AN ABSTRACT OF THE THESIS OF

ALCETTA GILBERT CAMPBELL for the MASTER OF SCIENCE
(Name) (Degree)

in BOTANY presented on 22 February 1973
(Major) (Date)

Title: VEGETATIVE ECOLOGY OF HUNTS COVE, MT. JEFFERSON, OREGON

Abstract approved: Redacted for Privacy
Dr. W. W. Chilcote

The vegetative communities in the subalpine meadows of Hunts Cove, Mt. Jefferson, and some of the major environmental factors affecting them were studied in the summer of 1971. Hunts Cove is in the subalpine *Tsuga mertensiana* parkland of the Central Oregon High Cascades. Habitats within the Cove vary considerably: elevation changes from 1500 m to 1900 m; water regime ranges from bogs and seeps to desert; snowlie varies as much as two months at different points in the same year.

Estimates of vegetative cover and frequency were taken on 300 quadrats. Snowlie was monitored on a weekly basis. Soils were collected and analyzed.

Eleven meadow communities were distinguished. They are:
A. The short sedge communities, 1) *Carex nigricans*-*Aster* and 2) *Carex nigricans*-*Polytrichum* on late snowfree, poorly drained sites;

B. Bryophyte, on very late snowfree, damp, shaded soil; C. Heath communities on well drained sites, 1) Phyllodoce-Cassiope on exposed late snowfree slopes, 2) Vaccinium deliciosum on moderately late snowfree slopes and 3) Potentilla-Carex nigricans on very late snowfree sites with rodent activity; D. Senecio lush herb on mesic warm sites; E. Hydric communities, 1) Eleocharis-Aulacomnium occurring in stagnant water, 2) Carex rostrata-Sphagnum in freely moving water, 3) Carex scopulorum in seeps and bogs with permanent water supply, probably an edaphic climax, and 4) Carex sitchensis in swamps flooded during meltoff.

These communities were arrayed in a floristic ordination and the position of all hydric, lush herb, and short sedge sample plots was found to parallel snowfree dates. Well drained heath communities became snowfree in the order expected from other studies.

Comparison of the communities with other studies from the Northwest suggests Phyllodoce-Cassiope, Vaccinium deliciosum and the Carex nigricans communities to be parts of a consistent vegetative pattern extending north into Southern B. C.

Vegetative Ecology of Hunts Cove, Mt. Jefferson, Oregon

by

Alcetta Gilbert Campbell

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1973

APPROVED:

Redacted for Privacy

Professor of Botany

in charge of major

Redacted for Privacy

Head of Department of Botany and Plant Pathology

Redacted for Privacy

Dean of Graduate School

Date thesis is presented 22 February 1973

Typed by Clover Redfern for Alcetta Gilbert Campbell

ACKNOWLEDGMENTS

I wish to thank Dr. William Chilcote for his continued interest and encouragement and Dr. William Denison for his advice and editing. Special thanks go to Kelly and Randy who walked and waited. This work was supported in its entirety by grants from the Husband Foundation.

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VEGETATIVE ECOLOGY OF HUNTS COVE, MT. JEFFERSON, OREGON

I. INTRODUCTION

Subalpine meadow vegetation and environment have been studied for mountain systems here and in Europe. In the Pacific Northwest a number of subalpine communities have been described in detail and their relation to gradients in soils, water regime and date of meltoff documented: Brooke (1970) in British Columbia; Douglas (1970) in Washington North Cascades; Kuramoto and Bliss (1970) in the Olympics; to the south, Van Vectin (1960) in the Three Sisters and Hickman (1968) in the West Cascades have studied similar vegetation.

It is to be expected that communities of similar structure and species content will be found in other subalpine localities in the same region. Probably similar community-environment relations occur throughout the subalpine areas of the northwest.

This study is concerned with the subalpine meadows of Hunts Cove on Mt. Jefferson in the High Cascades of Oregon. The objectives of the study are:

1. To describe the vegetative composition of the meadows in Hunts Cove,
2. To relate the communities to:
   a. Snowlie and meltoff

b. Water regime

c. Soils

3. To compare Hunts Cove communities with others reported in the literature.

Subalpine meadows are of scientific interest because of severe environment vegetation gradients and of general interest because of their beauty. In recent years recreation pressure on limited meadow areas has become extreme. Statistical information relating human impact to vegetative changes is almost non-existent. The present study is a preliminary to a more comprehensive study which will:

1. Describe and classify the subalpine communities of Mt. Jefferson Wilderness Area.

2. Develope a statistical model of human impact on the communities.

II. DESCRIPTION OF THE AREA

Hunts Cove was selected as a study area because of its varied environment as well as its vegetation. Within a small area there is an elevation change of 400 m; water supply changes from bog to semi-desert; snow duration may vary by two months. A description of the chief features follows.

Physical Features

Hunts Cove is located on the south shoulder of Mt. Jefferson, Oregon High Cascades (Figure 1). It is immediately west of the Cascade crest and below Cathedral Rocks, which are the Cascade divide at this point. It is the principle source of Hunts Creek which drains into Pamelia Lake and is part of the North Santiam River System.

The Cove is approximately two km long by one km wide. It is surrounded on the north, east and south by bluffs, plugs, ridges and talus slopes which rise 150 m to 300 m above the Cove floor. The Cove itself slopes from 1900 m at the high east end to 1500 m at the west end. This drop is not smooth, but is broken in a series of steep to moderate slopes and small flats. The relatively flat areas range up to four ha. Two of them contain lakes, Hunts Lake and Hanks Lake. Examination of stream cuts reveals that the flats are formed up hill

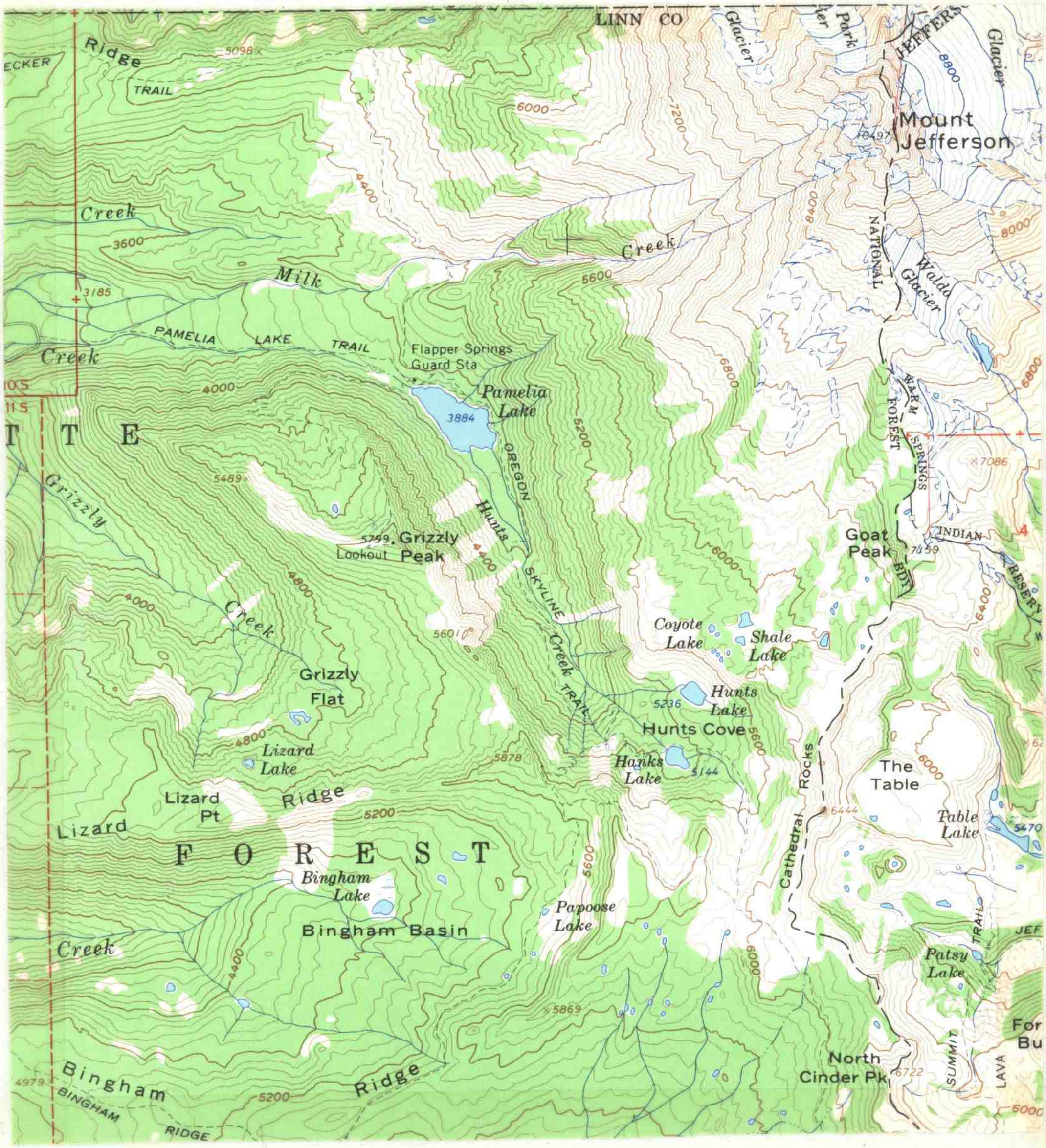


Figure 1. U.S. Geological survey map, Mt. Jefferson, Oregon. N4430-W12145/15. Scale 1:62500.

from igneous rock barriers which impede both drainage and erosion. A number of seeps, bogs and swamps are also formed. The topography is diagrammed in Figure 2.

Forest Vegetation

Hunts Cove is in the subalpine zone in a topographic climax where meadows replace forest (Figure 3). The surrounding forest at the lower elevations is mixed Abies amabilis and Tsuga mertensiana, and probably falls within the Abies amabilis - Tsuga mertensiana/ Vaccinium membranaceum Association of Franklin (1966). At upper elevations Tsuga mertensiana is the clear dominate and forest cover exists only on the warmest dryest sites.

Count of annual growth rings on a mature Abies amabalis shows it to be at least 350 years old. Since A. amabilis is a tree found in late stages of succession, it is reasonable to believe that fire history has had little effect on present meadow distribution.

Geology

Although there has been no geologic description of the Cove, Thayer (1939) proposes the general formation of the Jefferson Area. Outerson Basalts of pre-Plieocene eras underlay Minto Lavas which are occasionally exposed and probably form the rocky shelves of Hunts Cove (Voth, 1963). These lavas were part of a large flow which

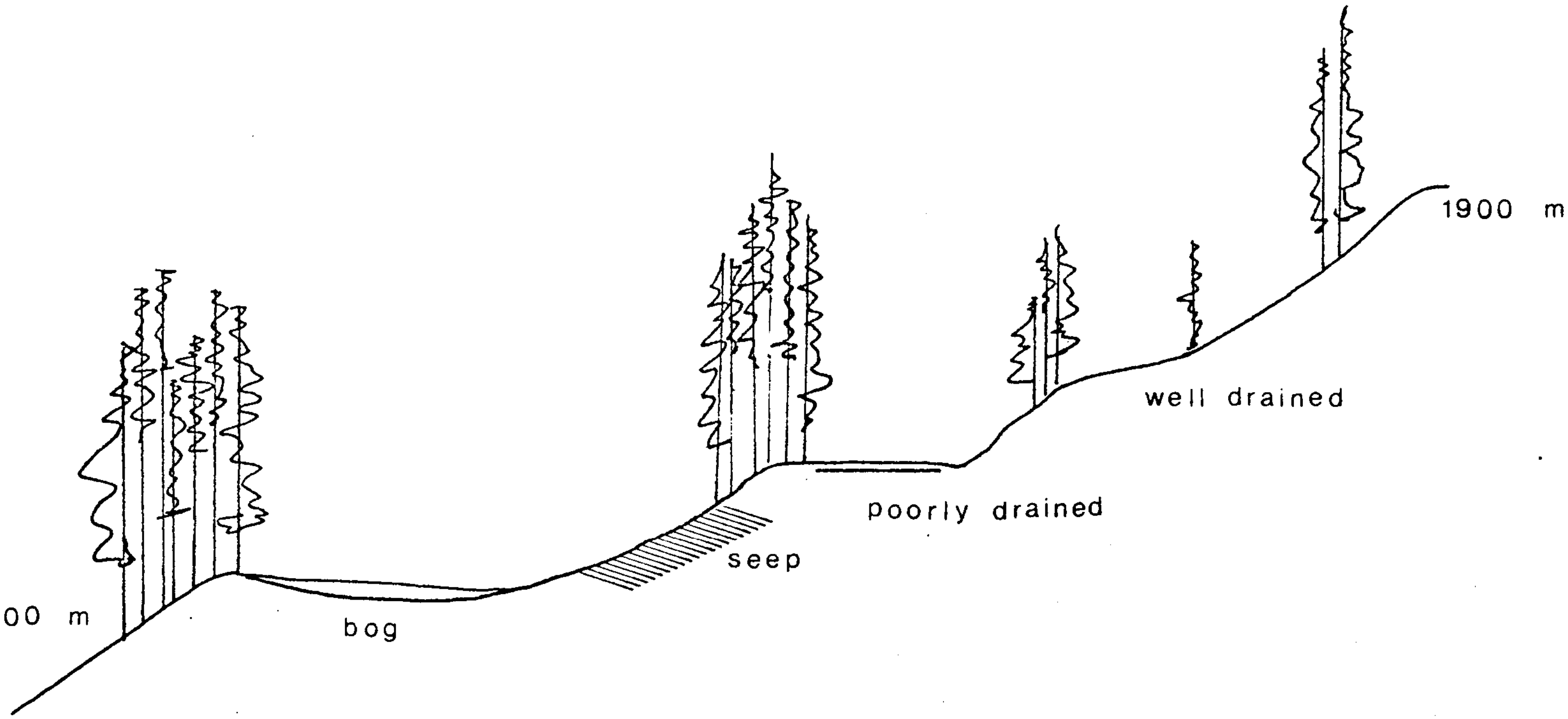


Figure 2. Diagrammatic representation of topography of Hunts Cove.

