VEGETATION TYPES IN NORTHWESTERN ALASKA AND COMPARISONS WITH COMMUNITIES IN OTHER ARCTIC REGIONS

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INTRODUCTION

In making surveys for reindeer winter lichen range in northwestern Alaska, a classification of the major kinds of vegetation was needed to show relationships between the distribution and abundance of lichens and the major types which could be readily distinguished on the ground or from the air. Previous classifications, of arctic vegetation, such as those used by Polunin (1934, 1935, 1948), Porsild (1937, 1951), Shelford and Twomey (1941), Palmer (1945), Hopkins and Sigafoos (1951), Seidenfaden and Sørensen (1937), Sørensen (1941), Trapnell (1933) and Hanson (1951) have usually been based upon topographic location, physiognomy, and major constituent species. Shelford and Twomey (1941), Holttum (1922), Oosting (1948), and Hanson (1951) used successional sequences to some extent. Raup (1941) summarized many of the difficulties in the delimitation of arctic plant communities and in the determination of successional relationships. Scandinavians, such as Du Rietz (1925b, 1930), Nordhagen (1928, 1936, 1943), and others have used topographic location, physiognomy, and major constituent species for delimiting the chief geographic communities, and they also have used data from sociological analyses for precise classifications to include orders, alliances, associations, and sociations. They also have included descriptions of habitats and successional relations. Sociological analyses and the classification based on them make it possible to determine the degree of similarity between communities studied in the same way in various parts of Scandinavia, the Alps, and elsewhere. Nordhagen (1943) stated that many things indicate that parallel alliances and orders can be established for Europe and North America. It is hoped that the present article will contribute towards the establishment of a classification applicable to the entire Arctic zone, but it should be emphasized that a vast amount of detailed work, especially in North America, is needed before this can be done.

No suitable classification for the surveys was found, so one was devised comprising 6 major groups and 22 minor groups, or types, based on physiognomy and important constituent species. These 22 types can usually be recognized from the air, preferably when flying at low altitudes as 200 to 500 feet above the ground and at about 90 to 100 miles per hour. For many ground studies a more detailed classification may often be desirable. Sociological analyses have been made of a few of these communities by Hanson (1951) and by E. D. Churchill and the author for the present paper. A classification based upon such analyses must await much additional field work. The classification and characterizations of types are based upon field work

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FIG. 1. Map of Northwestern Alaska, showing location of many places mentioned in the text.

during the summers of 1949–1951, in the northwestern part of Alaska, from the lower Noatak and Kobuk Rivers to the region southeast of Norton Sound (Fig. 1). Additional field work in this area, and in other parts of northern and western Alaska, will reveal other types. Similarities of these types to those described by other investigators, particularly in Scandinavia, are discussed.

The writer agrees with Nordhagen (1943) that vegetation is not a chaotic mixture of plants. Reasons for this are that areas, varying in size, commonly occur which are relatively uniform with respect to chemical and physical characteristics, soil moisture, insolation, depth to perennial frost, depth and duration of snow cover, exposure to wind. etc. The species which can grow under the conditions prevailing on each area become established, often gradually, and the species best adapted to the combination of conditions will survive the competition which usually follows establishment. The range in ecological amplitude of arctic species varies considerably, as shown by Løddesøl and Lid (1950) and others. Usually the stand consists of several to many species. Due to the considerable uniformity in the kinds of species and the number of individual plants of each species per unit area (for example, a square meter) throughout the stand, the composition is similar in its

several parts. Variation within the frame of the homogeneity of the stand occurs due to height and mass of constituent species, and to fluctuations from spot to spot in numbers and kinds of individuals.

The "sociation" is the lowest ranking community in the Scandinavian plant sociology. It forms the primary unit in classification in Scandinavia, and has application to Alaska, so some of Nordhagen's views are summarized as follows:

> Stands which belong to the same sociation show a far-reaching agreement with respect to layering and to the dominant species in each layer. The sociation concept symbolises a special biological equilibrium or balance between several or many species with respect to their individuals or shoots (sometimes only one species). This equilibrium in time may become effective over smaller or larger areas, which appear as more or less homogeneous stands or vegetation units, but their vegetation is never absolutely identical. The equilibrium has a more or less permanent character, enduring at least for years; but under man's influence or catastrophes the balance is often upset and then the process of developing a new balance starts. Or a sociation can "dig its own grave" by drying out the soil, etc. Successional series may not be the same for each stand of a sociation. Variation in stands of a sociation is due to difference in the age of stands, a different course of succession, differences in climate or substratum, influence of adjoining stands (vicinismen). The sociation is therefore an abstraction, the stand is concrete. The requirements of agreement of layers and of homogeneity in the stands of a sociation cannot be set on too rigorous a basis, but must fit natural conditions. Each sociation has its own range of amplitude (1943, pp. 41–44).

Palmer and Rouse (1945) noted little change in many permanent quadrats over periods of 4 to 11 years in northwest Alaska; in others changes occurred due to trampling, grazing, for unknown reasons, etc. Denuded quadrats were usually revegetated by the same kinds of species which had occurred previously. The writer has noted reinvasion by neighboring species on bare spots produced by frost action in dwarf shrub types, and others, apparently soon repairing the damage; but measurements and photographs of permanent sample areas over many years are needed for precise data on the rate of reinvasion and other changes. Except for the limited work by Palmer and associates, such data are lacking for Alaska arctic vegetation.

In 1949 cover and frequency were determined by the point-contact method (Hanson, 1951). In 1951, the method was changed so that the data could be compared directly to those of the Scandinavians and other Europeans. The sociological analyses were made by estimating herbage cover of each species in 10 one-meter-square quadrats located at regular intervals on a line through the stand. The Hult-Sernander scale (Braun-Blanquet 1932, Nordhagen 1943) of cover was modified so that in the records 1 denotes herbage cover of less than $\frac{1}{16}$ of the area of the square meter, 2—$\frac{1}{16}$ to $\frac{1}{8}$, 3—$\frac{1}{8}$ to $\frac{1}{4}$, 4—$\frac{1}{4}$ to $\frac{1}{2}$, 5—$\frac{1}{2}$ to $\frac{3}{4}$, and 6—$\frac{3}{4}$ to $\frac{4}{4}$. The data in the tables can be compared directly to those of the Scandinavian workers by changing "6" to "5."

Preliminary Classification of Vegetation Types in Northwestern Alaska

I. Forest Types
   1. White spruce-shrubs (*Picea glauca-Salix-Betula-Alnus*)
   2. White spruce-Alaska white birch-shrubs (*Picea glauca-Betula resinifera-Salix-Betula-Alnus*)
   3. Alaska white birch-shrubs (*Betula resinifera-Salix-Betula Alnus*)

II. Shrub Types (2.5 or more feet high)
   4. Willow types:
      A. Feltleaf willow (*Salix alaxensis*)
      B. Greenleaf willows (*S. richardsonii, S. pulchra, S. fuscescens*)
   5. Alder types (*Alnus crispa, A. fruticosa*)
   6. Willow-alder-balsam poplar (*Salix-Alnus-Populus tacamahaca*)
   7. Birch types (*Betula nana exilis, B. glandulosa*, and hybrids)

8. Birch-willow types (*Betula-Salix*)

III. Dwarf Shrub Types (less than 2.5 feet high)

9. Dwarf birch-heath-lichens (*Betula nana exilis-Ericaceae-Lichenes*)
10. Blueberry-heath-lichens (*Vaccinium uliginosum-Ericaceae-Lichenes*)
11. Four angled heather-blueberry-mosses (*Cassiope tetragona-Vaccinium uliginosum-Musci*)
12. Alpine bearberry-mountain cranberry (*Arctostaphylos alpina-Vaccinium vitis-idaea*)
13. Alpine dryas (*Dryas octopetala*)

IV. Dwarf Shrub-Marsh Types

14. Cloudberry-dwarf shrub-marsh (*Rubus chamaemorus-Betula nana exilis-Ericaceae*)

V. Herb-Dwarf Shrub Types

15. Alpine sedge-alpine dryas (*Carex-Dryas octopetala*)
16. Cottongrass-sedge-dwarf heath shrub complex (*Eriophorum spissum-Carex-Betula nana exilis-Ericaceae*)

VI. Herb Types

17. Sedge marshes, saline and fresh water (*Carex*)
18. Sedge Sphagnum-moss bogs (*Carex-Sphagnum-Musci*)
19. Grasslands (*Calamagrostis canadensis, Festuca altaica, Arctagrostis latifolia, Elymus mollis, et al.*)
20. Aquatic types (*Hippuris vulgaris, Ranunculus pallasii, Carex aquatilis, Scripus, et al.*)
21. Lichen-moss barrens (*Lichenes-Musci*)
22. Ruderal (*Calamagrostis canadensis, Epilobium angustifolium, Artemisia, et al.*)

I. Forest Types

1. *White spruce-shrubs (Figs. 2, 3)*

Shrubs, 4 to 8 feet high, which may be associated with the white spruce (*Picea glauca* (Moench) Voss.), are willows, birches, alders, spiraea (*Spiraea beauverdiana* Schneid.), currant (*Ribes*), rose (*Rosa acicularis* Lindl.), shrubby cinquefoil (*Potentilla fruticosa* L.), and ericaceous shrubs. A variety of herbaceous plants also occur, including *Calamagrostis canadensis* (Michx.) Beauv., *Festuca altaica* Trin., *Epilobium angustifolium* L., *Mertensia paniculata* (Ait.) G. Don., *Equisetum* spp., and ferns. In the openings and where the shade is not too intense, lichens, chiefly *Cladonia* spp. and *Cetraria* spp., 2 to 5 inches high, and mosses form tufts and mats, as in the vicinity of White Mountain and Council. In places where the stand is fairly open as near Shungnak and on the south side of the Waring Mountains, the lichens form continuous cover over extensive areas (Fig. 2). The white spruce-shrubs type occurs as far west as the valleys of the Noatak and Kobuk Rivers, into the southeastern part of the Seward Peninsula as far as the vicinity of Council, and to within less than a mile of the eastern shore of Norton Sound. West and north of Council, the white spruce appears to be migrating westward.

The forest affords protection to reindeer and caribou from winds during the winter, but herding of reindeer is difficult, and wolves have greater opportunity to seize their prey. The snow may not crust over so badly as in the open. If not shaded too much, reindeer lichens grow well in the forest because they remain moist for a longer time between rains. Fruticose lichens growing on trees afford emergency feed when the snow is excessively deep or a snow crust prevents the reindeer from pawing through to ground lichens (Hanson 1952).

This type is easily recognized from the air by the dark bluish green color and the spire-like growth of the spruces, the dark green masses of shrubs forming a lower layer. The lichens in the openings are conspicuous by their light gray to cream color.

FIG. 2. The white spruce-shrubs type, bordered by shrub types. In the treeless areas are dwarf shrub types and the cottongrass-sedge-dwarf heath shrub complex. White areas are lichens. South slope, Waring Mts., June 30, 1951.

2. *White spruce-Alaska white birch-shrubs* (*Fig. 3*)

This type was found chiefly along the Unalakleet and other rivers east of Norton Sound, and in places in the valleys of the Kobuk and Noatak Rivers. In the forest northwest of Moses Point Airfield a few birch trees are scattered among the spruces. Shrubs, as in the preceding type, form a lower layer. When the stands are not too dense lichens occur as in the preceding type. The birch trees can be distinguished from the spruce by the dark green color and the large, smooth-appearing globular crowns.

3. *Alaska white birch-shrubs* (*Fig. 3*)

This type, also of limited distribution, was seen on south-facing slopes bodering the Unalakleet River and other streams east of Norton Sound. Associated shrubs are alders, willows, birches, and dwarf heaths. White spruce and balsam poplar (*Populus tacamahaca* Mill.) are scattered in places. The large, rounded crowns of the birch trees (*Betula resinifera* Britt.) are very distinctive from the air. Stands of this type are often too dense to permit good growth of lichens, but in openings the lichens may cover much of the ground and grow to a height of 5 to 6 inches. Stands of this type may alternate with those of the white spruce-Alaska white birch-shrubs type, the latter often on the steeper slopes (Fig. 3).

