, 45; *Ledum,* 45; ground willow, 5; and *Empetrum,* 3) and 2 percent weeds (*Phlox*). By 1932 little change had occurred. The browse species exhibited some growth, and a few lichens and sedges had appeared. Vegetative changes appear to take place slowly in this type.

The fourth quadrat in the group was also left undisturbed, but little change was noted in its vegetation during the 4 years it was under observation.

Open quadrat.—A quadrat was established in the open, not far

from the exclosure, in order to make comparison between the vegetation inside and that outside the exclosure and to determine the effect of summer grazing on this type. When this plot was established in 1928 the vegetation had a density of 0.3 and was composed of 88 percent browse (ground birch, 45; *Empetrum,* 20; *Ledum,* 20; and willow, 3), 6 percent grasses, and 6 percent weeds (*Phlox* and *Tofieldia*). In 1932 it was noted that 3 small patches of lichens (*Alectoria*) had appeared. This was the only significant change. The rest of the vegetation appeared thrifty. There was no grazing on the Choris Peninsula during the period of these investigations.

DENUDED CORRAL SITES

PASTOLIK

The corral site at Pastolik was originally in the browse-grass tundra type. The corral was used from 1922 until 1925, and during that time the area studied was completely denuded of vegetation. In 1927 four 1-meter-square quadrats were established within a fenced exclosure to determine the time required to reestablish a vegetative cover and the plant species composing it. The soil is deep, with a top layer of humus that is peatlike in appearance; moisture is abundant. It is probable that the area is underlaid with ice, as considerable heaving and settling of the ground has occurred since the quadrats were established.

When the first plot in this group was established in 1927 there were 6 grass plants growing on it. These plants were too small for accurate identification but were thought to be *Arctagrostis.* The vegetation recovered steadily, and in 1931 a cover of 0.5 density was attained. It was composed of approximately 75 percent *Arctagrostis,* 13 percent *Carex,* and 12 percent *Eriophorum.* One weed seedling, too small for identification, was observed.

The second quadrat in this group was completely barren in 1927. No plants were observed on the area in 1928, but in 1931 six plants of *Arctagrostis* were found.

The third quadrat in the group contained 1 plant of *Arctagrostis* when it was established in 1927, and by 1931 there was merely a small clump of this grass formed by stooling of the original plant.

The fourth quadrat contained 11 grasses and 1 weed in 1927. In 1928 there were 12 individual grasses. By 1931 the vegetation had increased until its density was approximately 0.35, and was composed of 65 percent *Arctagrostis,* 25 percent *Carex,* and 10 percent *Eriophorum.*

The revegetation of this denuded corral site took place very slowly. Grasses (largely *Arctagrostis*) and sedges (both *Carex* and *Eriophorum*) were the most active invaders.

CHORIS PENINSULA

The corral site on the Choris Peninsula is on the low, narrow neck at the north end. In 1927 the reindeer corrals were moved