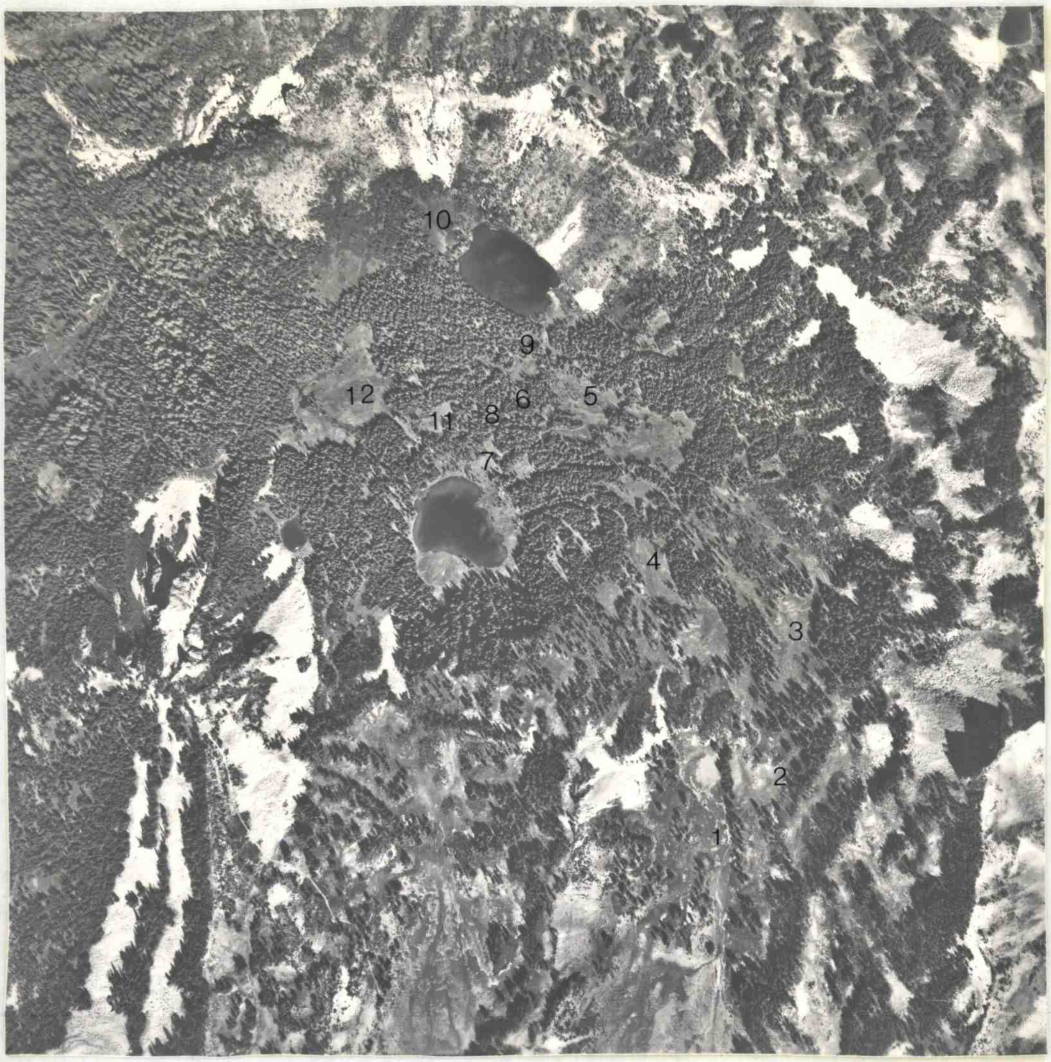


Figure 3. U.S. Forest Service air photo ESF 33-177, 8-25-67. Scale 1:15,840.

Key to location of sample plots:

1. Phyllodoce-Cassiope
2. Potentilla-Carex nigricans
3. C. nigricans-Polytrichum
4. Vaccinium deliciosum 2
5. C. scopulorum 4
6. C. nigricans-Aster
7. C. scopulorum 3
8. Senecio
9. Vaccinium deliciosum 1
10. C. rostrata-Sphagnum
    Eleocharis-Aulacomnium
    C. scopulorum 1
11. C. scopulorum 2
12. C. sitchensis

extended from Park Butte to Minto Mtn. The Minto lavas were deeply eroded before the Ollallie Basalts which compose the bulk of the present Mt. Jefferson were laid down, in the Pleistocene. Severe erosion again occurred before the most recent High Cascade Lavas were deposited, forming the uppermost crust of Mt. Jefferson and most of the pinnacles and plugs around Hunts Cove. The greatest percentage of this last formation has since been eroded. The final form of Hunts Cove is glacial, carved U shaped and steep sided, but without a classic cirque or morains.

Although many of the flows are termed 'basalt', in the Mt. Jefferson area, they tend to be olivine bearing andesites. Small, very recent cinder cones, some as young as 600 years, are common to this section of the High Cascades (Baldwin, 1964). They have laid down a mantle of loose scoria which still covers the moderate slopes and is many feet deep in depressions and on flats. This material is so recent that little soil formation has begun over much of the area.

Soils

Soils divide roughly into three groups: the organic soils of the bogs; spodsolic soils formed on scoria and ash of the typical subalpine communities; and soils under the *C. nigricans* communities which are commonly a combination of sedge peat, and alluvium.

In the upper part of the Cove, meadow soils are formed on a recent deposit of sandy scoria laid down over rocky ridges and talus slopes. Subsequent erosion has exposed the ridge tops which are now largely tree covered. On steep slopes erosion continues and soils are largely undeveloped. Where slopes are more moderate, the soil has stabilized and some humus has accumulated. Heavy precipitation, good drainage, healthy vegetation, and acid conditions have combined to form podzolic soils. These have thin to thick organic horizons depending upon vigor of vegetative growth and freedom from erosion.

At the foot of slopes considerable loess, alluvium, and snow-creep debris are deposited sometimes in the traditional fan shape. Frequently however, the bottom is a bowl with poor drainage which is flooded during snow melt. In this case a sedge peat with considerable amounts of alluvium builds up a flat bottom to the bowl.

At many points in the Cove, scoria and other mineral parent material is completely masked by organic deposits. Soils here are muck, moss peat, or sedge peat, depending primarily upon water movement and vegetation. Seeps, in which water rises all year, may be as large as one hectare. These soils are typically soft black muck, heavily root-filled. Flat bottoms which are always saturated and support a tall sedge community have sedge peat in which the soil is layered, root-filled, and fibrous. Areas adjacent to still water and those with water moving through them may have moss peat soil, but the mosses are different species. Moss peat is a spongy, water-filled mass which has almost no support except penetrating roots.

The division between organic soils and mineral soils is precisely the same as the division between typical and hydric communities, but the causative factors are those which control the formation of both, the presence or absence of permanent water supplies.

Weather

No accurate weather data are available from the Cove itself, but Santiam Pass and Crater Lake U.S. Weather stations provide information useful as estimates of temperature and precipitation. The station closest is Santiam Pass, 300 m lower than the Cove. This station is new (9 years) and does not contribute snow depth data. General patterns may be discerned however. Total yearly pptn. at Santiam Pass, 1964 through 1971, averages 229 cm and ranges from 181 cm to 280 cm. Of this yearly rainfall, only 11% fell during July and August, the months when the Cove is both warm and snowfree.

Night temperatures may drop below freezing at any time of the year. Of the nine years for which data are available at Santiam Pass, only three years had a full month with no frost of zero degrees centigrade. The average time between "agricultural killing frosts" of -2 degrees centigrade is 100 days. Temperatures during the winter months have little effect on meadow vegetation because of the extreme depth of snowpack. There is little evidence of frost heave. In October the soil was above freezing under two feet of powder snow.

Snowlie

The Cove has exceptionally heavy deposits of snow. The U shape of the Cove and its east-west orientation combine to catch snow and shield it from sun and warm winds. The result is a deep, persistent snowpack. Crater Lake weather station at an elevation of 1975 m, 150m higher than the Cove, reports snowfree dates roughly corresponding to those in the Cove. The average (23 years) end of snow pack at Crater Lake is June 22 and the average date of first permanent snow is October 31. There are only 130 days between these two dates.

The shortest summer on record at Crater Lake is 1971 with 81 days snowfree. The longest is 1967 when 154 days were snowfree. Within the Cove there is as much as two months difference between the date when the first meadow community is snowfree and the disappearance of snow from the last community.

III. METHODS

Vegetation Methods

During the summer of 1970 I surveyed the Cove, took cover estimates on several hundred quadrats and became familiar with the flora. On the basis of this survey I chose 15 stands to sample. Stands were chosen either because they represented a homogenous example of a regularly reoccurring community, or because they were strikingly different from the rest of the vegetation. In each stand selected, a macroplot 20 ft by 40 ft (6.1 m by 12.2 m) was laid out. This macroplot was subdivided into 100 possible 2 ft by 4 ft (6.1 cm by 12.2 m) addresses. From each macroplot 20 addresses were selected in stratified random design, two addresses per column (Cochran, 1963). An ocular sighting frame one-half meter by one-half meter was placed on the upper left hand corner of each address. The plot covered by the frame is hereafter called a quadrat.

Cover estimates were made by sighting on 49 points in each quadrat. In addition, all species occurring in the quadrat were recorded. A one-half meter by one-half meter quadrat is small, but reasonably standard (Gjaerevoll, 1950; Kuramoto and Bliss, 1970). Frequency value for a species is the number of quadrats (within the macroplot) in which that species appears. Cover and frequency values were each converted to percent then added together to form an

"Importance Value" for each species in each macroplot after the method of Kuramoto and Bliss (1970). Frequency values are included in the importance values to give added weight both to those species which are small but consistent such as Epilobium alpinum, and to those species which occur as ground cover but are not sighted because of an intervening vegetation layer.

To confirm homogeneity within a macroplot, cover samples composed of adjacent columns (4 quadrats; one square meter) were tested by chi-square (Grieg-Smith, 1964) against the cover values of the whole plot. In two cases the column at the edge of the plot had greater than 5 percent probability of coming from a different population. These columns were discarded. Inter-plot similarity coefficients (Bray and Curtis, 1957) were computed for all possible combinations of macroplots. A visual ordination based on community similarities was then constructed (Dick-Peddie and Moir, 1970) (see Appendix I).

C.L. Hitchcock et al., Vascular Plants of the Pacific North West was used to identify vascular plants. Most were confirmed by Mrs. La Rea Johnston. Sedges were identified with the help of Dr. C.L. Hitchcock, Bryophytes with the help of Dr. W.B. Schofield and Dr. Martha Springer.

Snowlie Methods

Snowlie patterns for all meadows were mapped on a weekly basis in 1972. Photographic reconnaissance documented all snowlie patterns. The first and last dates on which community types appeared were recorded.

The date each macroplot became snowfree was noted. A ranking relating that date to floristic ordination of the macroplots was constructed.

Soil Methods

Soil samples were collected at 0-15 cm and 15-30 cm from each of 13 meadow plots. These were returned to the lab and air dried at room temperature under forced air draft. pH was determined in the lab in a saturated paste solution using a Beckman pH meter. Cation exchange capacity was measured by the ammonium acetate method. Ca and Mg were extracted with ammonium acetate and determined by excited atoms. Soil organic matter was determined by the Walkley-Black method. Phosphorus was determined by the acid fluoride and bicarbonate methods. Total nitrogen was analyzed by Macro-Kjeldahl. Color is by comparison with the Munsell color charts on dry soil (Roberts *et al.*, 1971).

Undisturbed cores were taken from the upper 15 cm at 11 of the plots for moisture relations and bulk density determinations. Soil moisture tension was determined at the Forest Service Corvallis Research Laboratory using pressure and ceramic plates. Particle size was not determined. Personal experience has shown that high organic content coupled with the extreme fragility of the scoria make it impractical.

Soil samples were brought to the lab at weekly intervals and moisture content determined by drying at 105°C.

IV. RESULTS

Vegetation Results

Eleven community types were found in the Cove. To order them for purposes of this description, they are divided into "typical" subalpine community types and "atypical" or hydric types.

Typical subalpine communities are grouped this way:

Short sedge

Carex nigricans-Polytrichum

Carex nigricans-Aster

Bryophyte

Alpine bryophyte

Heath

Phyllodoce-Cassiope

Vaccinium deliciosum

Potentilla-C. nigricans

Lush meadow

Senecio

Atypical communities are:

Hydric

Carex rostrata-Sphagnum

Eleocharis-Aulacomnium

Hydric (continued)

Carex scopulorum

Carex sitchensis

In the following description it will be easier to distinguish types if they are first ordered by degree of similarity. To do this a floristic ordination (Figure 4) was constructed using as floristic characters the cover and frequency data for macroplots. The ordination is based on "most dissimilar" macroplots (Dick-Peddie and Moir, 1970), where the four poles are arbitrarily those macroplots with least total similarity to all other macroplots. Communities were found to fall in the groups listed above. Note also the role of environmental factors in community formation. All macroplots on the right are from communities which are never dry, while all plots to the left are from communities which probably have some water stress at least part of the year. The vertical spread corresponds to snowfree growing season for all but the heath communities. This general topic will be covered after communities are described.

Typical Subalpine Communities

The subalpine parklands of Hunts Cove contain a large number of community types within a small area. A comparison of the typical subalpine communities by species content is in Table 1. Descriptions of the individual communities follow.