Palmer (1945) recognized a forest type as comprising "essentially tundra range occupied by spruce and birch" with undercover of chiefly mosses and lichens. Hopkins and Sigafoos (1951) reported the occurrence of isolated stands of *Populus tacamahaca* on the dissected upland on the north and southwest margins of the Imuruk Lake region in the central part of Seward Peninsula. Du Rietz (1925a) classified the forest types of Scandinavia into two main regions, coniferous and deciduous. The former was divided into a northern and southern part, each of which included coniferous forests, deciduous forests, marshes, bogs, and other communities. He stated that the most important tree in the subalpine maritime birch forest region is *Betula tortuosa* Led., with associated tree species, *Alnus incana* (L.) Moench., *Populus tremula* L., *Sorbus aucuparia* L., *Prunus padus* L., and *Salix* spp. Some of these,

FIG. 3. In the foreground is the cottongrass-sedge-dwarf heath shrub complex with more sedge than cottongrass. Medium-dark area at left center is dwarf birch-heath-lichens type. Very dark area on plain near center is alder type, and beyond the alders is a large light-colored area of the feltleaf willow type. White spruce-shrubs type along the river at foot of hill, dense forest on hill is Alaska white birch-shrubs type, open stands are white spruce-Alaska white birch-shrubs type, and in the distance at left the cottongrass-sedge-dwarf heath shrub complex. Unalakleet River valley a few miles east of Norton Sound. June 13, 1951.

such as *Populus* or *Alnus,* may be the sole dominant. Nordhagen (1936) stated that *Betula tortuosa* forests in the subalpine zone in Norway could be divided into 4 alliances according to the composition of the dwarf shrub and herb layer, and that the birch forests in the mountains of Norway form a mosaic of communities differing floristically and synecologically from one another. He (1943) stated that the most important association (in distribution) in the subalpine birch forest was characterized by the constancy of *Vaccinium myrtillus* L. and *Deschampsia flexuosa* (L.) Trin., and often *Juniperus communis nana* Willd. This community requires long-lasting snow cover. Some of the open white spruce-birch stands in the Noatak and Kobuk River valleys resemble the *Betula tortuosa-Empetrum*

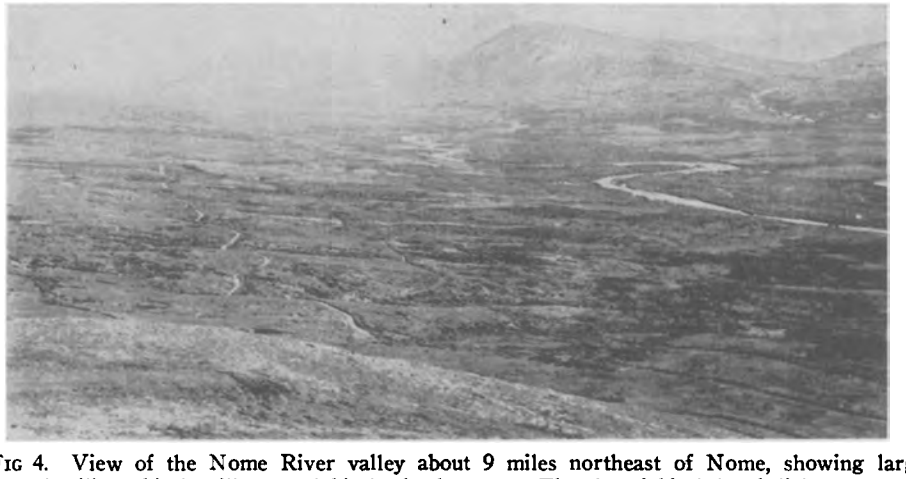

FIG 4. View of the Nome River valley about 9 miles northeast of Nome, showing large areas of willow, birch-willow, and birch shrub types. The dwarf birch-heath-lichens type is lighter gray and finer in texture than the shrub types; the blueberry-heath-lichens type is similar to the preceding but darker; large areas of sedge marsh between the shrubs; cottongrass complex on the distant slopes and benches. June 13, 1951.

hermaphroditum Hag.-*Cladonia alpestris* (L.) Rabenh. association of Nordhagen (1943), growing on dry moraines where the snow blows away quickly. There is similarity also between the white spruce-shrubs type in Alaska and the *Picea excelsa* (Lam.) Link. associations in Norway and in the Alps, the latter described by Du Rietz (1924). Nordhagen (1943) described other forest types in the order Aconitetalia, which comprises tall herb meadows in the mountains, and willow brush and birch forest with a tall herb layer.

FIG. 5. Sedge marsh stand on a gentle slope in the Nome River valley about 10 miles northeast of Nome. Scattered hummocks are dark due to cover of dwarf shrubs. Birch-willow and willow shrub stands beyond. July 12, 1951.

II. SHRUB TYPES

4. *Willow types (Figs. 3, 4, 5)*

The willow shrub types are divided into two groups: A. The feltleaf willow type (*Salix alaxensis* (And.) Cov. which is grayish green, and B, the greenleaf willow type which is green. The former is widespread, usually occurring on well-drained banks of streams with coarse gravel at a depth of about a foot (Fig. 3), often forming only a narrow zone (Fig. 4). In height this community may vary from less than 5 to over 15 feet. In some places the ground is hummocky. Some of the associated species are balsam poplar, alder, shrubby cinquefoil, grasses, sedges, and mosses. Lichens are usually lacking.

Several species such as *S. richardsonii* Hook., *S. pulchra Cham.*, and *S. fuscescens* And. may dominate singly or in mixture in the greenleaf willow type (Figs. 4, 5). The height varies from about 4 to 8 feet. This type is found throughout northwestern Alaska and in the aggregate covers much land, such as stream bottoms adjacent to the preceding type, steep banks, drainage ways on slopes where there is usually more or less running water. In poorly drained sites, sedges are more abundant; in drier sites, birch shrubs are associated with the willows.

Due to the presence of hummocks,[2] depressions, and channels, the vegetation

[2] Hummock, mound, and tussock are used in this paper similarly to their ordinary meanings. Hummock and mound are small rounded knolls or raised areas of land, usually covered with many plants, and from a few inches to several feet high. The author uses hummock for somewhat elongated areas, mound for more circular ones. A tussock is a tuft or bunch of grass, or grass-like plant such as *Eriophorum*, which is often separated more or less from other plants in the stand, consisting usually of a single plant.

and soil profile vary considerably from place to place. The depth to the frozen ground in the first part of July, on a gentle east-facing slope about 10 miles northeast of Nome, varied from only 9 inches under dense willows to more than 38 inches under a hummock in openings between the willows. Prominent species on hummocks were the grasses *Calamagrostis canadensis* and *Festuca altaica*. Other associated species were various sedges and forbs such as *Rumex arcticus* Trautv., *Sedum roseum* L., *Galium boreale* L., *Anemone narcissiflora* L., *Artemisia arctica* Less., *Dryas octopetala* L., *Mertensia paniculata, Viola langsdorfii* Fisch., and dwarf shrubs including *Empetrum nigrum* L., *Vaccinium uliginosum* L., *Salix reticulata* L., and *Andromeda polifolia* L. The last two, and *Potentilla fruticosa, Woodsia glabella* R. Br., *Sedum roseum, Salix reticulata, Carex aquatilis* Wahl., *Corydalis pauciflora* (Steph.) Pers,. *Polemonium acutiflorum* Willd., mosses, and others occurred in depressions.

The soil profile under dense willows, 8 feet high, on a 5° slope, in this stand which covered several square rods, examined on July 1, 1950, had a layer of loose leaves about an inch thick above a 0.5-inch layer of decayed plant debris. Below this for 9 inches, the silt loam was brown to dusky red, containing much organic matter, except for the 6–7.5-inch layer which contained much fine schist. The roots were numerous to 7.5 inches, then infrequent to the frozen ground at 9 inches.

A hummock only a foot away, covered mostly with grass, had a 2-inch litter layer, below which brown to dark reddish brown silt loam extended to 7.5 inches, containing considerable grayish brown silt loam at 5–7.5 inches. Between 7.5 and 17 inches stones and gravel were interspersed in the gray brown to reddish brown silt loam. From 17 to 38 inches (no frozen ground) the material varied from pale gray silt to grayish brown sandy silt with stones and gravel, the latter increasing with depth, so drainage was excellent. Roots were numerous to 17 inches. The soil reaction, determined colorimetrically by the LaMotte-Morgan Method, was similar in the two profiles, mostly pH 6.2 and 6.4, but the surface 2.5-inch layer in the hummock was pH 5.2.

Palmer (1945: 6) recognized only a "shrub-grass-weed type" occurring "on well-drained ground, usually along a stream, in a ravine or on a steep slope," and included alder with the green willows. Hopkins and Sigafoos (1951: 65) described willow communities in the Imuruk Lake area as follows: "Willow (*Salix pulchra*) thickets 4 to 10 feet high occur in the lower reaches of the swales draining higher slopes, on steep lake banks, and on flood plains of the larger streams. Depth to perennial frozen ground is more than 6 feet, and frozen ground may be absent locally under flood plains. Definite channels of running water are present under the willows in the swales; these channels are among the few sites where erosion by running water is occurring in the Imuruk Lake area." Trapnell (1933) recognized in his provisional classification of vegetation types in the Godthaab Fjord district in Greenland a *Salix glauca* L. community, 1 to 2 m. high, with associated *Alnus incana*, forming a continuous cover, hiding the field layer of grasses, ferns, *Potentilla maculata* Pourr. *et al.*, and a ground layer of typical *Brachythecium* spp. Nordhagen (1943) described 3 associations of willow types, consisting of *Salix lapponum* L., with which *S. glauca, S. lanata* L., *S. phylicifolia* L., and others, may be associated, often over 6 feet high, in the order Aconitetalia and in Order I are willow thickets with a sedge-marsh layer of many species. The 3 associations were distinguished chiefly by differences in the herbaceous species in them. Du Rietz (1925a) stated that these willow thickets, 1 to 2 meters high, are almost impenetrable, covering considerable ground along brooks, or where there is some running

water, in the lower alpine region in the Scandinavian mountains.

5. *Alder types* (*Fig. 2*)

The alder types (*Alnus crispa* (Ait.) Pursh., *A. fruticosa* Rupr.) form dark bluish green thickets on well-drained slopes and bluffs throughout the region, from about 3 to 12 feet high. They are very distinctive because of the dark color and dense masses. A lower layer of herbaceous and shrub vegetation is usually present, often with much *Calamagrostis canadensis*. Other prominent species, especially in the more open stands are *Betula* spp., *Spiraea beauverdiana, Vaccinium uliginosum, Salix* spp., *Cornus suecica* L., *Lycopodium annotinum* L., *Epilobium angustifolium, Pedicularis labradorica* Panz., *Carex* spp., *Hierochloe alpina* (Sw.) R. & S., mosses and lichens. In places, as where alders border streams the lowest parts of the stands may contain many willows. On the edges of stands a dense zone of low shrubs as birches, Spiraea, dwarf heath shrubs, and some herbaceous species such as *Calamagrostis canadensis, Epilobium angustifolium,* and *Petasites frigidus* (L.) Fries may occur. Occasionally alders are scattered in the cottongrass-sedge-dwarf heath shrub complex, as, for example, on slopes north of Unalakleet.