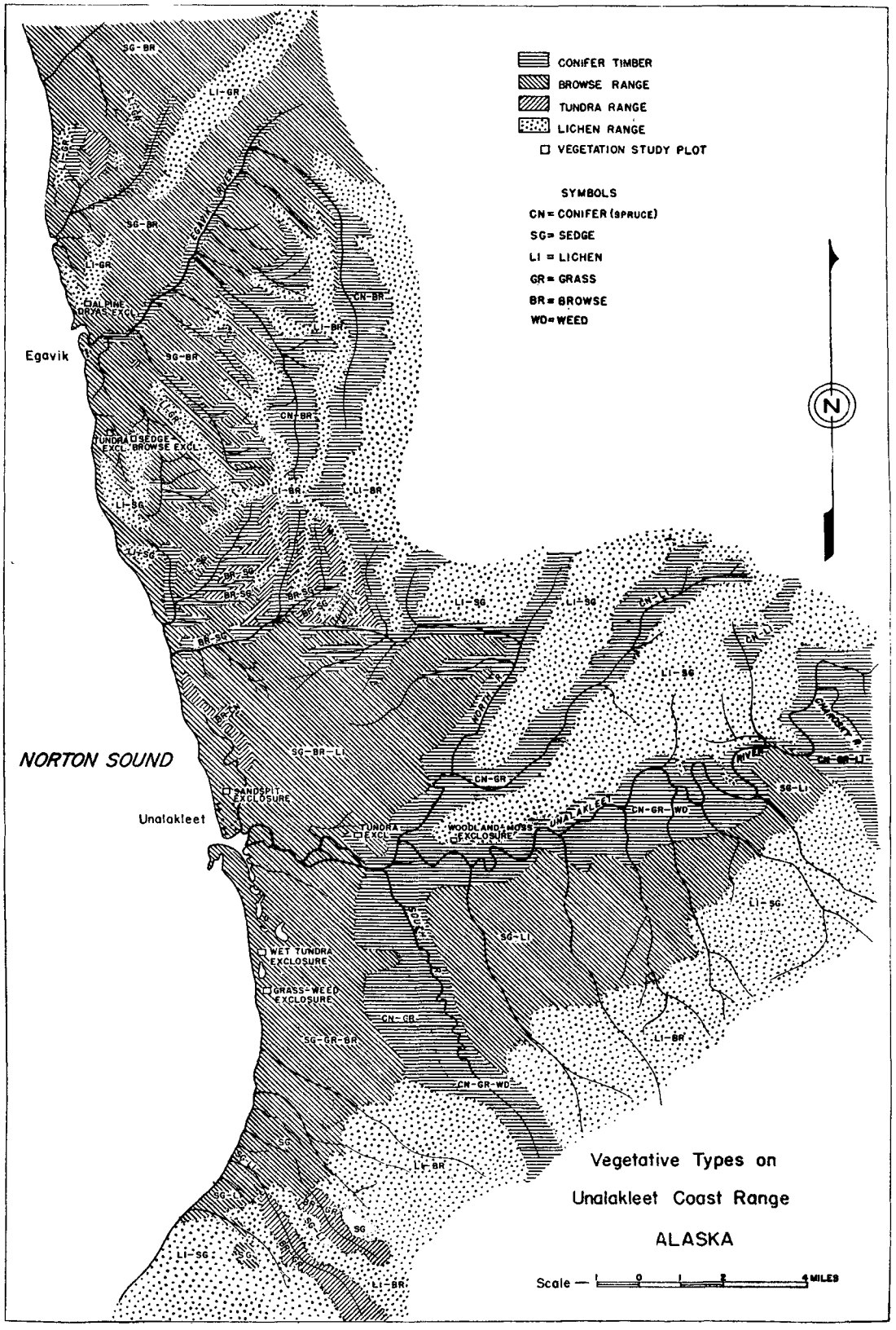

Figure 19.—Vegetative types on the Unalakleet-Egavik Reindeer Allotment on the Bering Sea coast, Alaska.