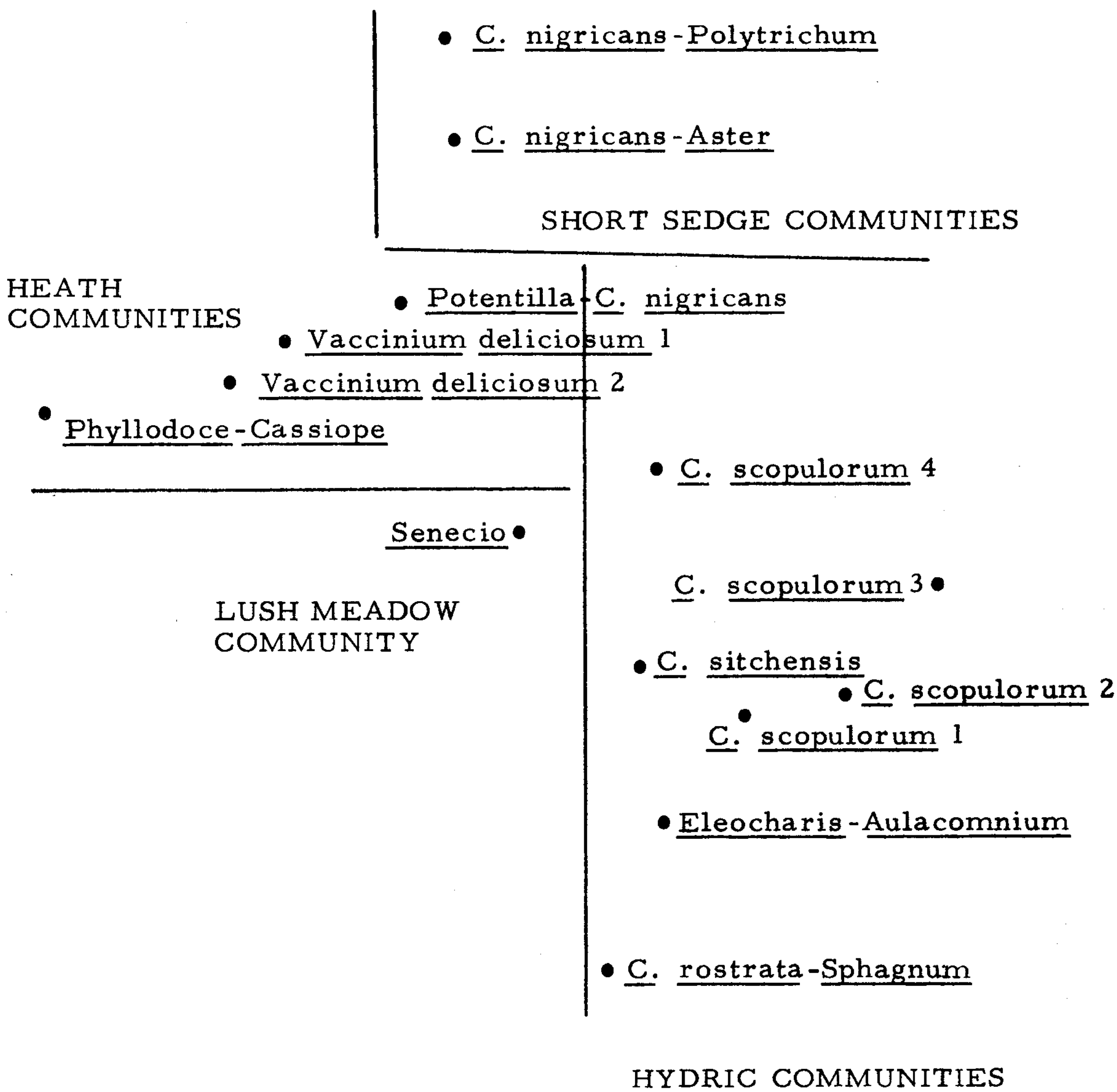


Figure 4. Floristic ordination relating similar macroplots. The hydric communities to the lower right are on sites which are never dry. Heath communities occupy well drained habitats while short sedge vegetation occupies poorly drained sites. The vertical axis is early snowfree below: late above, except for heath communities.

Table 1. Comparison of typical subalpine community types by importance value. Only importance values greater than 5 are included.

Species	Community					
	C. nigricans - *Polytrichum*	*C. nigricans* - *Aster*	*Potentilla* - *C. nigricans*	*V. deliciosum*	*Phyllodoce* - *Cassiope*	*Senecio*
Carex nigricans	111	52	30	8	8	
Ligusticum grayi	34	40	16	30	11	
Potentilla flabellifolia	8	21	47	10		16
Polytrichum norvegicum	46					
Aster alpigenus		23				
Agrostis thurberiana		7				
Hieracium gracile			12			
Castilleja oreopola			11			
Vaccinium deliciosum				55	8	
Phyllodoce empetriformis				27	54	
Luetkea pectinata				10	15	
Polytrichum juniperinum				10		6
Tsuga mertensiana				10		
Cassiope mertensiana					46	
Lycopodium sitchense					10	
Senecio triangularis						64
Aster occidentalis						14
Viola glabella						11
Carex spectabilis						10
Castilleja suksdorfii						7
Dodecatheon jeffreyi						6
Epilobium alpinum						6
Lupinus latifolius						5

A. Short Sedge. Carex nigricans meadows are a wide-spread component of alpine and subalpine vegetation in western North America. In the Cove I have divided them into two types: C. nigricans-Aster and C. nigricans-Polytrichum. The relation between these types is a clinical response to show free growing season.

Both typically occupy poorly drained bottoms where alluvium accumulates with poorly decomposed sedge and moss peat to form almost flat-bottomed basins. The soil is deep, root filled and high in organic matter. Although these locations may dry out to the wilting point in summer, they probably do so only for short periods.

1) C. nigricans-Polytrichum Communities: Poorly drained basins with very late snow lie may support stands of almost pure C. nigricans. Slopes are usually negligible. In the Cove they are found at elevations from 1600 m up, (Table 2).

Such a location supports only three vascular plants, Potentilla flabellifolia, C. nigricans and Ligusticum grayi. There are many places where only the sedge survives. The moss Polytrichum norvegicum is a consistent associate but composes almost none of the cover when viewed from above. Average height of the vegetation is 10 cm or less. The general impression is of a long shag carpet.

The C. nigricans-Polytrichum community is most closely related to C. nigricans-Aster. The similarity index is .56.

Table 2. Species and habitat of *Carex nigricans*-*Polytrichum* communities.

Habitat	Macroplot	Range within the Cove
Elevation	1600 m	1600-1800 m
Slope	None	0%-10%
Land form	Flat	Concave basin, flat bottom
Snowfree time	Late	Late - very late
Drainage	Poor	Poor - seasonally flooded

Species	% Cover	Frequency 20 Quadrats
Carex nigricans	71	20
Ligusticum grayi	18	8
Potentilla flabellifolia	4	2
Polytrichum norvegicum	6	20

2) Carex nigricans-Aster Communities: Poorly drained, moderately late snowfree flats are typically dominated by a dense low mat of Carex nigricans; with Aster alpigenus, Potentilla flabellifolia, and Ligusticum grayi, important co-dominants. In the Cove, elevations range from 1600 m to 1700 m. Slope is little or none. Frequently the community is found in a basin with shallow flooding in spring during meltoff, but with no further water supply.

Short growing season and poor drainage restrict the vascular components of this type. There are only eight vascular species found in the C. nigricans-Aster plots (Table 3), but the number of bryophytes is large: six were identified. Carex nigricans is the only sedge found in quantity, but Carex scopulorum occurs regularly where saturated conditions continue throughout the summer. Grasses, Agrostis thurberiana and Deschampsia atropurpurea are present in small quantities. Total vegetative cover is normally 100 percent.

The C. nigricans-Aster community is floristically between C. nigricans-Polytrichum and Potentilla-C. nigricans. Similarity index values are .56 with C. nigricans-Polytrichum and .35 with Potentilla-C. nigricans.

B. Alpine Bryophyte. The bryophyte community is limited to very small areas in the Cove, none of which is large enough to sample with 20 quadrats. Cover estimates were made directly on entire stands and are not comparable to the sampling of any other community.

Table 3. Species and habitat of Carex nigricans-Aster communities.

Habitat	Macroplot	Range within the Cove
Elevation	1600 m	1590-1725 m
Slope	None	0%-5%
Land form	Flat	Concave basin flat - bottoms
Snowfree time	Mid-season	Midseason - late
Drainage	Poor	Poor - seasonally flooded

Species	% Cover	Frequency 20 Quadrats
Carex nigricans	40	20
Ligusticum grayi	28	20
Potentilla flabellifolia	14	12
Aster alpigenus	11	20
Agrostis thurberiana	2	7
Luetkea pectinata	1	1
Carex scopulorum	+	2
Deschampsia atropurpurea	+	3
Polytrichum commutata	2	20
Aulacomnium palustre	+	20
Amblystegium trichopodium	+	20
Bryum sp.	+	20
Amblystegium serpens	+	20
Cephalozia bicuspidata	+	+
Litter	1	2

Therefore this community does not appear in the ordination.

Extremely late snowlie, chiefly in shady spots where deep drifts have formed, is the main feature of the habitat. There is no running water, but the soil appears to remain damp, at least partly from snow melt, all season. Snowfree time probably averages two months or less. It was less than six weeks in 1971 and about six weeks in 1972.

Elevations range from 1600 to 1725 m within the Cove. There is no slope.

Complete lack of vascular plants characterizes these stands. Only six bryophytes were identified (Table 4). Four are mosses; two hepatics. All are found on soil at high altitudes.

Table 4. Species and habitat of alpine bryophyte community.

Habitat	
Elevation	1600-1725 m
Slope	None
Landform	Flat
Snowlie	Very late
Drainage	Poor

Species	Percent Cover
Polytrichum norvegicum	6
Bryum alpinum	60
Pohlia ludwigii	20
Dicranella heteromalla	< 1
Moerchia blyttii	4
Barbilophozia lycopodioides	10

C. Phyllodoce-Cassiope Communities. This widespread community is represented here by a sparse, barren-looking heath. It occupies exposed, late snowfree slopes near 1730 m in subalpine parkland.

Phyllodoce empetriformis is the clear dominant. Cassiope mertensiana, an important alpine species, appears here in quantity. Marsupella brevissima and Polytrichum piliferum are common. Vaccinium deliciosum is absent or unimportant.

There are only 15 species found in these plots (Table 5). The bryophyte layer is extensive, but poorly developed. Marsupella brevissima and Polytrichum piliferum are common bryophytes of exposed and eroded soils, but they average only one-half cm thick here. Bare earth is exposed over nine percent of the area and there is almost no litter.

Erosion is evident from both wind and snow creep. The soil is poorly developed. A thin, dark layer with relatively high organic content is the only indication of development. After snow melt there is no water source and the coarse character of the soil promotes drainage. At the surface the soil dries quickly.

Tsuga mertensiana is invading, but 38 year old trees are less than one-half meter tall.

D. Vaccinium deliciosum Communities. This low shrubby heath is found on moderately late to late snowfree slopes. Vaccinium

Table 5. Habitat and species list for Phyllodoce-Cassiope communities.

Habitat	Macroplot	Range within the Cove
Elevation	1730 m	1700-1800 m
Slope	5%	5%-45%
Exposure	North, open	North and West
Land form	Slope	Slope
Snowfree	Late	Late
Drainage	Good	Good

Species	% Cover	Frequency 20 Quadrats
Phyllodoce empetriformis	39	20
Cassiope mertensiana	34	16
Luetkea pectinata	3	16
Ligusticum grayi	1	14
Lycopodium sitchense	3	9
Vaccinium deliciosum	2	8
Carex sp.	1	9
Tsuga mertensiana	1	1
Juncus drummondii	+	1
Hieracium gracile	+	2
Microseris alpestris	+	5
Castilleja oreopola	+	3
Marsupella brevissima	5	10
Polytrichum piliferum	1	4
Rhacomitrium canescens	1	1
Bare soil	9	11

deliciosum dominates with Phyllodoce empetriformis and Polytrichum juniperinum. Ligusticum grayi a wide spread species is common. Twenty species were found in these plots (Table 6); 43% were forbs. The bryophyte layer is poor and much bare earth and litter are visible.

The soil is well drained and receives little or no water after meltoff. There is a thin to thick, dark, decomposed organic layer on the surface. Gravel content is the highest of any soil in the Cove, one part in three in the 15 to 30 cm sample from the poorest site. There is evidence of podzolization (see soils, Appendix I).

Typically Vaccinium heath occupies a band along the abrupt edge of the mature Tsuga mertensiana forest. Invasion by Tsuga mertensiana and Abies lasiocarpa is common. Most trees were established around 1934.

Vaccinium heath is closely related to Phyllodoce-Cassiope communities, differing chiefly in its lack of C. mertensiana and in the proportions of the major components. The V. deliciosum community has a greater abundance of forbs. The similarity index between the two is .34.

E. Potentilla-Carex nigricans Communities. This community occurs on late snowfree sites with good drainage. Often the community is restricted to a narrow band below Phyllodoce-Cassiope communities and above one of the C. nigricans types. Slopes vary from

Table 6. Habitat and species list for Vaccinium deliciosum communities.

Habitat	Macroplot 1	Macroplot 2	Range within the Cove
Elevation	1600 m	1650 m	1600-1730 m
Slope	5%	8%	5%-30%
Exposure	North	South	Variable
Land form	Slope	Slope	Slope
Snowfree	Mid-season	Late	Early - late
Drainage	Good	Good	Good

Species	% Cover	Frequency 40 Quadrats
Vaccinium deliciosum	41	39
Phyllodoce empetriformis	15	39
Ligusticum grayi	9	7
Tsuga mertensiana	5	17
Luetkea pectinata	2	21
Potentilla flabellifolia	4	25
Lupinus latifolius	2	15
Aster alpigenus	2	18
Lycopodium sitchense	1	7
Dodecatheon jeffreyi	+	3
Spirea densiflora	+	2
Abies lasiocarpa	+	3
Castilleja oreopola	+	5
Xerophyllum tenax	+	7
Carex nigricans	+	7
Deschampsia autopurpurea	+	6
Sorbus sitchensis	+	4
Cassiope mertensiana	+	3
Hieracium gracile	+	2
Polytrichum juniperinum	3	26
Litter	12	27
Bare	4	11
Rock	+	1

three to ten percent. Orientation is variable. Snow remains longer than it does in shrub heaths, but usually not longer than on C. nigricans-Polytrichum.

Potentilla flabellifolia dominates with Carex nigricans a co-dominate. Eighteen species were identified from these plots (Table 7); three of them bryophytes. The average height of the vegetation is one dm. The over-all impression is of low, sparse, mixed forb and sedge.

Rodent activity in the form of winter runs, mounds and holes is usually evident. Bare earth accounts for a full 12 percent of cover. The common alpine invasive Luetkea pectinata is a consistent minor component. Soil is typically outwash and variable; it depends upon the slopes above for its material and structure.

The Potentilla - C. nigricans community is most closely related to the C. nigricans-Aster community. They have a similarity index of .35.

F. Senecio Community. Senecio triangularis dominates one small, lush, tall-herb meadow in the Cove. This tree-protected site has a southern exposure and a slope of 18%. This meadow is probably the last of the non-bog communities to reach wilting point. The community is rich with forest herbs such as Viola glabella and Erythronium grandiflorum as well as meadow flora. Thirty-two species of vascular plants are represented (Table 8), the greatest number of any

Table 7. Habitat and species list for Potentilla-Carex nigricans communities.