According to Hopkins and Sigafoos (1951), alder thickets are scattered on steep, better-drained slopes in the Imuruk Lake area. Trapnell (1933) reported finding one pure alder shrub thicket in a silted gorge in the Godthaab Fjord district in Greenland. Du Rietz (1925a) pointed out that forests of *Alnus glutinosa* (L.) Gaertn. are common along streams and lakes in the southern coniferous forest region in Scandinavia, and on moraines in the subalpine-maritime birch forest region. The similarity of Alaskan alder stands to an *Alnus viridis* DC. type is indicated in an analytical table by Du Rietz (1924: 47). Nordhagen (1943) mentions an alder association in the subarctic region of Norway as having a dominance of tall ferns (*Struthiopteris* sp. and *Athyrium filix-femina* (L.) Roth.) in the field layer.

6. *Willow-alder-balsam poplar type*

Dense thickets, about 10 to 15 feet high, of a mixture of *Salix* spp., *Alnus* sp., and *Populus tacamahaca* were seen on the flood-plain of the Unalakleet River. It probably occurs along other streams also. From the air it appears dark green.

7. *Birch types* (*Figs. 2, 4, 5, 6*)

These types, consisting chiefly of *Betula nana exilis* (Suk.) Hult., *Betula glandulosa* Michx., *Betula* hybrids, and scattered individuals of *Salix* spp., 2.5 to

FIG. 6. Birch shrub type with intermixed willows in foreground and on lower part of slope across the creek. Large light area is the cottongrass complex, *Eriophorum spissum,* headed out. Coffee Creek, west of Bendeleben Mts., central part of Seward Peninsula. June 23, 1951.

TABLE I. *Birch-shrubs stand, 10 miles northeast of Nome. Aug. 1, 1951*

Species	1	2	3	4	5	6	7	8	9	10	Aver. Cover	Freq. %
Betula nana exilis	5	4	6	6	6–	6	6	5	6	4	5.4	100
Salix richardsonii	1	3				1					2	30
Salix pulchra										4	—	10
Salix reticulata	1	2–	1–			1	1	3			2–	60
Vaccinium uliginosum	3–	3–	2	1	1	1	3	3	1	1	1.9	100
Empetrum nigrum	1	2	1	1	1–	1–	1	1	1	1	1	100
Vaccinium vitis-idaea		1	1	1	1	1	1	1	1	1	1	90
Ledum decumbens	1–	1	1	1	1–	1	1			1	1	80
Arctostaphylos alpina	1–	2	1–				1	1			1	50
Potentilla fruticosa	1–						1		1		1	30
Rubus arcticus					2	1		1–			1	30
Festuca altaica	1–	1–	1–		1–	1+	1–	1–	1–	1–	1–	90
Carex sp.		1		1	1	1–	1	1+	1	1	1	80
Calamagrostis canadensis		1–	1	1–	1	1–	1–	1–	1–		1–	80
Valeriana capitata			1			1–	2	1+	1	1	1	60
Polemonium pulcherrimum						1–	1	1	1–	1	1	50
Arctagrostis latifolia	1		1–		1–	1			1–		1–	50
Poa arctica?					1–		1–		1–	1–	1–	40
Polygonum bistorta plumosum						1–	1–	1	1		1–	40
Botrychium lunaria	1–	1–						1–	1–		1–	40
Arnica porsildiorum	1–	1–	1–								1–	30
Saxifraga punctata			1–				1	1–			1–	30
Papaver radicatum	1–	1–									1–	20
Cardamine pratensis	1–								1–		1–	20
Solidago virgaurea		1–						1–			1–	20
Equisetum scirpoides	1–						1–				1–	20
Pedicularis verticillata						1–		1–			1–	20
Cerastium beeringianum	1–						1–				1–	20
Mertensia paniculata								1–	1–		1–	20
Petasites frigidus									1–	1–	1–	20
Equisetum sp.			1–								—	10
Lycopodium annotinum						1					—	10
Mosses	6	6	6	3	6	6	6	6	6	6	5.7	100
Lichens	1	2	2		2	3	1	1	1	2	1.7	90
No. vascular spp. per m²	16	15	14	6	11	17	18	18	17	12		
Aver. No. vascular spp. per m²	14.4											

about 8 feet high, are widespread in northwestern Alaska. They occur usually on moderate slopes, at lower elevations, and cccupy in the aggregate considerable area. Density varies from open to closed. In the openings and on the edges of dense stands occur dwarf shrubs and herbs, and lichens up to 4 to 5 inches may be dense unless the area has been heavily grazed or burned. The ground within dense stands may be covered with a thick layer of moss with lichens sparse or lacking. From the air these types have a characteristic brownish green color; the gray to cream-colored lichens mats are conspicuous in the openings. This type is a good indicator of conditions suitable for excellent growth of lichens.

A sociological analysis of a stand, occupying an acre of more, similar to that on the right in Fig. 5, on an east-facing slope of about 5°, located about 10 miles northeast of Nome, is shown in Table I. The elevation was about 120 feet above sea-level. The stems of the birch shrubs were usually decumbent for 2 or 3 feet and then gradually ascended to an average height of about 3.5 feet. The lower parts of the stems become covered with an inch or so of moss and litter in which new roots develop. A single shrub may occupy an area as much as 10 feet in di-

ameter with its widely spreading branches. The scattered green willows were often a foot or two taller than the birches. The ground was covered with moss, chiefly *Hylocomium splendens* (Dedw.) Schimp. The most abundant shrub, after the birch, was *Vaccinium uliginosum*. All other vascular species had low cover, but some were high in frequency notably *Empetrum nigrum, Festuca altaica, Carex* sp., *Vaccinium vitis-idaea, Calamagrostis canadensis,* and *Ledum decumbens* (Ait.) Lodd. Important species among the lichens were *Cladonia rangiferina* (L.) Web., *C. sylvatica* (L.) Hoffm., *C. cornuta cylindrica* (Ach.) Asa., *Cetraria cucullata* (Bell.) Ach., and *C. islandica* (L.) Ach.

The soil profile, examined on July 10, 1951, had a surface layer, 2 inches thick, of moist, partly decayed, dark reddish brown plant fragments, with numerous living roots and rhizomes. The 2–9 inch layer was dark brown, wet, silt loam, rich in organic matter, with numerous roots to the working depth at 9 inches. The 9–16 inch horizon was compact, wet, gray to olive-gray silt, highly impervious to water, with included layers and pockets of gray-brown silt loam containing organic matter and pockets of yellow brown silt loam. The heterogeneity in this horizon appeared to be due to solifluction and frost action. Live roots were few and dead roots numerous below 9 inches. The 16–17 inch layer was brown silt with scattered stones. The ground was frozen at 17 inches.

Examination of several profiles in different stands in this vicinity showed the following general characteristics: 1) a moss layer on the surface, 2) a reddish brown organic layer containing little to no silt between the moss and 2 to 4 inches in depth, 3) in some stands, a silty loam layer rich in organic matter from about 2 or 4 inches to 7 or 9 inches, 4) below 9 to 13 inches a mixed up or irregular horizon of impervious gray to brown silt mottled with yellow brown. Schistose rocks become more numerous and compact with depth. The gray silt is like a stiff jelly when wet. Frozen ground was found in one profile at 17 inches, but in others none was found even as deep as the fairly compact schist at 22 and 29 inches. These birch shrub profiles resemble the one in the *Betula glandulosa* stand in Mt. McKinley National Park described by Hanson (1951: 361).

Palmer (1945) apparently included this community in his "lichen-shrub" type. Hopkins and Sigafoos (1951) wrote that thickets of *Betula nana exilis* in the Imuruk Lake area "occur on the better-drained, higher parts of steep banks and well-drained slopes. Depth to perennially frozen ground—is not known—but is probably more than 6 feet—." The birch shrub communities in Alaska are similar to those found in places in the low alpine zone in Norway where the dominant is *Betula nana* L., reaching a height of more than 2.5 feet. They are also similar to types where the dominant is a *Betula* hybrid according to Lagerborg and Holmboe (1938). *Betula nana* is usually less than 2.5 feet high in Norway, so communities dominated by it are probably more similar to the Alaskan dwarf birch-heath-lichen type discussed below. The birch shrub types in Alaska also resemble the "shrub tundra," or "jernik," of northern and eastern Siberia, which are dense communities of *Betula fruticosa* and *B. exilis,* 1 to 1.5 meters high, occurring on marshy lowlands with sedges, and also in dry open glades on slopes, according to Imanishi (1950).

8. *Birch-willow type*

This type is made up chiefly of *Betula glandulosa,* tall forms of *B. nana exilis,* or *Betula* hybrids. It resembles the preceding type, but contains a larger proportion of willows (*Salix pulchra, S. richardsonii, S. fuscescens*), and alders, *Spiraea,* or white spruce may also be scattered throughout. From the air it may appear spotted, due to the pale green willows, the dark blue alders, and the brownish green birches. The shrubs are 6 to 10 feet high,

the white spruce up to 20 or 30 feet. Dwarf shrubs such as *Ledum decumbens, Betula nana exilis, Vaccinium uliginosum, V. vitis-idaea, Rubus chamaemorus,* L. *Oxycoccus microcarpus* Turez., also occur, the last two in more boggy spots with *Sphagnum* and other mosses. Grassy spots are formed by *Calamagrostis canadensis, Festuca altaica, Poa* sp., *Mertensia paniculata, Sedum roseum, Cardamine pratensis* L., *et al.* Lichens, 4 to 6 inches high, form tufts on hummocks, and patches several rods square where the shrubs are scattered. Important species are *Cladonia rangiferina, C. sylvatica, C. cornuta cylindrica, C. gonecha* (Ach.) Asa., and *Stereocaulon tomentosum* Fries. This type was studied particularly in the vicinity of Council where it occupies large areas.

III. Dwarf Shrub Types

Only 5 of the more distinctive dwarf shrub types are described in this paper. They are usually less than 2.5 feet high, widely distributed, cover considerable areas, and can usually be readily recognized from the air. These 5 types are not coordinate in rank, and except for number 11, correspond roughly to major divisions, such as alliances, in the phytosociology of Nordhagen (1943), Du Rietz (1924, 1930), Braun Blanquet (1932), *et al.* Undoubtedly a number of distinct communities (associations and sociations according to the Scandinavian workers) occur in each of types 9, 10, and 13; but much additional field work and sociological analysis are needed for their idetntification, characterization, and classification.