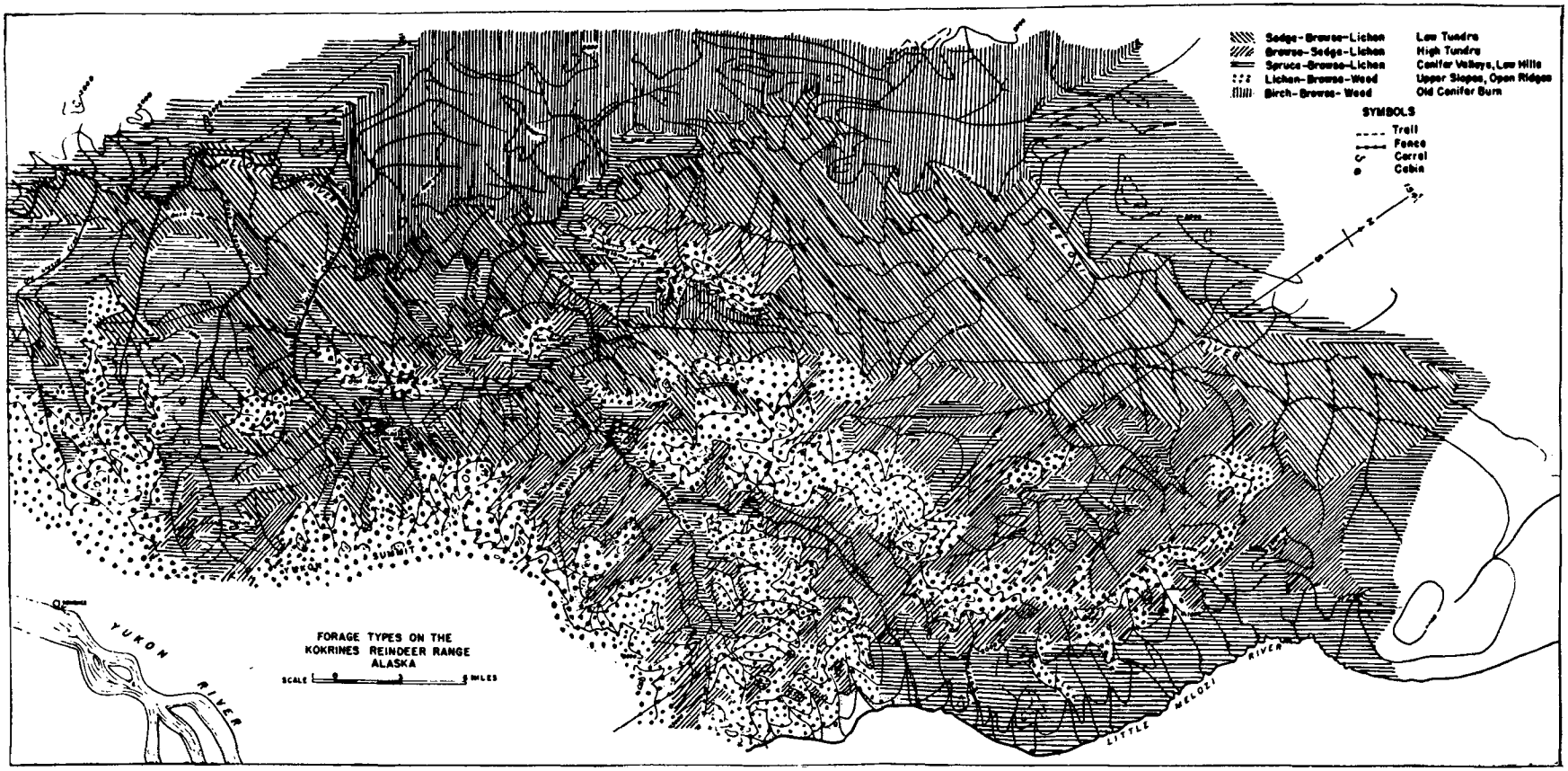

Figure 20.—Vegetative types on the Kokrines Reindeer Allotment on the lower Yukon River, Alaska.

and this quadrat location was excluded. The plot was not further disturbed during the period of these investigations. In 1928 the vegetation was of 0.2 density and was composed of 90 percent yellow mustard and 10 percent *Polygonum* and an unidentified grass. By 1932 the density of the growth had increased to 0.8, the vegetation consisting of 70 percent *Ranunculus* and 30 percent mustard. Several clumps of *Poa* and *Carex* were also present and appeared to be increasing in size.

The vegetation on the plot increased greatly in density and showed a marked change in composition in the 5 years following its establishment.