Habitat	Macroplot	Range within the Cove
Elevation	1725 m	1650-1740 m
Slope	10%	3%-10%
Land form	Slope	Slope
Snowfree	Late	Late - very late
Drainage	Good	Good

Species	% Cover	Frequency 20 Quadrats
Potentilla flabellifolia	37	19
Carex nigricans	21	19
Ligusticum grayi	7	15
Carex spectabilis	3	6
Hieracium gracile	4	16
Castilleja oreopola	3	15
Epilobium alpinum	1	11
Juncus drummondii	1	5
Carex subfusca	1	7
Phleum alpinum	1	9
Microseris alpestris	+	4
Phyllodoce empetriformis	+	3
Luetkea pectinata	+	1
Vaccinium deliciosum	+	2
Aster alpigenus	+	2
Polytrichum juniperinum	2	12
Pohlia gracilis	+	2
Ceratodon purpureus	+	2
Litter	5	7
Bare	12	17
Rock	+	1

Table 8. Habitat and species list for Senecio community.

Habitat	Macroplot		Range within the Cove
Elevation	1595 m		Same
Slope	18%		
Exposure	South		
Land form	Convex		
Snowfree	Midseason		
Drainage	Good		
Species		% Cover	Frequency 20 Quadrats
Senecio triangularis		56	20
Aster occidentalis		8	15
Potentilla flabellifolia		8	19
Viola glabella		4	17
Carex spectabilis		3	15
Lupinus latifolius		2	7
Dodecatheon jeffreyi		2	11
Castilleja suksdorfii		1	14
Epilobium alpinum		1	12
Erythronium grandiflorum		1	11
Anemone quincifolium		1	8
Ligusticum grayi		1	6
Polygonum bistortoides		1	5
Valeriana sitchensis		1	5
Mertensia paniculata		1	1
Muhlenbergia filiformis		+	11
Agrostis thurberiana		+	11
Veronica wormskjoldii		+	5
Hieracium gracile		+	2
Carex scopulorum		+	1
Carex luzulina		+	1
Juncus parryi		+	1
Juncus drummondii		+	1
Abies lasiocarpa		+	1
Tsuga mertensiana		+	1
Anaphalis margaritacea		+	1
Rubus lasiococcus		+	1
Sagina saginoides		+	1
Agrostis variabilis		+	1
Mimulus lewisii		+	1
Polytrichum juniperinum		1	11
Amblystegium sp.		+	+
Litter		3	8
Bare		5	14

community. Bryophytes are poorly represented with only two species identified, Polytrichum juniperinum composes slightly more than one percent of cover. The sedge species account for only five percent of cover, very low.

Senecio triangularis is the dominate with 56% cover. Aster occidentalis, another tall herb with 8% cover and .75 frequency, is a co-dominate. Viola glabella, a common forest type, and Potentilla flabellifolia which grows in all the wet meadows have high frequency.

The soil of this meadow is a fine, sandy loam with a greyish cast. It has an ashy texture. Organic matter is only about half that of soils in the Vaccinum deliciosum community. Drainage is good.

The Senecio type is not closely related to other meadow types, but it does have much in common with the narrow band of tall herbs which line small streams as they pass through other subalpine communities and with the forest-bog-interface flora of the seeps.

Hydric Subalpine Communities

Hunts Cove is notable among Cascade subalpine parklands for the number and area of its "wet meadows." Most of these are springs or seepage areas. Others are true bogs and swamps. In no case does a soil approach wilting point. All soils are histolic. Communities are compared by vegetative composition in Table 9. Descriptions of the individual communities follow.

Table 9. Importance values for species in hydric community macroplots. Only values 5 or larger are listed.

Species	Macroplot						
	Rostrata-Sphagnum	*Eleocharis-Aulacomnium*	*C. scopulorum* 1	*C. scopulorum* 2	*C. scopulorum* 3	*C. scopulorum* 4	*C. sitchensis*
Carex rostrata	50	25					
Eleocharis pauciflora	20	35					
Polygonum bistortoides	17	11	12	14	5	61	22
Carex illota	10		6	11	13	7	8
Muhlenbergia filiformis	7	12	8	5	9		
Epilobium alpinum	10	8	6	6			
Dodecatheon jeffreyi	6	6	12				11
Salix commutata	15						
Saxifraga oregana	10						
Pedicularis groenlandica	12						
Carex praeceptorium		11					
Carex scopulorum		21	83	24	32	88	
Caltha biflora				30	42		13
Carex luzulina				13	25		
Potentilla flabellifolia			6	6		14	
Viola macloskeyi			7	7			12
Carex interrupta				20			
Boykinia major				5			
Equisetum arvense				8			
Calamagrostis canadensis				8			19
Carex nigricans					9		
Carex sitchensis							69
Agrostis thurberiana			5				7
Ligusticum grayi						26	
Sphagnum squarrosa	11	5					
Drepanocladus exannulatus	7	8	6				
Calliergon stramineum	7	8	6	6			
Philonotis americana	6	12	7		11		
Aulacomnium palustre		12	6				
Philonotis fontana			6	9			

A. Carex rostrata-Sphagnum Communities. Carex rostrata, a robust sedge and Sphagnum squarrosa occur as co-dominates in the lower edges of low elevation (1540-1590 m), early snowfree seepage areas (Table 10). C. rostrata-Sphagnum bogs are located below the main seepage areas and are adjacent to Salix-dominated islands in the bog. Water moves through the surface layer of moss throughout the year.

Eleocharis pauciflora is an important component and Salix commutata is an invader. The dominating sedges average 5 dm tall. The vascular plant cover reaches about 90%. Members of the Cyperaceae account for 60% of total cover. The bryophyte layer is well developed; in fact it covers almost all litter by mid season. Water is visible on fewer than 2% of sightings, but the water table is roughly the same level as the surface of the moss. In some spots small channels one dm by one dm carry runoff.

Two species from this community reach subalpine environments only at the extreme upper altitude of their range. They are Carex rostrata and Lystichium americanum.

The soil is sedge-sphagnum peat, very heavily root-filled and only moderately well decomposed. It is easily compressed and has extremely low bulk density.

The C. rostrata-Sphagnum community is most closely related to Eleocharis-Aulacomnium community. The similarity index is .54.

Table 10. Habitat and species list for C. rostrata-Sphagnum communities.

Habitat	Macroplot	Range within the Cove
Elevation	1590 m	1530-1590 m
Slope	0-3%	0-8%
Land form	Below seep	Below seep
Snowfree	Early	Early
Water movement	Moderate	Moderate
Water source	Seep runoff	Seep runoff

Species	% Cover	Frequency 20 Quadrats
Carex rostrata	42	20
Eleocharis pauciflora	12	20
Polygonum bistortoides	9	20
Salix commutata	8	18
Epilobium alpinum	2	20
Dodecatheon jeffreyi	2	10
Saxifraga oregana	4	15
Pedicularis groenlandica	5	17
Carex illota	4	14
Muhlenbergia filiformis	+	17
Carex scopulorum	1	2
Viola macloskeyi	+	1
Caltha biflora	+	1
Sphagnum squarrosa	5	16
Drepanocladus exannulata	2	14
Calliergon stramineum	1	16
Philonotis americana	+	14
Litter	2	9
Water	2	10

B. Eleocharis-Aulacomnium Communities. Eleocharis pauciflora dominates small areas of stagnant shallow water from 1590 m to 1675 m (Table 11). Most of these are patches within a Carex scopulorum meadow. The largest is at the edge of a small pond within a raised bog and is the location of the macroplot. Water level is at the surface all year. Carex rostrata is a co-dominant in this plot and Carex scopulorum is an important minor component. Vascular plant cover is less than 80%, low for tall sedge vegetation.

Bryophytes form an almost continuous layer broken only by areas of free water choked with algae. Aulacomnium palustre and Philonotis americana, mat forming mosses, are dominant with Sphagnum squarrosa a consistent minor component.

This plot is early snowfree. Surface water is very slow moving, 30 cm to 150 cm per hour. It warms rapidly and is near 22°C much of the summer.

The soil in the macroplot is essentially an aqueous mass of poorly decomposed non-sphagnum moss and living roots. Bulk density is only .04.

The Eleocharis-Aulacomnium community is most closely related to the C. rostrata-Sphagnum community. The similarity index is .54.

C. Carex scopulorum Communities. Carex scopulorum, a strongly rhizomatous, sod forming sedge which may stand 60 cm tall, dominates most of the hydric communities of the Cove. These

Table 11. Habitat and species list for Eleocharis-Aulacomnium communities.

Habitat	Macroplot	Range within the Cove
Elevation	1590 m	1590-1675 m
Slope	None	None
Land form	Bottom	Bottom
Snowfree	Early	Early to late
Water movement	Very little	Little to none
Water source	Seep runoff	Seep runoff

Species	% Cover	Frequency 16 Quadrats
Eleocharis pauciflora	28	14
Carex rostrata	18	13
Muhlenbergia filiformis	5	14
Polygonum bistortoides	5	11
Carex scopulorum	14	11
Epilobium alpinum	1	14
Dodecatheon jeffreyi	1	10
Carex illota	1	2
Carex praeceptorium	6	8
Carex laeviculmis	2	1
Tofieldia glutinosa	+	3
Potentilla flabellifolia	+	1
Salix commutata	+	1
Viola macloskeyi	+	3
Pedicularis groenlandica	+	3
Aulacomnium palustre	5	14
Philonotis americana	5	14
Sphagnum squarrosa	3	3
Calliergon stramineum	+	14
Dreponocladus exannulatus	+	14
Litter	+	2
Algae	3	5
Water	4	8

communities occur from 1525 m to about 1675 m (Table 12). Emergence from snow cover is early on low elevation seep areas and late on high elevation flats. Slope varies from zero to twenty percent. Those C. scopulorum meadows which have more than five percent slope are mainly seepage areas in which water rises and runs off all, or the greater part of the year. Meadows with little slope apparently have very little water movement. Although they do not become flooded for any appreciable length of time, the soil is always saturated.

Four macroplots were used to sample all aspects of this community. The number of species present varies from a high of 27 in an early snowfree seep (C. scopulorum 2) to six on a moderately late snowfree flat (C. scopulorum 4). Polygonum bistortoides co-dominates on some spots and is consistently present (Table 13). Carex illota and Potentilla flabellifolia are consistent minor components.

There is a floristic subdivision within the Carex scopulorum community (Table 9). In the seeps (Carex scopulorum plots 2 and 3) Caltha biflora and Carex luzulina assume co-dominant importance values. Caltha biflora is an indicator of snow melt water running across the surface early in the season. It may be found in many communities, but forms especially dense stands in seepage areas adjacent to forest cover. Carex luzulina appears to prefer raised portions of permanently wet sites.

The water table in plots 1, 2, and 3 is high enough to form a

Table 12. Habitat of *Carex scopulorum* communities.

Habitat	Carex scopulorum Macroplot 1	2	3	4	Range within the Cove
Elevation	1590 m	1570 m	1570 m	1615 m	1525-1675 m
Slope	0-3%	20%	15-18%	1-3%	0-20%
Land form	Bottom	Slope	Slope	Flat	Slope - bottom
Snowfree	Early	Early - midseason	Midseason	Midseason	Very early - midseason
Water movement	Slow	Fresh	Fresh	Little or none	Stagnant - fresh
Water source	High water table	Seep	Seep	High water table	Seep - high water table

Table 13. Species list for *Carex scopulorum* communities.

	% Cover	Frequency 80 Quadrats
Carex scopulorum	43	76
Caltha biflora	13	43
Polygonum bistortoides	10	65
Carex luzulina	6	28
Carex illota	5	25
Carex interrupta	4	14
Potentilla flabellifolia	2	34
Calamagrostis canadensis	2	8
Ligusticum grayi	2	16
Muhlenbergia filiformis	1	38
Dodecatheon jeffreyi	1	26
Boykinia major	1	10
Carex nigricans	1	8
Viola macloskeyi	+	38
Epilobium alpinum	+	29
Agrostis thurberiana	+	18
Equisetum arvense	+	17
Aster occidentalis	+	9
Agrostis idahoensis	+	8
Habenaria saccata	+	7
Juncus ensifolius	+	7
Senecio triangularis	+	7
Pedicularis groenlandia	+	6
Castilleja suksdorfii	+	5
Spirea densiflora	+	4
Carex neurophora	+	3
Veronica wormskjoldii	+	2
Salix commutata	+	2
Eleocharis pauciflora	+	1
Carex praeceptorum	+	1
Carex lenticularis	+	1
Scirpus congdonii	+	1
Philonotis americana	2	39
Philonotis fontana	1	32
Calliergon stramineum	+	32
Aulacomnium palustre	+	16
Drepanocladus exannulatus	+	16
Sphagnum squarrosa	+	3
Litter	+	1
Bare (mud)	4	19
Water (moss free)	+	13

surface film early in the season before the bryophyte layer obscures it. In plot 1, the slope is less than five percent, and water is held by growing mosses and moves slowly. The soil is moss and sedge peat, root-filled and poorly decomposed. In plots 2 and 3 where the slope is approximately 18 percent, water rises all year, and the soil is muck, slick, black and well decomposed. In plot 4, while continually saturated, the surface is not obscured by water, there is no slope and it is unlikely that there is appreciable water movement. There is no bryophyte layer under the dense stand of sedge. The soil is sedge peat, poorly decomposed, root-filled and resilient.

Average similarity among the plots is .40. *C. scopulorum* 1 is most closely related to *C. scopulorum* 4 (.54), *C. scopulorum* 2 is most closely related to *C. scopulorum* 3 (.53).

D. *Carex sitchensis* Community. *Carex sitchensis* dominates a relatively large (4 ha), early snowfree meadow. The elevation is 1525 m (Table 14). Several springs and creeks cross the area, but there is no large, sloping seepage area. During spring runoff when sedges are beginning to emerge, most of the community is covered by up to one dm of moving water. The inundation may last up to three weeks, an appreciable part of the growing season.

Carex sitchensis, a robust sod-forming sedge found in shallow water and on wet soil is the dominant species. *Polygonum bistortoides* and *Calamagrostis canadensis* are consistent associates. All are tall,

Table 14. Habitat and species list for Carex sitchensis communities.