Table II. *Dwarf birch-heath-lichens stand, 10 miles northeast of Nome. July 30, 1951*

Species	1	2	3	4	5	6	7	8	9	10	Aver. Cover	Freq. %
Betula nana exilis	2	1	3	3	3+	3	2+	1	1	3	2.2	100
Vaccinium uliginosum	1	2	3		3+	4	1	4	4+	2	2.7	90
Empetrum nigrum	3	1	4+	1	2		4	2−	2	3	2.3	90
Vaccinium vitis-idaea	1	2	1	1	1	1	2−	2−	1	1	1.3	100
Loiseleuria procumbens			1	1	2		1	3	3	3+	2	70
Ledum decumbens	1	1+	1	1	1	1	1	1	1	1	1	100
Salix pulchra			1						2	1	1	30
Salix alaxensis		1									—	10
Salix reticulata			1					1	1	1−	1	40
Salix richardsonii					1			1		1	1	30
Spiraea beauverdiana					1−						—	10
Pyrola grandiflora?								1	1−		1−	20
Carex montanensis	1−	1−	1−	1−	1−	1−	1−	1−	1−	1−	1−	100
Pedicularis labradorica	1−		1−	1−	1−		1−	1−		1−	1−	70
Festuca altaica	1−	1−			1−	1−			1−	1−	1−	60
Poa arctica				1−	1−		1−	1−		1−	1−	50
Petasites frigida			1−	1−	1−	1−					1−	40
Luzula multiflora			1		1−					1	1−	30
Polygonum bistorta plumosum					1			1			1	20
Solidago virgaurea				1				1			1	20
Lycopodium annotinum				1−			1−				1	20
Cardamine?								1−	1−		1−	20
Calamagrostis canadensis			1								—	10
Agrostis borealis			1								—	10
Hierochloe alpina									1−		—	10
Saussurea angustifolia									1−		—	10
Mosses	2	5	6	6	6	5	5	6	6	6	5.3	100
Lichens	6	4+	5	4+	5	5	3+	2	4	4	4.2	100
No. vascular spp. per m²	8	8	14	11	15	7	10	16	15	15		
Aver. no. vascular spp. per m²	11.9											

Additional species in the stand but not in any quadrat: *Dryas octopetala, Potentilla fruticosa, Lycopodium selago.*

TABLE III. *Dwarf birch-heath-lichens stand, 10 miles east of Nome. July 30, 1951*

Species	1	2	3	4	5	6	7	8	9	10	Aver. Cover	Freq. %
Loiseleuria procumbens	4	4	1	1+	4−	2−	3−	2	4	1	2.6	100
Empetrum nigrum		1−	2	2−		1−	2	2	1	2−	1.6	80
Betula nana exilis	1−	1	1+	1+	2−	2−	1+	1	1+	3	1.4	100
Ledum decumbens	1−	1−	1+	1	1	1	1	2	1	2	1.2	100
Vaccinium vitis-idaea	1	1+	1	1	2−	2−	2+	1	1	1	1.3	100
Vaccinium uliginosum	1		1−	1			2+	1+		1+	1.1	60
Salix pulchra								1			—	10
Salix phlebophylla		1+									—	10
Carex montanensis	1	1−	1	1−	1+	1	1+	1−	1	1	1	100
Hierochloe alpina	1−		1−	1−	1−	1−	1−	1−	1−	1−	1−	90
Pedicularis labradorica			1−	1−	1−		1−	1−			1−	50
Luzula multiflora								1		1−	1−	20
Festuca altaica										1−	—	10
Luzula parviflora							1				—	10
Mosses	1−	1−	1	1	1−	1−	3	3	1	2+	1.5	100
Lichens	6	3	6	6	6	6	5	6	5	6	5.5	100
Bare ground	1	3		1	1−	1−			1−		1	60
No. vascular spp. per m²	8	8	9	10	8	8	10	11	8	10		
Aver. no. vascular spp. per m²	9.0											

Additional species in stand but not in any quadrat: *Arctagrostis alpina, Calamagrostis canadensis Lycopodium annotinum.*

9. *Dwarf birch-heath-lichens type (Figs. 2, 3, 4, 6)*

This type is usually characterized by the abundance of *Betula nana exilis* and by lesser abundance of several kinds of dwarf heath and similar shrubs such as *Vaccinium uliginosum, Ledum decumbens, Empetrum nigrum, Vaccinium vitis-idaea, Loiseleuria procumbens* (L.) Desv., and *Arctostaphylos alpina* (L.) Spreng., by scattered low willows, especially *Salix pulchra,* and *S. richardsonii,* by scattered herbs, and by an abundance of lichens of many species and several kinds of mosses. One or more of the heath shrub species may be more abundant in some stands than the dwarf birch, but the latter is always prominent in this type. The shrubs are usually less than a foot high. The spaces between and under the shrubs are occupied by lichens, 2 to 4 inches high.

The birch-heath-lichens type occurs throughout the region on gravelly and rocky slopes and terraces at lower elevations where the soil is well-drained and dries out rather rapidly after rains. These sites become free of snow early in the season and are probably bare during part of the winter also. Stands of this type are conspicuous from the air because of the short and scattered shrubs with the carpet of yellowish gray to gray lichens beneath. Microstands of this type are found on hummocks and mounds in other communities, as, for example, in the cottongrass-sedge-dwarf heath shrub complex, sedge marshes, etc. Where the lichens have not been depleted, it is valuable for winter and spring range for reindeer.

Analysis is given in Table II of a fairly typical stand of this type, and in Table III of a similar stand on shallower soil, each comprising several square rods. The latter stand might more appropriately be called a *Loiseleuria procumbens-Cladonia* community, or according to the Scandinavian system, a sociation in the dwarf birch-heath-lichens alliance. In the first there were 37 vascular species, in the latter only 14. The latter was much less dense, bare ground occupying $\frac{1}{16}$ of 6 of the quadrats, and the vascular plants were about half as tall as in the first, averaging about 6 inches. The average number of species

per quadrat in the first was 11.9, in the second 9.0. The chief kinds of vascular species in the first in order of high cover and frequency were *Betula nana exilis, Vaccinium uliginosum, Empetrum nigrum, Loiseleuria procumbens,* and *Vaccinium vitis-idaea*; in the second *Loiseleuria procumbens, Empetrum nigrum, Betula nana exilis, Vaccinium vitis-idaea, Ledum decumbens,* and *Vaccinium uliginosum.* The chief herbaceous plants in the first were *Carex montanensis* Bailey, *Pedicularis labradorica, Festuca altaica,* and *Poa arctica* R. Br.; in the other *C. montanensis, Hierochloe alpina,* and *Pedicularis labradorica.* Mosses had three times more cover in the former as in the latter; lichens about 25 per cent more cover in the latter. Lichens present in both stands were *Cladonia rangiferina, C. sylvatica, C. pleurota* (Floerke) Schaer., *C. cornuta cylindrica,* and *Cetraria cucullata*; they were taller and denser in the first stand. The following lichens were more common in the second stand: *Stereocaulon tomentosum, Cladonia macilenta squamigera* Vain., *C. delessertii* (Nyl.) Vain., *C. pleurota, Pertusaria coccodes* (Ach.) Nyl., *Pilophorus cereolus* (Ach.) Th. Fr., *Thamnolia vermicularis* (Sw.) Schaer., and *Nephroma arcticum* (L.) Torss. The more common mosses were *Polytrichum piliferum* Hedw., *Hylocomium splendens, Drepanocladus uncinatus* (Hedw.) Warnst., *Ptilidium ciliare* (L.) Nees., and *Bryum* sp. The moss-like *Selaginella selaginoides* (L.) Link. was also common.

Differences in the kinds of species and in their cover and frequency in these two stands can be explained largely by differences in the soil profiles. In general there was less silt and more rock close to the surface in the soil underlying the thin stand. The reaction in both was acid, with pH 4.6 to 5.0. Beneath the 2-inch layer of moss, lichens, and plant parts in the denser stand (Table II) was a 4-inch horizon of dark reddish brown silt, rich in organic matter, containing very many roots in the upper half. Between 4 and 7 inches, the brown silt was interspersed with many small, thin schistose stones, and the roots were frequent to the working depth at 7 inches. At 7–11 inches the grayish brown sandy silt, containing much gravel, was like a stiff jelly, tending to flow off the wall into the hole. Roots were infrequent. At 11–20 inches was pale brown, sandy silt, with gravel and small thin stones which increased in number and size with depth, so that at 20 inches there was more rock than silt. The roots were scarce.

A 2-inch layer of lichens and mosses covered the ground under the sparse stand (Table III). Below this was a horizon, varying in thickness up to 2 inches, which consisted of loose, dark brown, decayed plant debris with a few schist flakes and very numerous roots. Below this to about 5.25 inches was dark reddish brown silt loam with much organic matter, much more compact than the layer above, containing scattered gravel and schist pieces; the roots were infrequent. Between 5.25 and 14 inches was mostly loose, crumbling pieces of schist, with few roots. Palmer and Rouse (1945) stated that the stand of this type in the Dexter Creek area, 8 miles north of Nome, showed little change between 1922 and 1932. Quadrats which had been denuded became revegetated by the same species originally on the quadrats. They estimated that it would probably take about 25 years for the vegetation to return to the original condition of density, cover, and volume. When this area was examined by the writer in 1950 and 1951, the vegetation, except for reduced height growth of lichens due to grazing and trampling by reindeer, was similar to that described by Palmer and Rouse as occurring on the site in 1922. This type seems to have considerable permanence.

Dwarf birch-heath communities were included by Palmer (1945) in the "dry tundra type" and by Porsild (1951) in "dwarf shrub-heath" community in the "tundra" group. Oosting (1948:249) recognized in a general way various kinds of communities in the heath type in northeast Greenland, stating that *Betula nana* "may become a dominant in sheltered or

southern exposures of heath vegetation and especially on sites somewhat drier than the more widespread *Vaccinium* heath." Trapnell (1933) described and illustrated dwarf birch-lichen and *Ledum*-dwarf birch types in the Godthaab Fjord region which show much resemblance to communities in the Nome district. Du Rietz (1925a) discussed briefly various dwarf shrub-heath communities in the lower alpine region, the *Betula nana* heath resembling the type in Alaska. He stated that the lichen-rich areas in Scandinavia are the driest sites, while in the Alps the lichen-rich dwarf shrub-heath sites are the most moist. Du Rietz (1925b) pointed out that C. E. Fries in 1913 was the first to thoroughly characterize a large number of dwarf shrub heath associations in Scandinavia. Mosses and lichens, according to Du Rietz, Nordhagen, and others, are more sensitive to environmental conditions than dwarf shrubs and herbs. On the basis of both ground and field layers, he classified dwarf shrub heath communities into 3 major groups: 1) lichen-rich, 2) naked, poor in lichens and mosses, and 3) moss-rich. The stands in the Nome district discussed in the present paper show much resemblance to Du Rietz's (1925b) *Betula nana-Cladonia rangiferina-silvatica* association, which he stated is also important in the Alps. Nordhagen (1943) included in his Order A, dwarf shrub heath on lime-poor rock, two alliances, 7 associations, and 14 sociations. These communities occurred as a lower story in the spruce-pine and birch zones, as well as without a tree layer in the low alpine region. The stand analyzed in Table II shows most resemblance to his association number 4, dwarf birch-*Empetrum* heath. The stand analyzed in Table III resembles more his association number 1, *Loiseleuria* heaths. Both of Nordhagen's associations are important as reindeer range, often snow-free in winter, especially the latter community.

Another small stand of 1 or 2 square rods, resembling even more closely Nordhagen's association number 1, was examined on stony, gravelly sites on the ridge at Golovin. The sparse vegetation consisted of *Loiseleuria procumbens, Arctostaphylos alpina,* short lichens and mosses, and invading plants of *Ledum decumbens, Empetrum nigrum,* and *Betula nana exilis.* It appears that *L. procumbens, A. alpina,* and *Salix phlebophylla* And. become more abundant, and *B. nana exilis* and *Vaccinium* spp. less abundant in more rocky and gravelly soil and at higher elevations, such as at 500 feet on King Mountain north of Nome and at Salmon Lake. On a gravelly outwash, several acres in area, on the north side of Salmon Lake, the following species were abundant: *Loiseleuria procumbens, Salix phlebophylla, Vaccinium vitis-idaea,* and *Arctostaphylos alpina*; frequent: *Rhododendron kamtschaticum* Pall.; infrequent to scarce: *Betula nana exilis, Ledum decumbens, Vaccinium uliginosum, Salix chamissonis* And., *Carex* sp., and *Campanula uniflora* L. Mosses, especially *Polytrichum* sp., and short lichens of many kinds were abundant.

Nordhagen stated that *Betula nana* does not tolerate long-lasting snow-cover, shade, or unstable slide sites. It dominates on infertile gravel and sand deposits with acid humus or with extremely acid peat. It can raise itself better than any other dwarf shrub above compact lichen masses, so that only the tops of the shoots project above them.