UNALAKLEET-EGAVIK REINDEER ALLOTMENT, BERING SEA COAST

The vegetation type map of the Unalakleet-Egavik Reindeer Allotment on the Bering Sea Coast (fig. 19) shows the distribution of the vegetative types over a representative part of the Bering Sea coast of Alaska. It will be noted that the spruce-browse and spruce-grass types are confined to the borders of the larger streams and are, therefore, narrow in outline. The sedge, or "niggerhead," tundra occupies the low benches and flats back from the streams and occurs on the first low hills. Farther back, on the higher hills, on better drained and drier sites, the lichen-browse, lichen-grass, and browse-grass types are found.

KOKRINES REINDEER ALLOTMENT, LOWER YUKON RIVER

The vegetation type map of the Kokrines Reindeer Allotment on the lower Yukon River (fig. 20) shows the distribution and abundance of the vegetative types on an area typical of the interior of Alaska. The Kokrines area lies in the drainage of the Melozitna River, a tributary of the Yukon, at latitude 65° N., longitude 155° W., north of the village of Kokrines on the Yukon. The lay of the land does not differ greatly from that of the Bering Sea coast although generally the mountains in the interior reach greater elevations. A striking difference in the plant cover is seen in the greater proportion of spruce and woodland types. The tundra types are found at lower elevations and on the flats near the larger streams and there is a greater proportion of browse tundra.

SUMMARY AND CONCLUSIONS

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

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

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

Of the lichens, chiefly the forms of taller growth are herein treated. Species of *Cladonia* predominate, followed in order by those of *Cetraria, Alectoria,* and *Stereocaulon.* The lichen stand is often considerable and forms the principal winter food of the reindeer. Sampling of numerous areas indicated a forage production of 5 to 7 tons, air-dry weight, to an acre. Areas sampled were those in which the lichens comprised from 50 to 90 percent of the vegetation. *Cladonia,* because it was most abundant and of taller growth, generally gave the largest yields.

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

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

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

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

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

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

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

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

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

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

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

Very slow recovery occurred on denuded browse-grass tundra (dry site) during a 4-year period. Invasion by grasses and sedges was most active.

Further study of the complex nature of the Alaska tundra is needed. The climax association of the Arctic tundra, ordinarily given as *Cladonia-Carex*,[7] is not readily verifiable, the present cover being unstable, although this may be due, in part, to grazing. Disturbance by grazing and fire, accompanied perhaps by climatic changes, has resulted in a general confusion in the plant mixture and occupation. The removal or depletion of the insulating plant cover allows the subsoil to thaw to greater depths and opens the surface to drainage. This, no doubt, contributes largely to alteration of site conditions and causes further vegetative changes. The advance of tree growth on the tundra indicates that the formation is as yet unstabilized.

The wet tundra seems less stable than the dry tundra. On both the recovery of lichens from grazing or fire injury is slow, whereas the invasion and reestablishment of vascular plants are rapid. A depleted lichen range under complete protection re-

[7] Plant Succession and Indicators, by Frederic E. Clements, 1928.

quires from 20 to 40 years for restoration to the original density and height growth. Moderate grazing by open herding and rotational use, however, will permit sustained utilization of undamaged tundra range.

MANAGEMENT OF REINDEER ON NUNIVAK ISLAND

In 1938, the reindeer on Nunivak Island were estimated to number 12,000. During the next 6 years they increased in numbers until, in 1944, the Office of Indian Affairs estimated that there were 30,000 reindeer on the island. Overuse of the winter lichen range has caused about a 15-percent depletion beyond normal carrying capacity.

Musk oxen, numbering 115 in 1943, are confined principally to the sand-dune type and the dry tundra range at the western end of the island. It is estimated that the suitable range totals approximately 300 square miles.

On the basis of forage acres, the range capacity on Nunivak Island should carry 2,100 musk oxen and 8,000 reindeer. On the basis of this study and subsequent observations, it is recommended that reindeer be removed from the island until a population of 8,000 has been established. This is sufficient for a native population of 195, and would permit an annual export of 1,300 carcasses.

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