Habitat	Macroplot	Range within the Cove
Elevation	1525 m	1525 m
Slope	0-5%	0-10%
Land form	Bottom	Bottom
Snowfree	Early	Early
Water movement	Slow	Slow to rapid
Water source	Snowmelt runoff Seeps	Snowmelt runoff Seeps

Species	% Cover	Frequency 22 Quadrats
Carex sitchensis	56	21
Calamagrostis canadensis	12	10
Polygonum bistortoides	8	20
Caltha biflora	6	10
Dodecatheon jeffreyi	3	12
Carex illota	3	7
Salix commutata	2	3
Boykinia major	2	2
Viola macloskeyi	1	10
Agrostis thurberiana	1	9
Epilobium alpinum	+	5
Habenaria saccata	+	3
Potentilla flabellifolia	+	3
Juncus filiformis	+	3
Aster occidentalis	+	1
Carex neurophora	+	1
Eleocharis pauciflora	+	1
Ligusticum grayi	+	1
Philonotis americana	+	4
Calliergon stramineum	+	+
Drepanocladus exannulatus	+	+
Aulacomnium palustre	+	+
Litter	4	10
Bare	2	2
Water	2	2

six to eight dm high, and strong growing.

The soil is sedge peat, layered and moderately well decomposed. It is filled with extremely tough roots, rhizomes, and stems which make a resilient, if low density, sod.

Except for the dominant sedge, which accounts for 50% of cover, the vegetative composition is very similar to the Carex scopulorum community. Juncus filiformis is the only minor component not found in C. scopulorum. If the two species Carex scopulorum and Carex sitchensis are removed from calculation of the similarity index between the C. sitchensis macroplot and the closest (geographically) C. scopulorum macroplot, the similarity index is .85, higher than any two plots within the C. scopulorum community. As far as the minor components are concerned, these communities belong to the same complex.

Snowlie Results

In alpine and subalpine areas one of the most obvious gradients is in duration of snowlie. In Scandinavia Dahl (1956) and Gjaerevoll (1950) have shown a relation of community with duration of snowpack. Douglas (1970) in the North Cascades and Brooke in the Coastal Mountains of British Columbia have related snowlie to subalpine heaths and C. nigricans communities. The Cove has a snowpack which melts off over a two month period during the growing season. It also has communities similar to those already documented. Therefore it is to be expected that the same responses to snowlie will be found in the heath and C. nigricans communities in the Cove. By extension, the communities described here which have not previously been studied may be expected to be characteristic of early or late snowfree sites. Since many of the communities have species in common and can be related through similarity indexes, it is also likely that similar communities will have similar snowfree dates. To evaluate these ideas, Cove meltoff was monitored with weekly reconnaissance in the summer of 1972.

General Pattern of Meltoff in Subalpine Parklands

Meltoff pattern varies from place to place in response to microclimate, depth, drifting, and elevation. Given the same depth and elevation, there is a general tendency in subalpine parklands for the forested areas to be snowfree before meadowlands. At about the same time, more or less, springs and creeks are likely to appear. Drier meadows appear last.

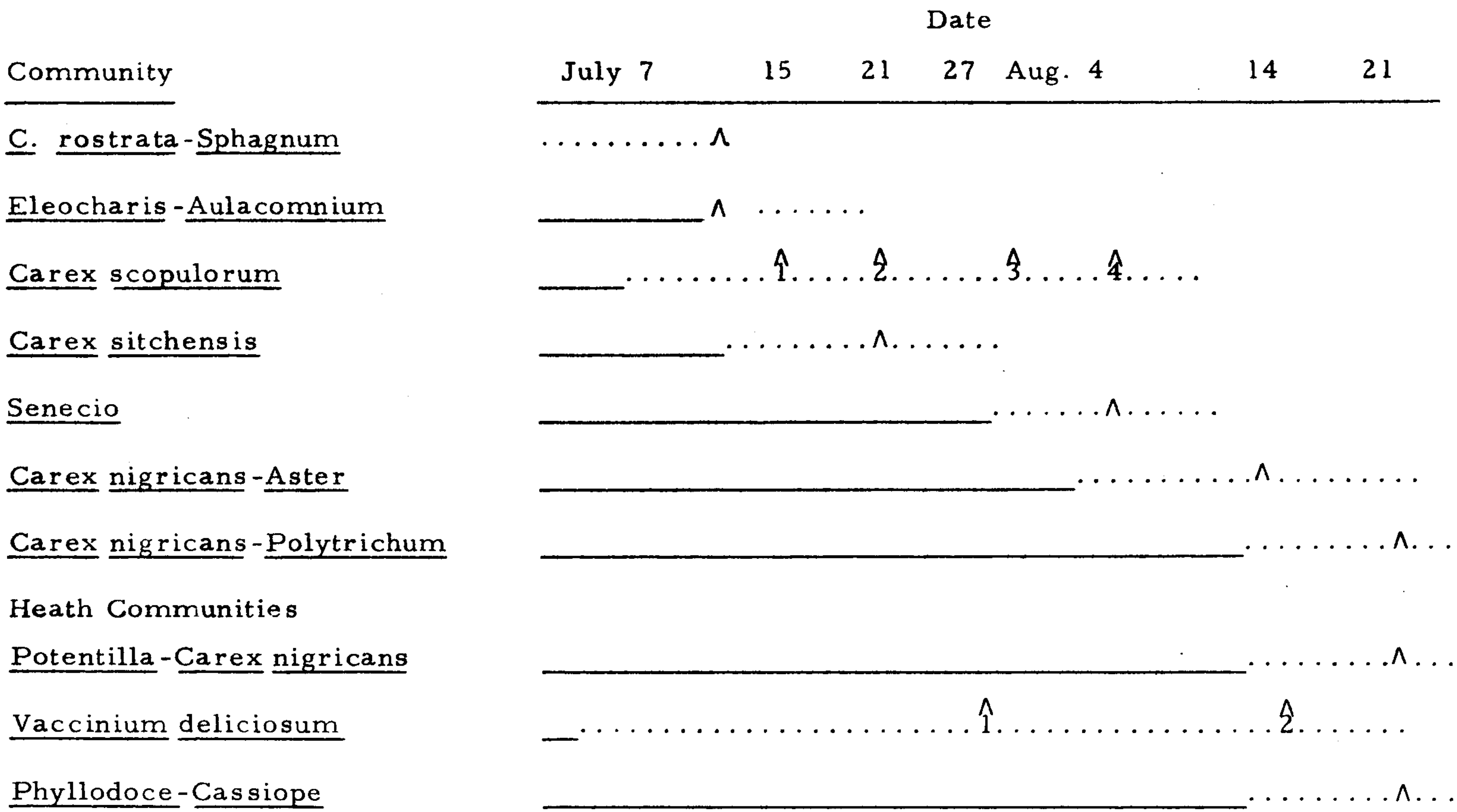
Within the meadows, seeps were snowfree before dry meadows; tops of slopes were exposed before the bottoms; low elevations before high elevations; and sunny locations before shaded ones.

Frequently a spring or seep and its drainage were snowfree several weeks before the surrounding meadow. In one case a stream had a wall of snow two meters deep on each side on July 7. Temperatures of the water in the springs ran about six degrees centigrade, high enough to affect meltoff speed. In seeps, where a thin layer of water ran over very dark muck, radiant energy on a sunny day raised the water temperature to 16 to 18 degrees centigrade within a meter or two of its source.

Snowlie Pattern in the Cove

Figure 5 gives the results of a study of meltoff from Cove communities in 1972. Any one community type may be partially exposed for a week or more, depending upon location and micro-environment. The dates at which specific plots were snowfree are noted in the figure. Vaccinium deliciosum, plot no. 1, and the Senecio macroplot each required more than one week to clear. In these cases an average date was used.

The first snowfree community was C. rostrata-Sphagnum. During the time that C. rostrata stands were becoming snowfree, Eleocharis-Aulacomnium and the first of the C. scopulorum stands emerged. C. scopulorum is widespread and the community habitats vary considerably, therefore the period during which the various stands became snowfree is quite long. In the interval from first to last C. scopulorum emergence, the C. sitchensis and Senecio communities became snowfree.



___ Period during which all parts of the community type were snow covered.
... Period during which at least one part of the community type was snowfree.
Λ Date on which the macroplot became snowfree in 1972.

Figure 5. Date of disappearance of snow from Cove communities in 1972.

All of the hydric community stands were snowfree before any of the C. nigricans Polytrichum stands became snowfree.

Vaccinium deliciosum heath became snowfree over a long period which overlaps the bogs and the earliest of the C. nigricans communities. It is followed by Phyllodoce-Cassiope, then by Potentilla-C. nigricans.

Ranking of Snowfree Date and Floristic Order

Although there is much overlap in the emergence of all stands of each community, there is little overlap in the dates that individual plots became snowfree. When the snowfree date of a single plot (heaths excepted) is arrayed beside the plot position on the vertical axis of the community floristic ordination, the ranking is the same (Figure 6). It is particularly interesting to note that those plots overlapped in snowfree date by the C. scopulorum macroplots appear snowfree in their floristic order.

The relative importance of species in these plots is listed in Table 1. Particularly in the closely related C. scopulorum and C. sitchensis macroplots, the flora is richer and more diverse in the earlier snowfree plots. It is clear that the relation is a subtle interaction of proportions rather than a clear cut sequence.

The geographically isolated character of hydric and lush herb communities prevented me from placing a transect from one

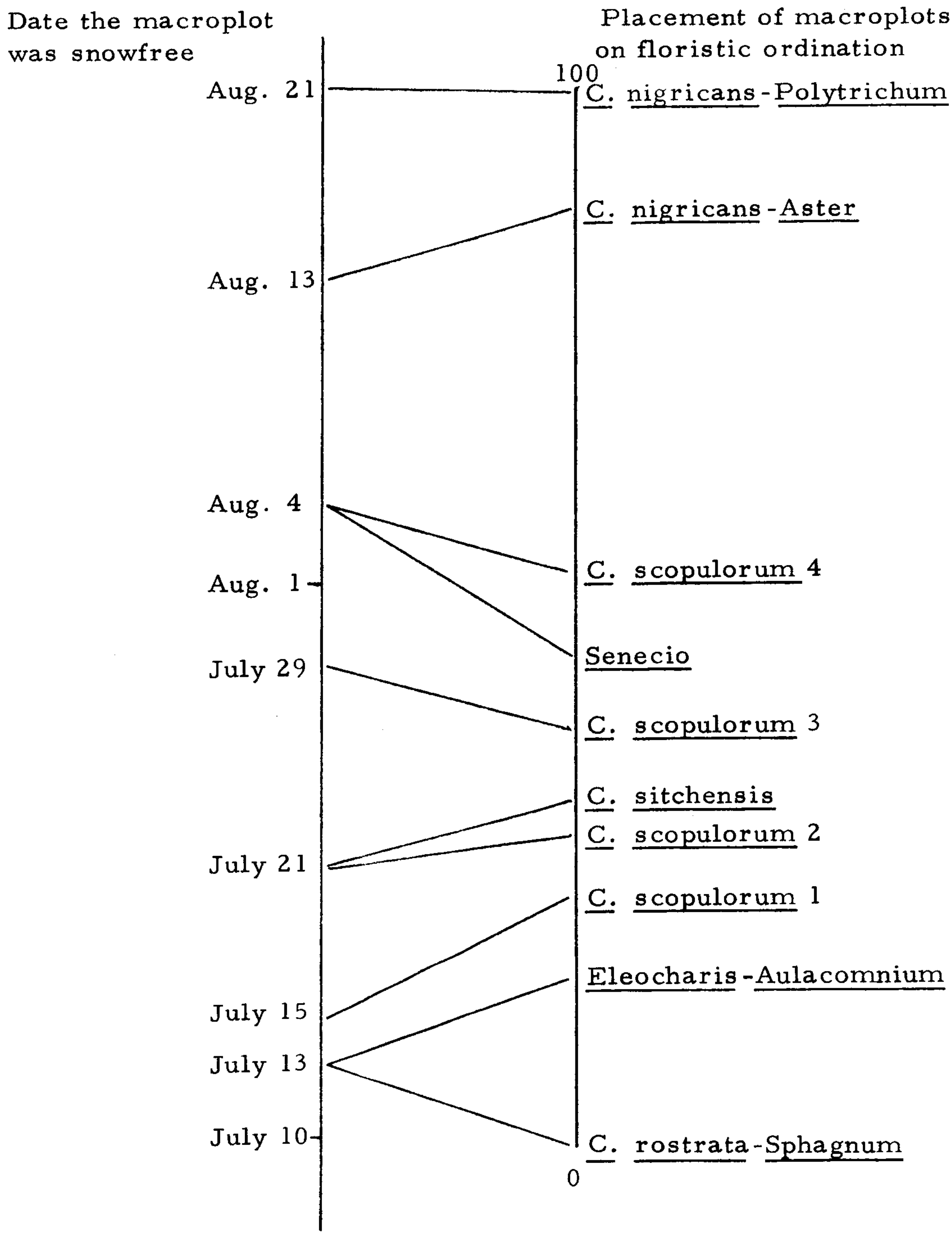


Figure 6. Ranking of macroplots by snowfree date and by placement on the vertical axis of the floristic ordination.

community to another. The relative snowfree time of the heath communities is as predicted from the literature. However, when the same communities are arranged in their floristic order, the ranking is different.

Floristic Order	Snowfree Order
Phyllodoce-Cassiope	V. deliciosum 1
V. deliciosum 2	V. deliciosum 2
V. deliciosum 1	Phyllodoce-Cassiope
Potentilla-C. nigricans	Potentilla-C. nigricans

Part of the discrepancy arises in ranking these communities with non-heath types. But it is apparent that some factor other than snowfree date has a great influence.

The snowfree date determines only one end of the growing season. In hydric communities, or those that are moist for most of the season snowfree interval is the time available for growth. However, the length of growing season in the well drained communities is determined by snow melt at the beginning of the season and by lack of water at the end. The floristic order then may reflect the total length of growing season.

Clinal Response within Carex nigricans Communities

Within Carex nigricans communities I have found a clinal response to the snowfree time gradient. Cover class estimates were taken at two dm intervals across a single meadow from the edge of Vaccinium deliciosum through Carex nigricans-Aster and C. nigricans-Polytrichum into the Bryophyte community. Results are given in Figure 7. As the season becomes shorter the species are eliminated in this order: Aster alpigenus, Potentilla flabellifolia, Ligusticum grayi, Carex nigricans, until only Polytrichum norvegicum remains.