10. *Blueberry-heath-lichens type (Fig. 4)*

This type resembles the preceding one, but blueberry (*Vaccinium uliginosum*) is the chief dominant, often forming very dense stands. *Betula nana exilis* is much less abundant, and when present is often very short and scattered. *Empetrum nigrum* and *Ledum decumbens* are more numerous usually than in type 9. Other important dwarf shrubs are *Vaccinium vitis-idaea, Loiseleuria procumbens, Salix pulchra,* and *Arctostaphylos alpina.* Herbs, such as *Luzula, Calamagrostis canadensis, Festuca altaica, Carex, Valeriana capitata* Pall., and *Pedicularis capitata* Adams are scattered. Mosses are generally distrib-

uted. Lichens are more spotted in occurrence than in type 9, the shrubs often being too dense for their growth. In shorter, more open stands, however, lichens may cover 75 per cent of the ground. This type occurs on gentle to steep slopes where gravel and rocks are close to the surface, but the sites are moister than in type 9. While it is found at the same elevations as the dwarf birch-heath-lichens type, it also covers large areas at higher elevations, as 400 to 500 feet or more north of Nome, elevations where the dwarf birch type is lacking. The snow probably remains later than in the dwarf birch type, but not so late as in type 11 where there is more *Cassiope tetragona* (L.) D. Don.

The blueberry-heath-lichens type is widespread in hilly parts of the Seward Peninsula, and is conspicuous from the air because of its dark bluish green color, with the gray of the lichens interspersed in spots, and because of the smooth texture. When not damaged by overgrazing or fire it is valuable for winter grazing by reindeer. Stands intermediate between types 9 and 10 were found, but their status cannot be definitely determined until sociological analyses are available.

Palmer (1945) included stands of *Vaccinum* spp. and associated species in his "dry tundra type." Oosting (1948) recognized a heath type dominated by *Vaccinium uliginosum microphyllum* (Lge.) Nath. in northeast Greenland, especially inland on sandy slopes with associates *Empetrum nigrum* and *Arctostaphylos alpina*. Trapnell (1933) also refers to communities dominated by *V. u. microphyllum* in Greenland. Seidenfaden and Sørensen's (1937) ecosystem on "moderately moist sheltered precipices and rock ledges," especially at heads of fjords, in northeast Greenland, was dominated chiefly by *V. uliginosum*. *Salix arctica* was another dominant, and associated species were *Dryas octopetala* on upper dry areas, and *Cassiope tetragona* on lower moist areas. Also present were *Rhododendron lapponicum* (L.) Wahl., *Empetrum nigrum*, and several herbs. He wrote that this type is supplied with water until late in the summer, and that *V. uliginosum* "within our areas can be said with no little right to replace *Betula nana* of the somewhat more southerly areas" (p. 121). Du Rietz (1925a) stated that *V. uliginosum* heath plays an important role on wind-exposed slopes, without solifluction terraces, in the lower alpine zone in Scandinavia. Du Rietz (1924) showed similarities in *V. uliginosum* communities in Scandinavia and in the Alps. Some of the species present in both locations, as well as in Alaska, were *Empetrum nigrum, Loiseleuria procumbens, Vaccinium vitis-idaea,* and others. The Alaskan type is similar to Nordhagen's (1943) low alpine *Vaccinium uliginosum* heath (association number 2), and the low alpine *V. myrtillus* heath (number 8), the latter occurring where the snow lies late.

11. *Four-angled heather-blueberry type*

This type shows relationships to the preceding type, but occurs where the snow lies later. It is found on hilly sites throughout the region. The dominant dwarf shrubs are *Cassiope tetragona* and *Vaccinium uliginosum,* but *Empetrum nigrum* also rates high in frequency and cover. An analysis of a stand about 8 miles north of Nome is given in Table IV. Additional dwarf shrubs in this stand were *Dryas octopetala, Salix reticulata, S. chamissonis, Betula nana exilis,* and *Ledum decumbens.* The herbs with the highest cover and frequency were *Carex* sp., *Festuca altaica, Polygonum bistorta plumosum* (Small) Hult., *Equisetum scirpoides* Michx., *Pedicularis verticillata* L., and *Hedysarum alpinum americanum* Michx. Mosses formed a layer over the ground. Lichens, 1 to 3 inches high, were widely distributed but sparse, usually not sufficient for winter range. The ground was completely covered with vegetation, usually with two layers. The total number of species in the ten m^2 quadrats was 32, the average number per quadrat 15.5, both figures larger than in most stands. In some stands, where

TABLE IV. *Heather-blueberry-moss stand, 8 miles north of Nome. Aug. 1, 1951*

Species	1	2	3	4	5	6	7	8	9	10	Aver. Cover	Freq. %
Cassiope tetragona	3+	3+	5+	4	4	3	4	4+	4−	4−	3.8	100
Vaccinium uliginosum	5−	5−	2	3	3	3	3	3	3	4	3.4	100
Empetrum nigrum	2	3	3	3+	3−	3−	2	1	3	3	2.6	100
Dryas octopetala	2	1	1	1	1	3	2	1	2−	1	1.5	100
Salix reticulata	1	1		1	1	2	3	1−	2	1	1.5	90
Salix chamissonis	1	1	1+	1	1+	2		1		1	1.1	80
Betula nana exilis			1−	2	1	1					1	40
Ledum decumbens						1−					—	10
Carex sp.	1−	1	1	1	1	1	1+	1	1	1	1	100
Festuca altaica	1−	1−		1−		1	1−	1	1−	1	1−	80
Polygonum bistorta plumosum	1−	1	1	1			1−	1−	1	1−	1−	80
Equisetum scirpoides	1−	1−	1	1−		1−	1−	1−			1−	70
Pedicularis verticillata					1	1−	1−	1−	1	1−	1−	60
Hedysarum alpinum americanum	1−		1−	1−			1		1−	1	1−	60
Dodecatheon macrocarpum	1+					1		1	1−	1	1	50
Calamagrostis canadensis		1−	1−			1−	1−		1−		1−	50
Cerastium beeringianum	1−			1−					1	1−	1−	40
Anemone narcissiflora	1					1−		1−		1−	1−	40
Pyrola minor								1−	1−		1−	20
Polygonum viviparum	1			1−	1−		1−				1−	40
Equisetum arvense	1−				1−				1−	1−	1−	40
Arnica porsildiorum		1−	1−						1−		1−	30
Artemisia arctica						1−		1−		1−	1−	30
Cardamine pratensis						1−			1−	1−	1−	30
Papaver radicatum	1−	1−							1−		1−	30
Valeriana capitata								2	1−		1	20
Luzula multiflora	1−										—	10
Equisetum sp.	1−										—	10
Saxifraga hieracifolia									1		—	10
Claytonia sarmentosa						1−					—	10
Saussurea angustifolia								1−			—	10
Lycopodium annotinum										1−	—	10
Mosses	6	6	6	6	6	6	6	6	6	6	6	100
Lichens	1−	2	2	3	3	4	1	1	1	1+	1.9	100
No. vascular spp. per m²	19	13	12	14	11	18	13	17	20	18		
Aver. no. vasc. spp. per m²	15.5											

Additional species in the stand but not in any quadrat: *Polemonium pulcherrimum, Saxifraga hirculis, Salix alaxensis.*

snow apparently melts later, *Cassiope tetragona* is the sole dominant. From the air this type appears dark bluish green, even darker than type 10, and smooth in texture. Occurring more in depressions it often alternates with stands of the dwarf birch-heath-lichens type on exposed ridges, and with taller shrubs, especially willows in deeper draws. In some draws, where the snow does not melt until in July, meadow-like stands occur in which the following are abundant: *Rhododendron kamtschaticum, Anemone narcissiflora, Salix reticulata, S. chamissonis, Equisetum arvense* L., *Carex* spp., *Festuca altaica, Artemisia arctica, Viola langsdorfii, V. biflora* L., and *Sedum roseum.*

Palmer (1945) probably included this type in his "dry tundra." Oosting (1948) noted that in northeast Greenland, important heath species were *Cassiope tetragona* and *Vaccinium uliginosum microphyllum,* that either may be dominant, that Cassiope is less important inland, and *Rhododendron lapponicum* usually occurs as patches in the dwarf shrub heath. Seidenfaden and Sørensen (1937)

noted that *Cassiope tetragona* was associated with *Vaccinium uliginosum* et al., on lower, moister parts of slopes in their ecosystem 7, "moderately moist sheltered precipices and rock ledges." Their ecosystem number 9, "moderately moist, well drained, snow patches and fossil polygon fields" was "entirely dominated by *Cassiope tetragona.*" Some additional species of common occurrence were: *Salix arctica, Polygonum viviparum* L., *Poa arctica, Hierochloe alpina, Luzula nivalis* (K. and R. P.) Trautv., *Pedicularis hirsuta* L., *Papaver radicatum* (R. P.) Trautv., and *Lycopodium selago* L., the last "exclusively associated with *Cassiope* heath." "This ecosystem is one of the few systems within the area which principally manifests itself by its vegetation, the patches and belts of brown *Cassiope* heath so conspicuous in the landscape—snow-covered in the winter, but not exposed to any considerable accumulation of snow" (p. 122). Trapnell (1933) described briefly the "open mat" type with *Cassiope tetragona* as the "physiognomic dominant" over much of the montane zone (500–600 m.) in the Godthaab Fjord region. Associated species were *Dryas integrifolia* M. Vahl., *Rhododendron lapponicum, Vaccinium uliginosum microphyllum, Diapensia lapponica* L., various herbs, a few mosses, and many lichens. This community is more xeric than the Alaskan type (number 11).

Du Rietz (1925a) wrote that *Cassiope tetragona* plays a great role in northern Lapland, greatest in the upper part of the lower alpine zone (over 1,050 m.). It may form unbroken stands over very large areas. It requires long-lasting snow-cover, in contrast to *Empetrum nigrum* heath, which occupies wind-exposed sites. The latter community, according to Du Rietz, is the most important dwarf shrub heath in the Scandinavian mountain chain. In the lower part of the lower alpine zone, *Cassiope* heath occurs in soil moderately rich in lime, but in the upper part it is indifferent to the lime content. Nordhagen (1936: 43) stated that this very characteristic community occurs on lime-rich soil in Finnmark province (where it is transitional to *Dryas* heath), but farther southwest in Troms and in neighboring parts of Finnish and Swedish Lapland, excellent stands are found on lime-poor sites. Some of the more important associated species in Nordhagen's analysis of this

TABLE V. *Alpine bearberry-mountain cranberry stand, Cape Nome, 13 miles E. of Nome. Aug. 2, 1951*

Species	1	2	3	4	5	6	7	8	9	10	Aver. Cover	Freq. %
Arctostaphylos alpina	5	4+	5	6	5	6	4+	5	5	5	4.9	100
Vaccinium vitis-idaea	3	3	4	3	4	3	4	4	3	3	3.4	100
Ledum decumbens	2	2	2	1	1+	2	1	1	1	2	1.5	100
Vaccinium uliginosum	2	2−	1		2	1	1	1		2	1.5	80
Betula nana exilis	1	2	2	1	1		2	1			1.4	70
Empetrum nigrum		1		2	1			1	2		1.4	50
Loiseleuria procumbens							1−		1−		1−	20
Salix chamissonis					1−					1−	1−	20
Hierochloe alpina		1−	1	1	1−	1	1−	1−	1−	1	1−	90
Carex lugens	1−						1−	1−	1−		1−	40
Agrostis borealis		1−	1−							1−	1−	30
Pedicularis verticillata		1−				1−			1−		1−	30
Luzula parviflora										1	—	10
Mosses	1	1	2				1	1−			1.2	50
Lichens	2	2	2	1	1	1−	3	1	1		1.6	90
No. vascular spp. per m²	6	9	7	6	8	6	8	8	8	8		
Aver. no. vasc. spp. per m²	7.4											

FIG. 7. Alpine sedge-alpine *Dryas* type at Black Hill, about 1500 feet elevation, near the head of Kougarok River, west-central Seward Peninsula. Remains of reindeer in the foreground. Alpine *Dryas* type and lichen-moss barrens on hills.

community were *Dryas octopetala, Carex rupestris* All., *Silene acaulis* L., *Polygonum viviparum, Vaccinium uliginosum, Empetrum hermaphroditum, Salix reticulata,* and *Festuca ovina* L. *Cassiope tetragona* community apparently does not occur in the Sylene and Sikilsdalen regions in central and southern Norway, because Nordhagen does not include it in his studies of these areas (1927, 1943). According to Du Rietz (1925a: 37), *Cassiope tetragona* heath is restricted to the northeastern part of the Scandinavian mountain chain.

12. *Alpine bearberry-mountain cranberry type*

A stand, about 4 inches high and a few square rods in area, of this wind-resistant community was found on gravelly material between boulders at 400 to 500 feet elevation on Cape Nome headland, east of Nome. It probably occurs in similar sites in many places in the region. An analysis is given in Table V. The chief dominants were *Arctostaphylos alpina* and *Vaccinium vitis-idaea.* Other important shrubs were *Ledum decumbens, Vaccinium uliginosum, Betula nana exilis,* and *Empetrum nigrum.* Also present were *Loiseleuria procumbens* and *Salix chamissonis.* Lichens, averaging about 0.75 inch high, formed fair cover; mosses were scattered. The average number of species per quadrat was only 7.4.

According to Oosting (1948), *Empetrum nigrum* may be a dominant locally in northeast Greenland, and where *Empetrum* is abundant, *Arctostaphylos alpina* also occurred. This type number 12 could probably be classified as a sociation in Nordhagen's association number 4 because of its resemblance to the *Arctostaphylos alpina* variant of the *Empetrum-Cetraria* sociation (1943: 95).

13. *Alpine Dryas type (Fig. 7)*

This type is common throughout the region on upper slopes and summits of hills and mountains. The most common and abundant species is usually *Dryas octopetala,* with a large number of associated herbs, dwarf shrubs, mosses, and lichens. On a hill, about 650 feet high, about 5 miles northeast of Nome, a total of 48 species of herbs and dwarf shrubs, and 14 species of lichens were listed by Hanson (1951: 370). A stand on a hilltop north of Egavik on the shore of Norton Sound, contained few species, similar to the stand analyzed in Table VI which was several square rods in area. Bare or lichen-covered rocks are usually dull gray in color, while the *Dryas* stands are pale bluish gray-green due to *Dryas.* Variations are caused by patches of other spe-

TABLE VI. *Alpine Dryas stand, about 13 miles east of Nome. Aug. 2, 1951*

Species	1	2	3	4	5	6	7	8	9	10	Aver. Cover	Freq. %
Dryas octopetala	3	3	6	4	6	4	4	5	5	4	4.4	100
Salix chamissonis	3	3	2		2	3		1	2	3	2.4	80
Ledum decumbens	1	1	1–	1			1–	1–	1–	1	1–	80
Empetrum nigrum							1	1	1		1	30
Rhododendron kamtschaticum		1					1	1			1	30
Loiseleuria procumbens		1		1							1	20
Diapensia lapponica obovata		1						1–			1–	20
Vaccinium vitis-idaea	3										—	10
Agrostis borealis	1–	1–		1–	1–	1–	1–		1–	1–	1–	80
Carex lugens	1–	1	1–		1–		1	1	1–	1	1–	80
Hierochloe alpina	1	1–	1	1–	1–	1–	1–				1–	70
Artemisia arctica	1–		1–		1–		1–			1–	1–	50
Luzula parviflora	1–			1				1		1	1	40
Campanula lasiocarpa	1			1–	1–						1–	30
Antennaria sp.				1							—	10
Tofieldia pusilla								1–			—	10
Mosses	1	1	1	2	2	1	2	1	1	1	1.3	100
Lichens	4	5	3	5	3	4	3	3	3	3	3.6	100
Rocks with crustose lichens	3	4	2	4	2	3	4	3	3	1	2.9	100
No. vascular spp. per m²	10	9	6	8	7	4	8	9	6	7		
Aver. no. vasc. spp. per m²	7.4											

cies, especially *Loiseleuria procumbens,* giving a greener color. Darker green areas and stripes occur in moister depression because of the greater density and more luxuriant growth of sedges, low willows, grasses, and *Cassiope tetragona,* the last often dusky green in color. The soil under rocks remains moist during the summer, but the wind blows much of the time, causing many of these areas to be bare in winter. Many kinds of lichens are scattered, but the cover and density are low and the height is usually less than 0.5–1.0 inch. In small depressions they are denser and up to 2 inches high. The variety of dwarf shrubs and herbaceous plants gives a wide choice of forage for summer grazing by reindeer seeking higher elevations to escape flies and mosquitoes. In many places, the lichens are too short and scattered for winter grazing, but when icing-over occurs at lower elevations, this type is most important because of its freedom from snow much of the time. The lichens, though short, are more nutritious than the taller kinds (Palmer 1945). A similar community on raised gravelly beaches, exposed to wind, in the vicinity of Kotzebue, was described by Hanson (1951: 369). The chief species were *Dryas integrifolia, Saxifraga tricuspidata* Retz., *Empetrum nigrum, Arctostaphylos alpina,* and *Salix reticulata.* Short lichens and mosses covered much of the ground between the shrubs.

Palmer and Rouse (1945) also called this community the alpine *Dryas* type. Oosting (1948) discussed a *Dryas*-sedge (preclimax) community on gravel areas in which many pioneer species also were present, in northeast Greenland. According to Seidenfaden and Sørensen (1937), *Dryas octopetala* is an important constituent of their dry-barren-ground and dry-loess-fields ecosystems in northeast Greenland. One of Trapnell's (1933) important communities in the Godthaab Fjord region was the *Dryas* mat barren, comprising cushions of *D. integrifolia* among lichens and xeric herbs. Nordhagen (1943) included a similar type in his *Dryas-heath* alliance, Kobresieto-Dryadion, in Order L, rock communities in mountainous regions. He stated that

this alliance included a number of associations and sociations, of which the most important were Dryadetum scandinavicum, Kobresietum myosuroides scandinavicum, and Caricetum nardinae. Floristically and environmentally, this alliance is closely related to the middle European Seslerion coeruleae alliance. Earlier, Nordhagen (1936) had described and analyzed 10 sociations in this alliance, some with few species in them, usually xerophilous and on rocks rich in lime. Additional research in the hills and mountains of western Alaska would undoubtedly reveal communities with greater similarity to those of Norway. The *Dryas-Kobresia-Hedysarum* community at 3,200 feet in Mt. McKinley National Park described by Hanson (1951) is in this alliance also, so this alliance is widely represented in Alaska. It furnishes valuable grazing for reindeer, caribou, and mountain sheep.

Christophersen (1945) stated that the *Dryas*-flora (*Dryas octopetala, Salix polaris* Wahl., *Betula nana,* and other hardy species) formed the first vegetation following the glacial period in Norway, and some of these species may have survived the glacial period in favorable spots not covered by ice. He also stated that *Dryas octopetala* grows only where there is lime in the soil, and it is found farther north than any other flowering plant, as far north as Lat. 83° 15′ in Greenland. Lagerborg and Holmboe (1937–40) wrote that this species is found only in soil containing lime, and that it forms the most characteristic kind of *Dryas*-heath, to which attention was called by Chr. Smith as early as 1812. Du Rietz (1925a) also stated that *Dryas octopetala*-heath is restricted to calcareous substrata, and that it is indifferent to the duration of snow cover. Du Rietz (1924) published an analysis of a *Dryas octopetala* heath at 2,350 meters elevation in the Alps, which resembles the Scandinavian and Alaskan communities. Besides the dominant *D. octopetala,* species common in stands of the three locations were *Polygonum viviparum, Silene acaulis,* and *Cetraria islandica.* Du Rietz reported also *Selaginella selaginoides* in a *Dryas*-heath in the Alps, Nordhagen (1936, 1943) in similar communities in Norway, and Hanson (1951) in Alaska.

IV. Dwarf Shrub-Marsh Types

This major group is distinguished from the dwarf heath shrub types on firm land by the association of such characteristic bog species as *Rubus chamaemorus, Oxycoccus microcarpus, Carex* spp., *Eriophorum* spp., *Sphagnum* spp., and mosses, with dwarf shrubs including *Betula nana exilis, Vaccinium vitis-idaea, V. uliginosum, Ledum decumbens,* and *Empetrum nigrum.* Lichens may be abundant also. This group resembles very much Nordhagen's Order J, Oxycocco-Ledetalia palustris (1943), the "Zwergstrauch Gesellschaften der Moorböden" (1936) occurring on hummocks or series of joined hummocks and mounds as "islands" and "stringers" in complex types, or surrounded by grass-marsh. According to Nordhagen, this group forms the final stage in the progressive development from open water to grass-marsh to dwarf-shrub marsh. When hummocks reach a certain height they become drier, the protecting snow-cover becomes thinner, and lichens may become dominant, as described by Hanson (1951 : 338).

14. *Cloudberry-dwarf shrub marsh*

Dwarf shrub marsh types are of common occurrence on lower, flat lands in the region. In a previous publication (Hanson 1951 : 338), a stand was described on low mounds and ridges surrounding fresh water marsh on the Kotzebue spit. On the lowlands north of Imuruk Basin, east of Teller, large areas are covered with the cloudberry-dwarf shrub marsh type. An area examined on August 6, 1951, had a prolific crop of berries, being picked by two camps of Eskimos for winter. As in Norway, this type shows a better development of the cloudberry than occurs in other types. Analysis of a stand, about

TABLE VII. *Cloudberry-dwarf shrub-marsh, about 12 miles east of Nome. Aug. 2, 1951*

Species	1	2	3	4	5	6	7	8	9	10	Aver. Cover	Freq. %
Vaccinium vitis-idaea	4	4	4	3	3	4	4	3+	3	3+	3.5	100
Betula nana exilis	4	3	4+	4	3	4	3	2	2	4	3.3	100
Empetrum nigrum	3	4	4	3	4	4	2	2+	2+	4	3.2	100
Rubus chamaemorus	3+	3	3	3	3−	2	2	3	3	3+	2.8	100
Ledum decumbens	2−	2		2+	2	2	3−	2+	2	3	2.2	90
Vaccinium uliginosum		1				1	2−	1	3		1.6	50
Spiraea beauverdiana		1	1	1−	1−	1	1	1			1	70
Arctostaphylos alpina								4			—	10
Cornus suecica	1−	1−	1−		1−	1	1				1−	60
Calamagrostis canadensis			1−	1	1	1−	1−	1−			1−	60
Equisetum sylvaticum			1−		1−						1−	20
Mosses	1	1	1	2	6	4	3	1	5	2	2.6	100
Lichens	3	3	2	3	3	2	3	3	5	4	3.1	100
No. vascular spp. per m²	6	8	8	7	9	9	9	9	6	5		
Aver. no. vasc. spp. per m²	7.6											

Additional species in the stand but not in any quadrat; *Salix pulchra*.

0.5 acre in area, of this type east of Nome is given in Table VII. It occurred on moist peat, in strips parallel to the gentle south-facing slope, alternating with fresh water sedge-marsh. It was only a few hundred feet from the seacoast, exposed to strong south winds. The plants were only 3 to 6 inches high, the cloudberry and dwarf heath shrubs giving it a characteristic appearance. It was conspicuous from a distance because of the large leaves, turning orange to red in late summer, and the large fruits which turn pale yellow to pink. In order of high frequency and cover, *Vaccinium vitis-idaea* rated first, followed by *Betula nana exilis, Empetrum nigrum, Rubus chamaemorus, Ledum decumbens,* and *Vaccinium uliginosum.* Both lichens and mosses rated high in cover and frequency. The average number of vascular species per quadrat was only 7.6, total number in 10 square-meter quadrats was 12.