Response of Individual Species

In the Cove as a whole, plants found only in the earliest snow-free areas are: Carex rostrata, Lystichium americanum, and Sphagnum squarrosa. Species found in early to moderate snowfree springs are Dodecatheon douglasii, Castilleja suksdorfii, Montia sibirica, Caltha biflora, and Boykinia major. Late snowfree bogs are not distinguished by the presence of species as much as by the absence of all but a few species such as Philonotis fontana, Epilobium alpinum, and Mimulus tingilii. Polytrichum norvegicum, Bryum alpinum, and Pohlia ludwigii are limited to very late snowfree, non-bog sites.

Soil Results

Soil genesis may simply parallel community development in sub-alpine locations, but there are soil characteristics which may affect

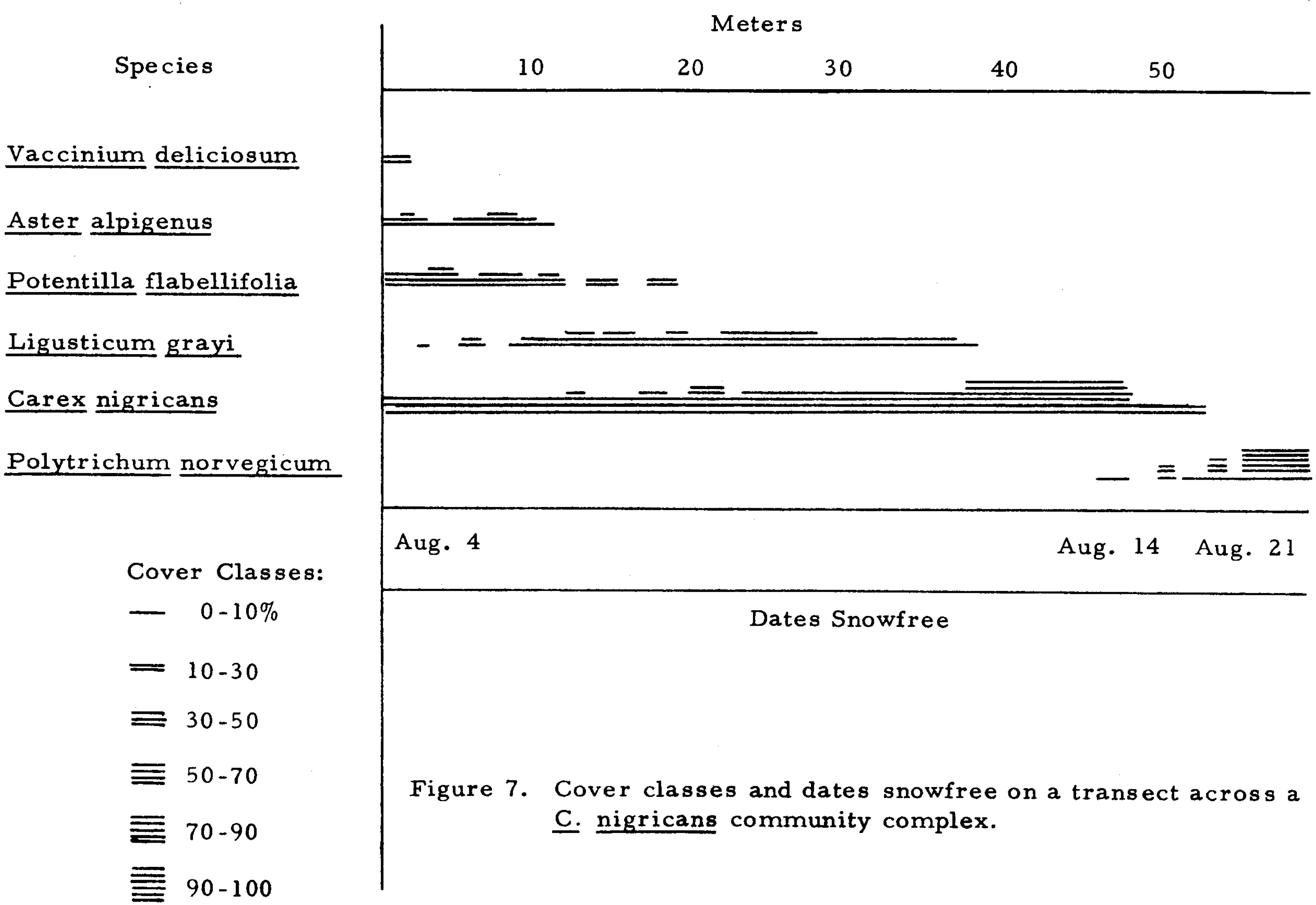


Figure 7. Cover classes and dates snowfree on a transect across a *C. nigricans* community complex.

community development. In the Cove all soils have an exceptionally low bulk density. This affects plant nutrient supply. The soils are fragile and have a high water content at 15 atm tension (Table 15).

Bulk density was low in all samples. In the hydric communities it ranges as low as .04, little more than a liquid suspension of roots and organic matter. In the heaths and meadows the high proportion of pumice-like scoria has the same effect.

One result of this extreme low density is that nutrient content is low. Nutrients are within the ranges of other subalpine soils in similar situations when reported on a weight/weight basis. However they are much less plentiful on a weight/volume basis in a soil which is fluffy (Heilman, 1968). Table 15 lists nutrients in kg per ha per 50 cm which emphasizes the low nutrient status of all soils that support heath communities. Nutrient content varies with community type, but there is no evidence that it is a controlling factor. Within the hydric communities the nutrient status agrees well with the 'rich fen' classification (Heinselman, 1963) in which the water supply is ion rich, particularly as regards Ca.

Another result of low bulk density is the fragility of the soil. When vegetative cover is broken, erosion is almost sure to follow. When the soil is dry, it is literally blown away. Any trail becomes a drainage during rains, with severe erosion. Within the bogs and seeps the structure of the soil is soft. Since there is little structure other

Table 15. Nutrients expressed as kg/ha x 50 cm; water in grams per cc and percent soil.

Community	B.D.	Total soil in millions kg/ha x 50 cm	Nutrients in kg/ha x 50 cm P	K	Ca	Mg	Na	Water gm/cc 1/3 Atm	Water gm/cc 15 Atm	Water % 15 Atm	Lowest of 1971
Phyllodoce-Cassiope	.43	2.2	30	95	136	36	28	.24	.16	46	89
Vaccinium deliciosum	.35	1.8	12	365	508	147	88	.33	.20	59	131
Potentilla-C. nigricans	.65	3.3	104	178	836	90	209	.25	.13	21	41
C. nigricans-Aster	.27	1.4	16	297	174	146	124	.56	.42	153	245
Senecio	.42	2.1	21	184	668	195	107	.37	.23	56	98
C. rostrata-Sphagnum	.06	.3	29	374	1578	212	9				
Eleocharis-Aulacomnium	.04	.2	12	18	1200	188	46				
C. scopulorum 1	.08	.4	26	343	1600	250	54				
C. scopulorum 2	.13	.7	17	91	1118	195	97				
C. scopulorum 3	.26	1.3	10	429	585	207	287				
C. scopulorum 4	.14	.7	38	257	844	222	44				

than roots, any damage is permanent.

Another point common to all soils sampled is the exceptionally high water content at 15 atm, the arbitrary "wilting point." Pumice and organic matter each retain large amounts of water at what is conventionally considered the wilting point. It is possible that heath plants are able to tap the water supply in coarse pumice over a long period during a summer, thus mitigating somewhat the lack of water. The exact opposite may also be true. Some soils which feel 'damp' may in fact develop a high water tension during the summer. For example, the C. nigricans-Aster community has an extreme 153% water content at 15 atm (Table 15). Chemical analysis is reported in Appendix II. Efforts to monitor water tension at the surface in 1971 were not successful due to summer rains. The results are in Appendix II.

V. DISCUSSION

General

The combined action of drainage, snowlie, sunlight and possibly animal activity influence the distribution of subalpine communities. The same conditions which limit community development also control soil formation. Major (1951) stated this as an equation: vegetation, or soil, is a function of climate, relief, parent material, time and organisms. The processes of soil and community formation are probably interdependent. Thus, no one can say that soil determines vegetation, or that vegetation determines soil. Water source is not a major part of the equation in most circumstances, but is of great importance in hydric communities. For alpine communities in well drained soils, the growing season is initiated by meltoff of snow and most usually curtailed by moisture stress. For hydric communities or those that are moist throughout the season, the growing season is probably the length of the snowfree season.

In the following discussion, interrelations among Hunts Cove typical subalpine communities are summarized in terms of what appear to be major environmental factors; drainage, snowlie, sunlight, and animal activity. The hydric communities are summarized in relation to snowlie, water movement, and succession. Then there is a proposed successional pattern for three of the Cove's communities.

Finally the communities at Hunts Cove are compared with subalpine communities described elsewhere.

Interrelations Among Meadow Communities in Hunts Cove

Typical Subalpine Communities

The physical positions of Vaccinium deliciosum, Phyllodoce-Cassiope, C. nigricans and the bryophyte communities (Figure 8) in relation to slope, drainage, and snowlie are similar to those described for similar communities by other Northwest authors.

In the Cove a narrow belt at the edge of the mature Tsuga mertensiana forest and above Vaccinium deliciosum is dominated by Lupinus latifolius and V. membranaceum. I did not describe it as a community type, although it is a common combination, because it is a very narrow transition to forest communities. It is affected by forest cover, and is common to areas that are early snowfree, dry and usually sunny.

The first heath community to become snowfree is Vaccinium deliciosum (Table 16). It occupies well drained locations on stable soil. The Phyllodoce-Cassiope and the C. nigricans-Aster communities are snowfree at about the same time but are distinguished by drainage and soil type. Phyllodoce-Cassiope occupies well drained slopes, frequently on poorly developed soils. C. nigricans

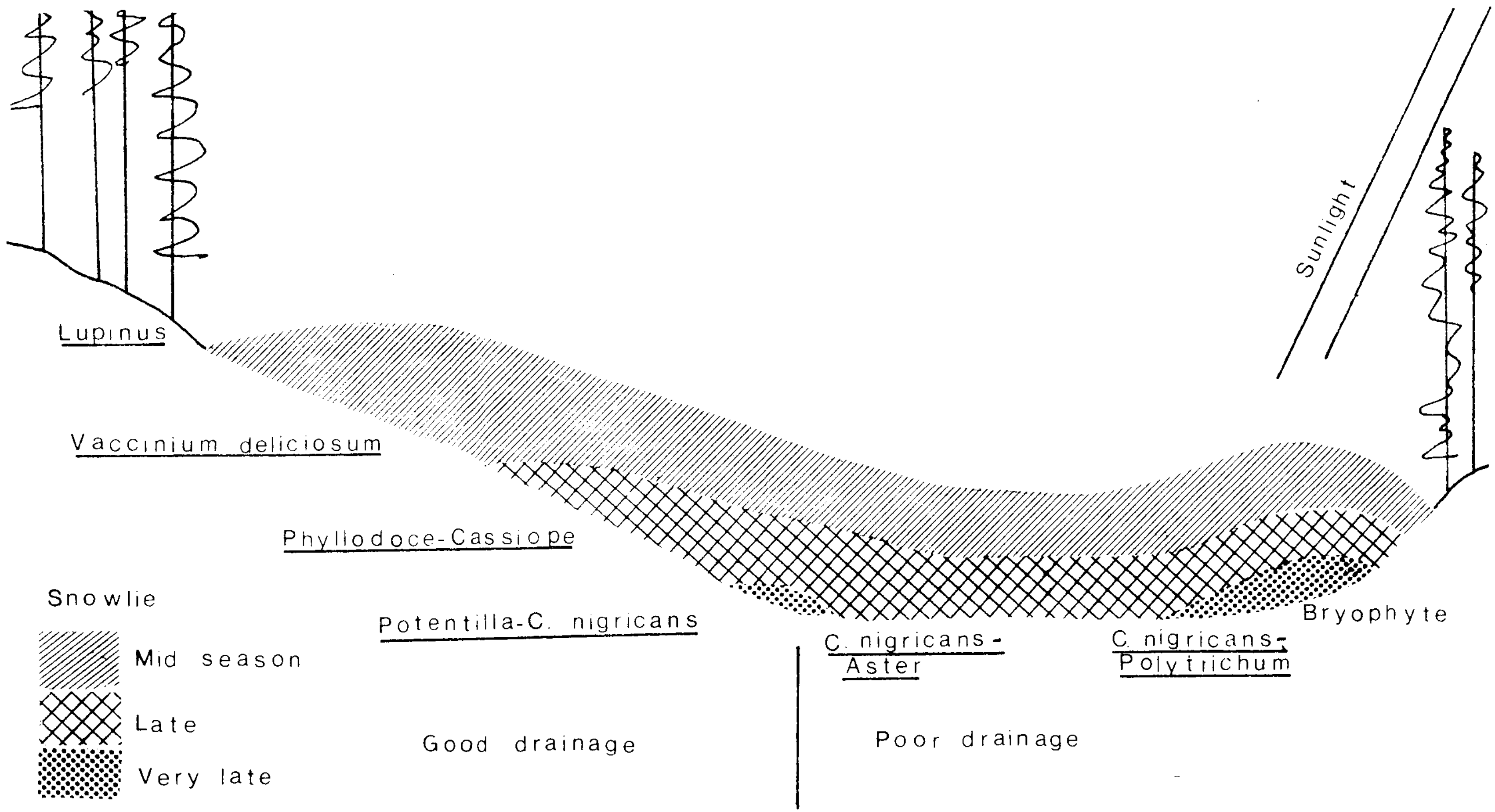


Figure 8. Diagram showing relation of snowlie, drainage, and sunlight on subalpine communities.

Table 16. Environmental characteristics of typical subalpine communities.

Community	Drainage		Snowlie			Sunlight		Animal activity		
	Good	Poor	Moderate	Late	Very late	Sun	Shade	Grazing	Soil disturbance	Little
V. deliciosum	x		x			x		x		
Phyllodoce-Cassiope	x			x		x		x		
Potentilla-C. nigricans	x				x	x		x	x	
C. nigricans-Aster		x		x		x	x			x
C. nigricans-Polytrichum		x			x	x	x			x
Bryophyte		x			x		x			x

communities lie in poorly drained, frequently flooded basins which receive considerable alluvium. Slow decomposition leads to accumulation of peat deposits. The Phyllodoce-Cassiope community occurs on hills with good cold air drainage, while C. nigricans is in cold basins.