According to Nordhagen (1943) this order was first recognized in Finland. Oosting (1948) mentioned that raised parts of older bogs in northeast Greenland show all the characteristics of typical ericaceous heath, *Rubus chamaemorus* was not listed. Trapnell (1933: 327) found in the Godthaab Fjord region a somewhat similar community, with *Vaccinium uliginosum* and *Drepanocladus* sp. forming a cover on turf hummocks, following an earlier stage of *Carex rariflora* (Wahl.) J. F. Smith-*Salix chlorocladus.*

V. HERB-DWARF SHRUB TYPES

15. *Alpine sedge-alpine Dryas type (Fig. 7)*

This type occurs at higher elevations, as, for example, at 1,500 feet on Black Hill, in the west-central part of Seward Peninsula. It grows below the alpine *Dryas* type in sites where more soil has accumulated between the rocks and where there is more moisture and probably longer lasting snow-cover. Common species in this stand were *Carex spp., Dryas octopetala, Salix reticulata, Luzula confusa* Lindeb., *Hierochloe alpina, Oxytropis* sp., *Poa arctica,* and mosses. Lichens were scattered, mostly on the sides of low hummocks, the chief species being *Thamnolia vermicularis,* and *Stereocaulon tomentosum,* with very little *Cetraria* spp. and *Cladonia* spp. The presence of *Dryas octopetala* indicated lime in the soil. A stand very similar to this was studied in 1949 on Eagle Sum-

FIG. 8. Detail of the cottongrass-sedge-dwarf heath shrub complex on Baldwin Peninsula. Dwarf birch is prominent at left between the cottongrass tussocks. Aug. 12, 1951.

mit, northwest of Fairbanks, at an elevation of 3,900 feet (Hanson 1950).

This type is closely related to the alpine *Dryas* type (number 13), because of the abundance of *Dryas octopetala* and other species listed above, both belonging to the same alliance, discussed under type 13. It is placed in the herb-dwarf shrub group because of the physiognomic importance of the herbaceous species. The alpine sedge-alpine *Dryas* type corresponds most closely to Nordhagen's (1936: 37, 39) *Dryas octopetala-Carex rupestris* sociation in the *Dryas*-heath alliance. It also corresponds to Du Rietz's (1925a) *Dryas* meadows on soils rich in lime in the lower alpine region and Christophersens' (1945) *Dryas*-grass-heath communities in the middle alpine zone, both in Scandinavia.

16. *Cottongrass-sedge-dwarf heath shrub complex* (*Figs. 2, 3, 4, 6, 8*)

This is called a "complex" in recognition of the occurrence of several communities and microcommunities in close association. These communities often occupy only a few square feet, or less, but in places they form a fairly uniform cover over many acres. The frequent occurrence of mounds and hummocks, with ponds, lakes, and marshes adds to the heterogeneity in many areas. Larger stands of aquatic and sedge marsh types can readily be segregated. However, areas where the summit of a mound may be in the dwarf shrub-heath-lichens type, the depression a small sedge marsh type, and in other spots a mixture of cottongrass tussocks, scattered sedges, and dwarf shrubs, it appears best to designate the vegetation on the area as a complex.

This complex covers more area than any other type in the region. It can probably be considered the most characteristic kind of tundra in northwestern Alaska, in view of the tussock form of growth of the cottongrass (*Eriophorum spissum* Fern.), the chief tussock former. There is considerable variation, from almost continuous and uniform growth of well

developed tussocks with sparse growth of sedges and dwarf shrubs (Fig. 6), to stands where the tussocks are sparse or almost lacking and sedges and dwarf shrubs are abundant (Fig. 3). The land may be fairly level and uniform, or it may be hummocky and irregular, with small wet areas of sedge marsh in the depressions. The dwarf shrubs, especially dwarf birch, Laborador tea, crowberry, blueberry, and mountain cranberry, and in places alpine bearberry and dwarf willows, grow usually in the depressions, on the sides of tussocks, and they may dominate mounds and hummocks. Often the bottom of the spaces between the tussocks may be filled with several inches of moss or *Sphagnum*, upon which the dwarf shrubs grow. Lichens also grow on mosses and *Sphagnum* in depressions and on the sides and tops of tussocks or on the tops and sides of hummocks where they may form most of the cover, especially where they are exposed to much wind.

Usually this complex occurs on fairly level to gently sloping land, underlaid by peat, with perennially frozen ground as close as 1 to 1.5 feet below the surface in places. The tussocks can be seen from the air to a height of about 1,000 feet, giving an irregular stippled appearance, pale yellowish green in color, and, if lichens are abundant, with a pale yellowish tinge. Cottongrass areas appear bright white when headed out (Fig. 6). Lichen areas can be distinguished from the cottongrass heads by the more yellowish gray color. Hummocks often have a cover of dwarf shrubs, brownish green in color, adding heterogeneity to the stand. Interspersed sedge-marsh areas are usually bright green, willow thickets are darker green, and alder clumps are dark bluish green.

The cottongrass complex, when not overgrazed or burned, furnishes much lichen forage because the lichens find almost optimum conditions of moisture and light in the spaces between the tussocks. Often they form dense tufts, 4 to 5 inches high.

The stand shown in Fig. 8, on Baldwin Peninsula, was described in detail in an earlier paper (Hanson 1950: 625, 626). The "tussock-birch-heath vegetation" of Hopkins and Sigafoos (1951), described in much detail, especially with respect to the results of frost action, corresponds to the cottongrass-sedge-dwarf heath shrub complex. Palmer (1945) used the term "tundra" for this complex, and he divided it into the wet and dry kinds, the latter having more lichens and dwarf shrubs. Porsild (1951: 132) stated: "In unglaciated Alaska—a climax undoubtedly has been attained in the 'niggerhead' tundra which is so characteristic of the coastal plain landscape." This complex shows some resemblance to associations, especially numbers 99 and 100, in Nordhagen's "Torfmoosreiche Graskrautmoore" (1928), placed later in Alliance 17, the meso-oligotrophic grass marshes (1936: 17, 1943). The cottongrass complex in Alaska seems to be almost intermediate to Nordhagen's Order I-A, meso-oligotrophic grass marshes (Scheuchzerietalia) and Order J, dwarf shrub marsh (Oxycocco-Ledetalia palustris) because the dwarf shrubs are more abundant usually than in Order I-A, but they do not dominate as in Order J. Instead, cottongrass as tussocks usually dominate (Figs. 6, 8), but often sedges dominate (Fig. 3). While cottongrass is rooted in mineral soil (Fig. 8), shown also by Hopkins and Sigafoos (1951: 64), mosses and *Sphagnum* usually form mats and tufts between the tussocks and a layer of peat usually lies beneath them. However, the cottongrass complex does not fit Order I-A very well because there is too great an abundance and variety of dwarf shrubs, greater dominance of cottongrass, and absence or sparseness of species that usually grow in wetter areas, such as *Scirpus caespitosus* L. and *Menyanthes trifoliata* L. The cottongrass complex appears to be intermediate to the grass marshes rich in mosses, the cottongrass-*Scirpus* marsh, and the dwarf shrub marshes in the classification of marsh and

bog types in Norway by Løddesøl and Lid (1950). Closer resemblance, however, is found to the community described as "jernik" by Imanishi (1950) in northwestern Manchuria, a sedge marsh (*Carex* spp. and *Eriophorum vaginatum* L.), made up of tussocks about a foot apart, often containing *Sphagnum,* dwarf *Betula exilis,* and *B. fruticosa.*

The cottongrass-sedge-dwarf heath shrub complex, then, appears to be floristically and physiognomically a unique type, without close resemblance to communities in Scandinavia. Sociological analyses are needed for more precise comparisons. Environmental factors undoubtedly play an important role in this uniqueness.

VI. Herb Types

The types included in this class are characterized by the dominance of herbaceous plants, usually sedges or grasses. Forbs may be important in some of them, but dwarf shrubs and shrubs are usually scarce or lacking.

17. *Sedge marshes, saline and fresh water (Figs. 4, 5)*

Saline marshes occur extensively on estuaries, borders of lagoons, and other areas near the sea. Fresh-water marshes are also extensive, bordering lakes and streams, in drainage strips in shallow draws separating expanses of the cottongrass complex, and in other poorly drained sites (Fig. 5). The sedges vary in salt tolerance from saline species such as *Carex cryptocarpa* C. A. Mey. and *C. subspathacea* Wormskj., to fresh-water species such as *C. aquatilis* and *C. rotundata* Wahl. Other characteristic species on saline estuaries, often early invaders on mud flats, are *Puccinellia borealis* Swal., *Stellaria humifusa* Rottb., and *Potentilla pacifica* Howell. The total number of species is few in saline marshes, but often high in fresh-water marshes. Narrowleaf cottongrass (*Eriophorum angustifolium* Roth.) is often conspicuous in the latter, especially where the ground has been disturbed, as by tractors. Some additional species in fresh-water marshes are *Salix pulchra, S. richardsonii, S. reticulata, S. ovalifolia camdensis* Schneid., *Potentilla fruticosa, Andromeda polifolia, Saxifraga hirculus* L., *Dodecatheon frigidum* C. & S., *Saussurea angustifolia* DC., *Polygonum bistorta plumosum,* P. *viviparum, Arctagrostis latifolia* (R. Br.) Griseb., *Juncus triglumis* L., *Iris setosa* Pall., *Thalictrum alpinum* L., *Luzula multiflora* (Retz.) Lej., *Equisetum arvense, Eriophorum spissum, E. brachyantherum* Trautv., *Calamagrostis* spp., *Pedicularis capitata, P. arctica* R. Br., *P. oederi* Vahl., *Petasites frigidus,* and *Gentiana glauca* Pall. Mosses and *Sphagnum* form a ground layer in many places.

An analysis is given in Table VIII of a sedge marsh containing a large number of dwarf shrubs. This stand, occupying several acres, was on a moderate, south facing slope near Cape Nome. It alternated with stands of the dwarf shrub marsh type (Table VII). It is classified with the fresh-water marshes because of the dominance of the sedges, the prominence of *Petasites frigidus,* and the abundance of moss.

Often hummocks, 6 to 8 inches high, are scattered over the surface in the fresh-water marshes. They have a greater cover of grasses, especially *Calamagrostis canadensis, Festuca altaica,* and *Arctagrostis latifolia,* and dwarf shrubs, than the depressions. From the air the sedge marshes are easily recognized because of the pale green to yellow green color and the smooth texture.

A profile made on July 1, 1950, in a depression in a stand of this type about 10 miles north of Nome showed dark red to brown fibrous peat to a depth of 12 inches. Two layers of dark gray silt loam occurred at 3–4 and at 5–7 inches. Below 12 inches there was gravel and rocks and the soil was frozen. The profile was seeping with water, the reaction was pH 5.6 to 5.8. The roots were mostly in the upper 4 inches. Under a 6-inch high hummock, peat formed a layer 14 inches

TABLE VIII. *Sedge-moss marsh, about 12 miles east of Nome. Aug. 2, 1951*

Species	1	2	3	4	5	6	7	8	9	10	Aver. Cover	Freq. %
Carex bigelowii	2	4	5	4	4	4	5	4	4	3	3.9	100
Eriophorum angustifolium	5			1		1	1–			1	1.8	50
Vaccinium uliginosum	1	2	3	4	4	2	4	2	2	3	2.7	100
Empetrum nigrum	3	2–	2	3	2	3	3	3	3	2	2.6	100
Ledum decumbens	1	2–	1	2	1	2	2	2	1	2	1.6	100
Vaccinium vitis-idaea	1	1	1	2	2	1	2	2	1	2–	1.5	100
Arctostaphylos alpina		3	2		2	2			1	2	2	60
Betula nana exilis			1	1	1–	1	1–	3	3		1.6	70
Rubus chamaemorus	1–	1	1		1–	1–		3	1	2–	1.1	80
Alnus crispa	1		1–								1–	20
Salix pulchra	1—										—	10
Salix chamissonis								1			—	10
Petasites frigidus	1	3	1–		1		1				1.4	50
Luzula multiflora	1–	1–									1–	20
Pedicularis verticillata		1–									—	10
Mosses	2	3	5	5	3	4	4	4	3	3	3.6	100
Lichens	1	2	3	3	4	4	4	4	4	5	3.4	100
No. vascular spp. per m²	11	10	10	7	9	9	8	8	8	8		
Aver. no. vasc. spp. per m²	8.8											

thick on top of dark gray silt loam which continued to the frozen ground at 16 inches.