The Potentilla-C. nigricans, C. nigricans-Polytrichum and bryophyte communities become snowfree very late. Of these, only Potentilla-C. nigricans is on a well drained soil. However, its position at the base of a slope implies a long period of water supply, hence a relatively long growing season. Severe rodent activity may be a more important factor, maintaining the community in a seral state.

C. nigricans-Polytrichum abuts those few places where a bryophyte community is found. Although snowfree dates overlap for the two communities in different places, C. nigricans is always on the sunny warmer side, the bryophyte community in deep shade, cool and damp. Soil may be very thin (bryophyte peat over rocks) in the bryophyte community.

Hydric Communities

Although in the hydric communities duration of snowpack is of great importance floristically, the chief environmental determinant is water. It is doubtful that the subalpine parkland character of the Cove would extend to the lower elevations if it were not for the abundance of wet sites.

Carex scopulorum communities dominate by far the largest area and widest hydric habitat range in the Cove. The other three communities occupy specialized positions. Eleocharis-Aulacomnium, which is snowfree about the same time as C. rostrata-Sphagnum and the first of the C. scopulorum meadows (Table 17), is probably an example of hydrarch succession. Evidence rests on its geographic position and vegetative composition. It is found in very sluggish or stagnant water.

The C. rostrata-Sphagnum community which is probably also a successional stage, occurs in freely moving water. Usually it is at the lowest end of a seepage area where the ion content of the water may be low. It is very early snowfree and contains species intolerant of short season: Carex rostrata and Lysichitum americanum.

The Carex sitchensis meadow appears snowfree midway through the C. scopulorum stands. It is flooded for one to three weeks during the early summer meltoff. The only other community type with flooding is Carex nigricans, the short sedge found in very late snowfree situations. The Carex sitchensis community is very closely related to Carex scopulorum community. Snowfree time and minor vegetative components overlap completely. It appears that Carex scopulorum is sensitive to flooding, which allows Carex sitchensis to dominate.

The Carex scopulorum community occupies a variety of habitats. It is the community found on seeps throughout the Cove. It also

Table 17. Interrelations of hydric communities.

Community	Snowfree		Succession		Area Flooded to 4 cm		Running Melt Water		
	Early	Midseason	Seral	Climax	Yes	No	Much	Little	None
C. rostrata-Sphagnum	x		x			x		x	
Eleocharis-Aulacomnium	x		x			x			x
Carex sitchensis		x		x	x			x	
Carex scopulorum	x	x		x		x	x	x	
Caltha biflora subtype		x		x		x	x		

occupies flats where the water table is at the surface, but not flooded at any time throughout the year. These two habitats differ in the dominance of Caltha biflora, a species which blooms in running melt water. Heavy concentrations of C. biflora grow on the upper edges of seeps adjacent to the forest where the ground is snowfree early and the supply of cold running water is good.

Succession

Succession proceeds exceedingly slowly, if at all, in most typical subalpine habitats. In the Cove evidence for this rests in the abrupt edge of forest, where there are trees probably over 300 years old, adjacent to a Vaccinium heath which has only recently been invaded by trees. Just what change occurred to allow succession to proceed after such a lapse is not known, but the time of establishment agrees with a general pattern throughout the Northwest (Franklin, 1966), most probably based on a weather modification.

In some locations it is unlikely that succession will proceed beyond its present state. The combination of late snowlie and poor drainage restricts the habitat. For instance, C. nigricans communities would be replaced only as a result of a change in land form which improved drainage, or a change in climate.

The Potentilla-C. nigricans community on the other hand may be a seral stage. I do not know why Phyllodoce-Cassiope or C. nigricans does not invade the locations where Potentilla-C. nigricans is found. A possible answer is soil disturbance. Bare earth, chiefly from rodent activity composed 12% of cover. Long lived perennials such as Phyllodoce empetriformis and C. nigricans are not as important as in the adjoining communities. C. nigricans, a logical dominant, is slow to colonize disturbed areas. In one instance no new growth was observed during a period of three summers following destruction by foot traffic near a campsite area. However Potentilla flabellifolia, E. alpinum, L. pectinata, H. gracile are all undemanding species found in disturbed sites. Since low cover for C. nigricans and presence of the other species distinguishes Potentilla-C. nigricans, it is quite possible that this community is maintained in a seral state by rodents.

Within hydric communities there is a different situation. Bog formation processes tend to be cyclic. A ponded area may be invaded by vegetation, the soil level rises and the water pattern changes, flooding a new area and allowing a more advanced successional stage to invade. But succession is not unidirectional: the more advanced stages may be flooded in turn at a later time. This pattern has been well documented (Heinselman, 1963; Sjors, 1948). In the Cove we do not have peat sample cores, but one of the classic indications is present, the surface of the bog is 50 cm to 1 m above the large stream which drains it. In other instances it appears that Salix succession in moving water has raised the surface of the soil so that now the surface is relatively dry and drainage follows a new pattern. In one case it has changed the water movement pattern enough to kill mature trees at the edge of the seep.

In the Cove, the evidence of geographic position and vegetative composition indicate that Eleocharis-Aulacomnium is a seral community. It is restricted to an area adjacent to a pond below a large seep. Carex rostrata, Eleocharis pauciflora and Carex praeceptorium, major components of the vegetation, may be found growing alone in shallow water elsewhere in the Cove, indicating that these species are pioneers. Aulacomnium palustre and Philonotis americana are common invasives along stream banks. Thus the majority of the vegetation in the Eleocharis-Aulacomnium community is pioneer type.

Carex scopulorum, the dominant of the next stage, is a minor part of the vegetation and is more dense on the land side of the community. The Carex scopulorum stand adjacent to Eleocharis-Aulacomnium contains remanents of Eleocharis pauciflora, Aulacomnium palustre and Philonotis americana.

The water is warm, approximately 22° C at 3 cm, and slow moving and the plot is early snowfree. A probable successional pattern is:

Slowly moving water:

Eleocharis
↓
Eleocharis-Aulacomnium
↓
Carex scopulorum

C. rostrata-Sphagnum also appears to be a successional stage, this time in moving water. Sphagnum squarrosa and Carex rostrata invade moving water below seepage areas. Carex scopulorum remains as a minor component. Small Salix commutata shrubs are invading the C. rostrata-Sphagnum community. Immediately adjacent to C. rostrata-Sphagnum in several places are tall (to 3 m) Salix commutata islands. There is no water movement through the soil here and Carex rostrata is missing, but Sphagnum squarrosa remains as a low-vitality ground cover.

The probable successional pattern is:

Freely moving water:

Carex rostrata-Sphagnum
↓
Salix commutata

Ionic Content of Water

Vegetation patterns in bogs reflect the ionic content of the water supply. Many plants are excluded from those waters which are poor in ions. There is no evidence in the Cove of the presence of the classical "raised bog," a convex land form which receives water only from rain or snow and thus is extremely ion poor. But the two successional communities are in a position which suggests they may be relatively ion poor; that is, they are at the lower end of a bog whose vegetation and soils adsorb ions from the seeps. Two of the major vegetational components, Carex rostrata and Aulacomnium palustre are "poor fen" indicators, that is, they can exist in ion poor waters (Nordhagen, 1954). We have neither water analyses from the Cove nor any classification of bog plants found in the Pacific Northwest with which to confirm the hypothesis. This is a subject which should be explored further.

Floristic Comparisons

General Considerations

It may be hypothesized that similar vegetation patterns will exist under similar conditions, and further that geographically related areas will have the same communities. The following comparison of Cove vegetation patterns with those reported in the literature shows this to be true, at least in part.

Meadow types are widely distributed in arctic and subalpine situations. In Europe many that are analogous to ours have been described in detail. Dominant genera frequently found in both, e.g., Vaccinium, Phyllodoce, Carex and Polytrichum, have few species in common.

In North America these are descriptions of subalpine meadows for only a few areas. Detailed vegetation studies include those of Brooke (1970) for the North Cascades and Coastal Mountains of British Columbia; Douglas (1970) for the North Cascades of Washington; Kuramoto and Bliss (1970) for the Olympic Mountains. Locally, Van Vectin (1960) studied land forms and accompanying communities in the Three Sisters Wilderness area. Swedberg (1961) ran a transect from the crest of the Cascades near Three Finger Jack to the east, chiefly concentrating upon forest cover. Hickman (1968) studied the western Cascades, south and west of Mt. Jefferson, and concentrated upon endemic species. All three describe communities similar to those in the Cove, but none list composition in a way that makes detailed comparison possible.

Descriptions of Northwestern hydric subalpine communities are practically unknown. Ives (1942), Rigg (1922), Rigg (1958) and Retzer (1962) have dealt with high elevation bogs in connection with other studies. Lowland North American studies (Conway, 1949; Gorman, 1957; Heinselman, 1963; Moss, 1953) and arctic (Heilman, 1968; Sjors, 1948) studies deal primarily with the processes of bog formation. Among the reports are detailed vegetation analysis, but only a few widely adaptable species are also found in the Cove. Detailed comparison and classification of hydric communities is not practical until there is a larger body of literature from the Pacific Northwest.

Detailed comparisons may be made with typical subalpine communities of Douglas (1970), Brooke (1970) and Kuramoto and Bliss (1970). All three find communities very similar in composition and structure to those of Hunts Cove. Kuramoto and Bliss combine the Vaccinium deliciosum and Phyllodoce-Cassiope communities, but his "shrub heath" is compatible with the combined values of Vaccinium deliciosum and Phyllodoce-Cassiope given in other studies. It is my feeling that the heath communities of the Cove represent southern extensions of the same vegetation pattern.

Vaccinium deliciosum Heath

The Vaccinium deliciosum community appears to be consistent throughout its range, which is roughly limited to the area covered by the studies above (Table 18). Vaccinium deliciosum is the clear dominant and composes 40 percent or more of the cover in each of the studies. Phyllodoce empetriformis is a strong codominant in the communities mentioned by Brooke and Campbell, weak in those seen by Douglas. Luetkea pectinata occurs as a consistent minor component. Cassiope mertensiana, characteristic of the higher alpine heaths is a minor component of communities in the three northern studies. This

Table 18. Relative quantities of species in four Northwest community studies.

	Shrub heath	*Vaccinium deliciosum*			*Phyllodoce-Cassiope*		
	(1)	(2)	(3)	(4)	(2)	(3)	(4)
Cassiope mertensiana	35	1200	1	--	5510	41	34
Phyllodoce empetriformis	50	4743	9	15	6530	31	39
Luetkea pectinata	26	614	7	2	860	8	3
Vaccinium deliciosum	40	5229	67	41	612	10	2
Polygonum bistortoides	5						
Erythronium montanum	20						
Hieracium gracile	6				12	T	+
Deschamosia atropurpurea	7	11	T		33	1	
Orthocaulis floekii		1414			1380		
Tsuga mertensiana		459	T	5	326	1	1
Cetraria islandica		171					
Dicranum fuscescens			7			4	
Lycopodium sitchense		150		1	624	2	3

(1) Kuramoto and Bliss, importance value Olympic Mountains.
(2) Brooke, cumulative % Coastal Mts., of B.C.
(3) Douglas, Percent cover N. Cascades, Washington.
(4) Campbell, Percent cover Mt. Jefferson.

Note: The values here are taken directly from the studies and are not in the same units.

species does not occur in my Vaccinium deliciosum community. Usually it does not occur much below timberline. My plots were at the very lowest extent of subalpine meadow types. Since Cassiope mertensiana and Vaccinium deliciosum occur together higher on Mt. Jefferson I feel that Cassiope mertensiana probably belongs in the description of the heath, even this far south.

The species which distinguish one area from another are in the bryophyte layer. Kuramoto and Bliss do not list species in the bryophyte layer, but the other studies do. In the British Columbia Cascades, Orthocaulis floekii is a characteristic species and Cetraria islandica (a lichen) is listed as a differentiating species. Neither of these is listed in Douglas nor found in my area. Douglas lists Dicranum funescens as a selected species, this moss does not occur in either of the other lists. Polytrichum juniperinum, while certainly not a restricted species, does separate my community lists from the northern ones.

Phyllodoce-Cassiope Heath

Phyllodoce-Cassiope communities frequently occur adjacent to a Vaccinium deliciosum community but in areas that are snowfree for a shorter season. The line between the two is often indistinct; the major species are the same but the proportions change. In the Cove, because of the patchy nature of the meadow vegetation, the two types are physically separated.

In all the Northwest studies cited above the composition of the shrub and herb layers is similar (Table 18). Phyllodoce empetriformis is important and forms approximately half the total vascular cover. Cassiope mertensiana is almost equal to P. empetriformis in importance. Vaccinium deliciosum is a minor component. Lycopodium sitchense has low cover but is consistent. Several species characteristic of disturbed or eroded sites occur in each study: Marsupella brevissima, Polytrichum piliferum and Luetkea pectinata.

The bryophyte layer again had distinguishing species. Orthocaulis floekii and Kaeria falcata are characteristic species in British Columbia, but are not listed by Douglas. In the North Cascades, Dicranum funescens and Cladonia chlorphea are selected species. In the Cove Polytrichum piliferum and Rhacomitricum canescens were characteristic but not listed by the other authors. Marsupella brevissima is a differentiating species which is found both in British Columbia and the Cove, but not listed in Douglas' paper.

These "differential" species are widely spread. I see no reason to believe that they will continue to distinguish one geographic area from another when more comprehensive work is done. It may be that ecological variants can be defined this way, e.g., both Polytrichum piliferum and Rhacomitricum canescens from the Cove are characteristic of dry habitats. A detailed study over the range of the

Phyllodoce-Cassiope community will be interesting.

Carex nigricans

Carex nigricans meadows occur throughout the Northwest sub-alpine zones. They are characteristically situated in poorly drained basins with early snow deposit and very late snowlie. There is little or no slope and little or no evidence of freeze damage.

There is no good analogy in European literature, perhaps because similar basins in Europe freeze before they are snowfilled. Brooke classifies Carex nigricans under Salicetalia herbaceae which occupies similar habitats and contains order character species found in this order of the Braun-Blanquet Classification. However these species, with the exception of Polytrichum norvegicum, are not found in the Carex nigricans series in the Cove. Dahl (1956), Gjaerevoll (1950) and Nordhagen (1954) describe various communities in late snowlie, poorly drained locations of Scandinavia. There is little or no correspondence to the Carex nigricans communities of the Northwest. The Scandinavian communities have a much richer flora with a higher proportion of grasses and lichens.