Hanson (1951) described and gave analyses of stands of *Carex subspathacea, C. rariflora,* and *C. aquatilis-C. rotundata* on the lowlands in the vicinity of Kotzebue, and discussed in detail differences in the flora and environment of hummocks and depressions. The formation of mounds and hummocks on the Kotzebue lowlands was discussed by Hanson (1950: 624) as being due to a number of processes including frost action and the accumulation of plant remains, and some of the voluminous literature was cited. Hopkins and Sigafoos (1951) and Sigafoos (1951) discussed the formation of tussocks, mounds, and hummocks, peat ridges, etc., as being caused chiefly by frost action. They described a "sedge sod" type, occurring in poorly drained sites where water occurs at the surface and where lateral movement is slow. Palmer (1945) and Palmer and Rouse (1945) included lowlands sedge marshes in their wet-tundra. Porsild (1951) included such communities in "marsh and wet tundra," and in "lagoon and salt marsh subject to floods."

Oosting (1948) presented the importance of sedge marshes in hydrarch successions in northeast Greenland, in which were included communities of *Juncus-Carex, Carex* and *Eriophorum.* Apparently similar to the *Carex rariflora* community at Kotzebue, were the "Extensive areas of saturated soil between the pools, —covered with a turf-like mat of *Carex rariflora*" (p. 255). Seidenfaden and Sørensen (1937) stated that their ecosystem "water-soaked ground-swamps" occurs in all the climatic zones and on all kinds of soil in the area included in their study in northeast Greenland. Many species are the same as in northwestern Alaska. Among the species listed in salt marshes in another ecosystem is *Carex subspathacea.* Nordhagen (1943) proposed a classification of marshes, bogs, and willow thickets with grass-marsh or bog vegetation ("myr"), under two orders in the class "Eriophoretae," with 5 alliances and 18 associations. The first order, "eutrophic-mesotrophic grass marshes (Caricetalia goodenowii)," cor-

responding to the "Wiessenmoore" or the "Flachmoore" of central Europe, comprises 3 alliances: 1) Caricion atrofuscae-saxatilis on lime-rich ground in mountains and subarctic regions, 2) Schoenion-ferrugini on lime-rich ground in lower regions, and 3) Caricion canescentis-goodenowii, broadly tolerant in soil needs, in all regions up to the midalpine. Most of the Alaskan sedge marshes studied would probably fit best in his third alliance. Nordhagen's second order, the "meso-oligotrophuc grass marshes (Scheuchzerietalia)," corresponds in part to the "Zwischenmoore" of central Europe, and the rest to the oligotrophic-acidiphilous *Sphagnum-rich* grass-marsh or bog of the marsh complex termed "hogmossar' in Sweden, together with related types. This order has two alliances: 4) Stygio-Caricion limosae on wet ground, mid-acidiphilous, meso-oligitrophic, from lowlands to highlands, and, 5) Leuko-Scheuchzerion, the most oligotrophic-acidiphilous of these five alliances, with a ground layer usually of *Sphagnum,* usually occurring below subalpine and subarctic regions. The first three of these alliances are supplied with infiltration water, ground water or from streams, occurring in depressions with a permanently high ground-water level (varying in depth with precipitation and melting time of snow).

18. *Sedge-Sphagnum-moss bog*

This type is characterized largely by the abundant growth of *Sphagnum,* often several inches thick, usually with intermixed mosses, forming the ground layer. Sedges, cottongrass, dwarf shrubs especially heaths, and a few grasses and forbs grow to a height of about 15 inches on the cushiony substratum. In the eastern part of the region under study, small black spruces (*Picea mariana* (Mill.) B. S. P.) are also found. Lichens are usually sparse. This type is widespread, found usually as small stands in depressions, and can ordinarily be recognized from the air by the bright yellowish green or orange color of *Sphagnum* and mosses, beneath the pale green of the sedges.

The most abundant species in a well developed stand occupying a depression which appeared to have been a pond, on the north side of Salmon Lake, about 30 miles north of Nome, were *Carex* spp., *Sphagnum* spp., and *Rubus chamaemorus.* Fairly numerous were *Eriophorum* sp., *Betula nana exilis, Vaccinium vitis-idaea,* and *Ledum decumbens.* The following were infrequent to scarce; *Vaccinium uliginosum, Empetrum nigrum, Oxycoccus microcarpus,* mosses, lichens especially *Cetraria islandica,* and *Salix* sp.

Sedge-*Sphagnum*-moss bogs, with more or less dwarf shrubs, are widely distributed in the northern hemisphere (Hanson 1951: 367). Dachnowski-Stokes (1941) described the vegetation, and especially the profiles of many bogs in Alaska. When sedges are dominant many of the Alaskan stands can probably be classified under Nordhagen's 5th alliance, Leuko-Scheuchzerion, in the meso-oligotrophic grass-marsh order (see discussion under type number 17).

19. *Grassland types*

The most common grassland type is the bluejoint community (*Calamagrostis canadensis*). It occurs in various sites such as mounds and hummocks in fresh water sedge marshes, on fairly well drained knolls and slopes, on disturbed ground around buildings, mines, roadsides, corrals, in places where the snow lies late, etc. The perennial frost is usually near the surface. From the air, this type appears pale yellow to yellowish green due to the old foliage forming a loose mat on the ground until the new foliage becomes tall enough to give it a pale green color. Later in the season it appears pale purple because of the flowers. Descriptions of specific stands were published by Hanson (1951: 349).

Tall fescue (*Festuca altaica*) stands were seen occasionally occupying small areas on steep south-facing slopes along creeks. Dense stands resembled some-

what the preceding in appearance, but open stands were more tufted, and contained more dwarf heath shrub and lichens. The deep soil is rich in organic matter. A more detailed description was given by the writer in a previous paper (1951: 353).

Mixtures of bluejoint and tall fescue with sedges, dwarf shrubs, and with *Arctagrostis latifolia* (R. Br.) Griseb. were found on banks of streams, in valley bottoms, and between willow thickets on slopes, but usually the areas occupied were small. One stand of this kind, located about 10 miles northeast of Nome on a gentle east-facing slope, was studied in detail. The willows surrounding it were 2.5 to 4 feet tall. Abundant species were *Carex* sp., *Solidago virgaurea* L., *Salix reticulata,* mosses, and *Arctagrostis latifolia.* Moderately abundant were *Potentilla fruticosa, Vaccinium uliginosum,* and *Festuca altaica.* The following were infrequent to scarce: *Cerastium beeringianum* C. & S., *Petasites frigidus, Mertensia paniculata, Arctostaphylos alpina, Empetrum nigrum, Botrychium lunaria* (L.) Sw., *Vaccinium vitis-idaea, Alopecurus alpinus* L., and lichens on some of the hummocks. On the surface was an inch-layer of moss, liverworts, and litter. The soil in the first 4.5 inches below the litter was dark reddish brown, mostly organic matter but with a little silt, moist, with very many roots and rhizomes. Between 4.5 and 12.5 inches was brown silt, with occasional pockets of reddish brown silt rich in organic matter, wet, with numerous roots. Between 12.5 and 22.5 inches was olive gray to yellow brown silt with schistose rocks and gravel, wet, rather impervious to water, compact, the rocks becoming more numerous with depth. The roots decreased rapidly in number in this horizon, working depth was at 20 inches.

Other grass species such as bluegrasses and alpine holy grass (*Hierochloe alpina*), in association with sedges and many species of forbs form extensive communities of higher elevations and in late snow-melting sites. Along sandy and gravelly beaches, above the reach of ordinary high tides, and along some streams, is found the distinctive beach rye type (*Elymus mollis* Trin.) growing to about 5 feet in height. This type is widespread in Alaska and other northern lands (Hanson 1951). Associated with this coarse grass is usually the beach pea (*Lathyrus maritimus* (L.) Bigel.), *Poa eminens* Presl., and a few other forbs. First invaders on these shores are the mat-like sea lungwort (*Mertensia maritima* (L.) G. Don.) and sea-beach sandwort (*Arenaria peploides* L.). On the landward side in more stabilized soil, *Festuca rubra* L. with *Poa* sp., and a variety of forbs often forms a meadow-like community. Lichens are absent from these beach types. The beach rye type is conspicuous from the air, appearing pale bluish in color. It is important in binding sand and gravel, offering much resistance to erosion by waves and wind. Porsild (1951) included similar vegetation in "sand dunes and gravel beaches" in "strand communities group."

20. *Aquatic types* (*Fig. 4*)

In shallow parts of fresh-water ponds and in the bordering wet soil of ponds and streams occur species such as *Ranunculus pallasii* Schlecht., *R. aquatilis* L., *Hippuris vulgaris* L., *Potamogeton* spp., *Callitriche* sp., *Equisetum fluviatile* L., *Carex aquatilis,* and others. In brackish water *C. subspathacea* and *Hippuris* sp. also occur. Porsild (1951) separated his group "vegetation of fresh waters" into a) "ponds and lakes," and b) "brooks and rivers."

21. *Lichen-moss barrens* (*Figs. 5, 7*)

The alpine *Dryas* type persists in many favorable areas at higher elevations in the mountains, but as the soil becomes thinner and other environmental conditions less suitable, the vegetation becomes reduced to mostly crustose and foliose lichens, mosses, and very short herbs and dwarf shrubs in depressions and in other

protected spots, and finally the rocks become almost bare. Porsild (1951) included this type in his "rock desert" community.

22. *Ruderal types*

These weed or weed-like types occur on ground that has been more or less disturbed, as in and adjacent to towns, around mining and fishing camps, corrals, etc. *Calamagrostis canadensis* is one of the most common indicators of disturbance, but a number of annual and perennial weeds also occur such as *Epilobium angustifolium, Artemisia* spp., *et al.* This type is considered to form a group, distinct from the grassland types, because forbs often dominate.

Summary and Conclusions

1. As a result of study during the summers of 1949, 1950, and 1951, a preliminary classification of the vegetation of northwestern Alaska is presented. It contains 6 major physiognomic classes and 22 types.

2. A characterization is given of each type, including the species composition, some of the environmental conditions, and aerial recognition characteristics.

3. Eight new phytosociological analyses of different communities are presented in tables.

4. The types occupying the largest land areas are the cottongrass-sedge-dwarf shrub-heath complex, sedge marshes, alpine *Dryas,* dwarf shrub, willow shrub, birch shrub, and white spruce-shrubs.

5. Important factors influencing the development and the maintenance or changes in the species composition within types are soil moisture, mineral and organic composition of the soil, soil texture, soil reaction, depth to which the soil thaws during the summer, freezing and thawing processes in the soil (congeliturbation), drainage conditions, depth and duration of snow cover, exposure to wind, biotic influences such as grazing and trampling by reindeer and other animals, rodent activities, plant competition, and various man-caused influences such as burning, drainage, flooding, earth-moving, etc.

6. Similarities of the Alaskan communities to those in other arctic and subarctic regions, especially Scandinavia, are pointed out.

7. Suitable conditions for good growth of lichens, furnishing winter pasturage for reindeer, occur in many of these type, particularly in open forest types, open stands of the birch shrub type, the dwarf birch-heath-lichens type, the blueberry-heath-lichens type, and the cottongrass-sedge-dwarf shrub heath complex. The lichens have, however, been depleted over large areas by overgrazing and fire.

8. This classification has been found useful in making aerial surveys of lichen range suitable for grazing during the winter by reindeer. The various types are valuable in indicating soil conditions such as depth to perennial frost, kind of surface and subsurface materials, and moisture and drainage conditions. As a result, the classification is of value when surveys are made for locating roadways, camp sites, landing fields, etc.

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