The outstanding characteristic of Carex nigricans communities in all descriptions is the high cover value of Carex nigricans itself, which may be from 75 to 100 percent. Other vascular plants vary in number and type. Deschampsia atropurpurea is common to all descriptions.

Brooke lists Juncus drummondii as a character species. The rest of his vascular plants are occasional invasives from the Phyllodoce-Cassiope heath, such as Luetkea pectinata, Phyllodoce empetriformis and Vaccinium deliciosum. These three are in all the descriptions. Douglas finds in addition to all of the Brooke's species, Epilobium alpinum, Agrostis thurberiana, and Carex spectabilis. Kuramoto and Bliss do not list Juncus drummondii, but find many more vascular plants, including Carex albonigra, Lupinus latifolius, Erythronium montanum, Hieracium gracile and Potentilla flabellifolia. Polytrichum norvegicum is the only bryophyte species found in all Northwest locations.

In my study the C. nigricans community has been divided into two closely related sections. First, poorly drained, moderately late snow-free C. nigricans-Aster communities include Agrostis thurberiana, Deschampsia atropurpurea, Luetkea pectinata, Aster alpigenus, Potentilla flabellifolia and Ligustricum grayi. Neither community includes Erythronium montanum which may be unknown on Mt. Jefferson, nor does it include Juncus drummondii, C. albonigra, H. gracile or L. latifolius, all of which are found in well drained situations.

C. nigricans-Polytrichum communities which are very late snow-free may contain only one vascular plant, C. nigricans. Polytrichum norvegicum is the common associate, but makes up very little of the total cover. This community is very restricted floristically and no doubt is included as a part of the C. nigricans communities of the other authors.

Potentilla-C. nigricans

Potentilla-C. nigricans communities are well drained, very late snowfree. They do not correspond to any single community of any other author. It is possible that Kuramoto and Bliss have included similar communities in their 'short sedge' classification, since it contains a number of species typical of well drained habitats, or the type may have a narrow geographic distribution.

Senecio

The lush herb type meadow is widely distributed and appears in many forms in subalpine literature. In the Pacific Northwest, all descriptions have one or more tall herb communities. Brooke's closest community is Leptarrheno-Calthetum leptosepalae found in wet habitats, spring lines and so on. It has a high proportion of mosses and a wetter habitat and is not comparable to my Senecio community. Douglas' Valeriana sitchensis-Veratrum viride and Kuramoto and Bliss' Valeriana forb do have elements in common with Senecio (Table 19). Valeriana sitchensis and Polygonum bistortoides and Lupinus latifolius are in all three lists but with lower cover in the Cove. Carex

Table 19. Comparison of major species occurring in lush meadow communities.

	Campbell Percent Cover	Douglas Percent Cover	Kuramoto Importance Value
Polygonum bistortoides	1	3	8
Dodecatheon jeffreyi	2		
Potentilla flabellifolia	8		
Aster occidentalis	8		
Senecio triangularis	56	1	
Carex spectabilis	3	6	
Valeriana sitchensis	1	33	24
Viola glabella	4		16
Lupinus latifolius	2	6	19
Viratrum virides		29	12
Mitella breweri		3	2
Carex albonigra			21
Senecio integerrimus			8
Erythronium montanum			9

Note: These values have been taken directly from the above studies and can be compared only as proportions.

spectabilis and Senecio triangularis are shared with Douglas' community, Viola glabella with that of Kuramoto and Bliss. Veratrum virides and Mitella breweri, both wet land plants, are common to the other two studies but do not occur in the Senecio community in mine.

IV. SUMMARY

1. Eleven vegetative communities in the subalpine meadows of Hunts Cover are described. Six of these are typical sub-alpine vegetation similar to communities found from British Columbia south. They are: 1) Phyllodoce-Cassiope, 2) Vaccinium deliciosum, 3) Potentilla-Carex nigricans, 4) Carex nigricans-Polytrichum, 5) Carex nigricans-Aster and 6) Senecio. One is alpine bryophyte. Four are hydric communities and are probably typical only of specialized conditions. They are: 1) Eleocharis-Aulacomnium, 2) Carex rostrata-Sphagnum, 3) Carex scopulorum and 4) Carex sitchensis.
2. The position of all hydric, lush herb and short sedge sample plots on a similarity ordination was found to parallel snow-free dates.
3. Well drained heath communities became snowfree in the order reported in the literature, but the did not array on the ordination by snowfree date.

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APPENDIX I

Similarity Ordination

Vegetation macroplots are compared on a phytosociological basis and are ordered in two-dimensional space according to their degree of similarity to reference stands at each end of the X and Y axes, according to a modification of Dick-Peddie and Moir. Similarity is computed by Bray and Curtis' similarity index. Ordination distances along the X and Y axes are found by comparing each macroplot, i, with reference macroplots R1 and R2, of each axis. The ordination distances, D_x and D_y are computed as follows:

$$a = 1 - \text{sim}(i, R1)$$

$$b = 1 - \text{sim}(i, R2)$$

$$D_x = 50 + 50(a^2 - b^2),$$ where R1 and R2 are X axis reference macroplots

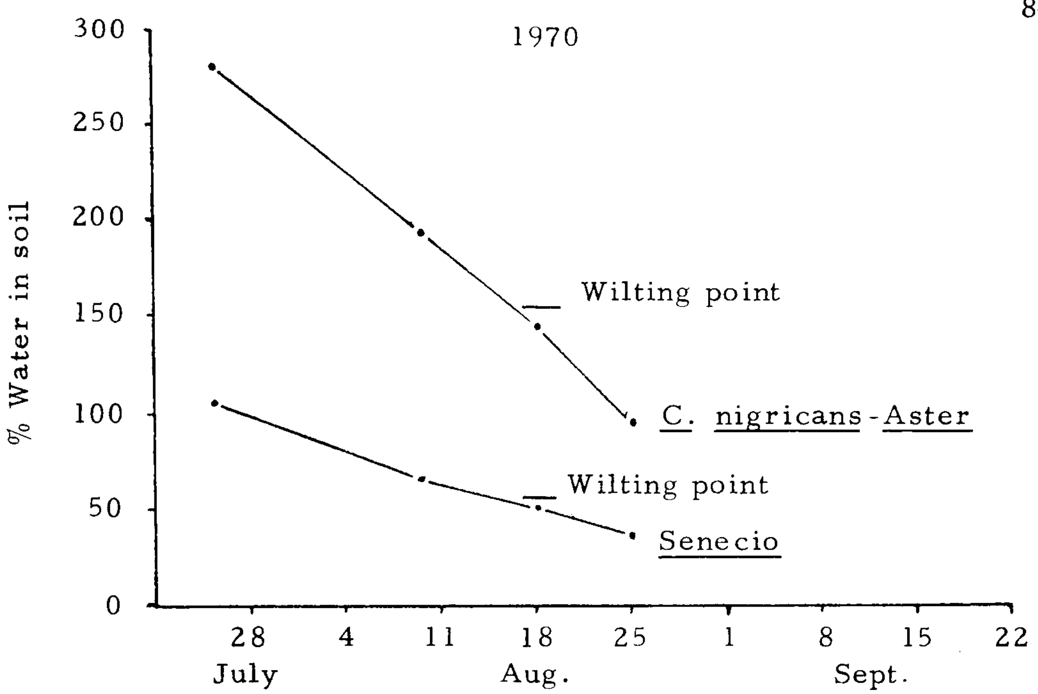
$$D_y = 50 + 50(a^2 - b^2)$$ where R1 and R2 are Y axis reference macroplots

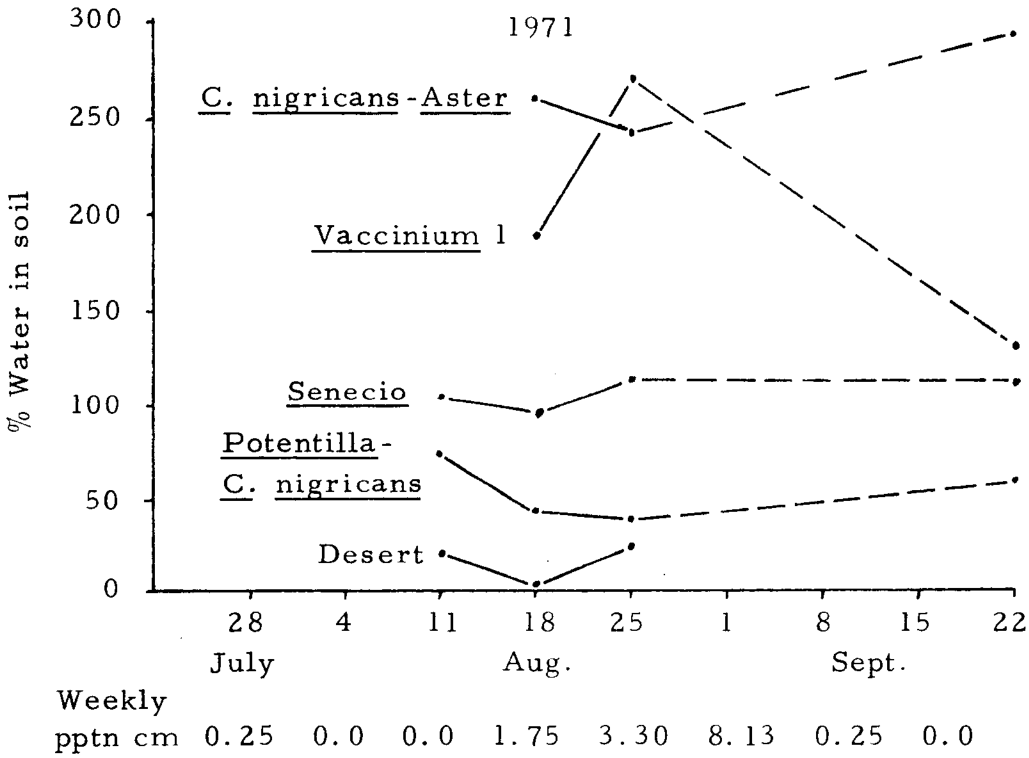
Reference macroplot R1 of the X axis is that stand having the least similarity to all of the macroplots taken as a whole. It is found by summing the columns of a stand similarity matrix and choosing that column with the lowest sum. A stand with complete dissimilarity to the first stand, that is with no species in common, is then chosen as the R2 macroplot. Reference macroplots for the second (Y) axis are chosen from macroplots clustered near the center of the X axis. Thus the pair of reference stands have little similarity to those of the first axis. R1 and R2 stands for the Y axis are those with the lowest total similarity from this group.

APPENDIX II

Community	Depth cm	pH	meq/100 gm CEC	Ca	Mg	K	Na	Total Bases	% Base Sat.	% OM	P NaHCO$_3$	P NH$_4$F	N	C/N
Phyllodoce-Cassiope	0-15	5.1	21.1	.3	.14	.11	.18	.73	3.5	11.7	14	2.3	.39	17
	15-30	5.2	13.6	.2	.86	.04	.22	1.32	9.7	8.8	18	2.3	.27	20
Vaccinium 2	0-15	4.8	45.5	.5	.35	.28	.96	2.07	4.5	26.7	5	3.5	.59	26
	15-30	4.8	24.6	.2	.09	.02	.17	.48	2.6	10.7	17	2.3	.23	28
Vaccinium 1	0-15	4.4	66.1	1.8	.87	.67	.04	3.38	5.1	42.1	7	7.0	.85	29
	15-30	5.5	36.2	.2	.14	.11	.04	.49	1.4	21.8	22	2.3	.45	28
Potentilla-C. nigricans	0-15	5.1	25.1	1.3	.28	.14	.04	1.76	7.0	14.4	32	7.0	.35	24
	15-30	5.3	14.4	.2	.07	.03	1.91	2.21	15.3	5.9	17	2.3	.16	22
C. nigricans-Aster	0-15	4.9	46.2	.6	.49	.56	.40	2.05	4.4	40.8	12	4.7	.99	24
	15-30	5.1	36.2	4.2	2.08	.62	.09	6.99	19.3	19.7	22	4.7	.74	15
Senecio	0-15	4.9	45.6	1.6	.76	.23	.22	2.81	6.2	20.7	10	2.3	.67	18
	15-30	5.1	27.0	1.4	.87	.02	.22	2.51	9.3	8.5	18	2.3	.36	14
Eleocharis-Aulacomnium	0-15	4.9	74.3	30.0	8.24	2.28	1.03	41.55	55.9	81.9	60	-	1.78	27
	15-30	4.7	73.4	18.4	4.43	.70	.43	23.96	32.6	84.6	40	-	2.02	24
C. rostrata-Sphagnum	0-15	5.2	62.7	26.3	5.94	3.16	1.26	36.76	58.6	76.2	98	-	1.81	24
	15-30	5.3	82.0	22.6	4.98	1.12	.58	29.28	35.7	82.6	26	-	1.71	28
C. scopulorum No. 1	0-15	5.2	64.6	19.7	5.20	2.21	.59	27.70	42.9	81.6	66	-	2.00	24
	15-30	5.1	68.8	18.1	4.15	1.20	.42	23.87	34.7	82.3	11	-	2.14	22
C. scopulorum No. 2	0-15	5.2	60.1	8.6	2.51	.36	.65	12.12	20.2	85.1				
	15-30	4.7	63.5	1.1	.83	.51	.36	2.80	4.4	76.9	26	-	1.64	27
C. scopulorum No. 3	0-15	5.2	52.6	2.3	1.31	.84	.96	5.41	10.3	30.6	8	-	.83	21
	15-30	4.9	48.2	2.6	1.12	.70	.18	4.60	9.5	32.0	14	-	.84	23
C. scopulorum No. 4	0-15	4.6	77.2	6.4	2.77	1.01	.29	10.47	13.6	61.2	58	-	1.90	19
	15-30	4.7	86.6	3.9	1.11	.67	.14	5.82	6.7	76.5	33	-	2.28	19
C. sitchensis	0-15	4.6	62.6	12.3	6.37	1.83	1.58	22.08	35.3	80.0	79	-	2.40	20
	15-30	5.1	68.8	8.1	3.46	1.08	2.27	14.91	21.7	81.3	46	-	2.00	23

Soil chemistry





Soil water content in sample plots in 1970 and 1971.

APPENDIX III

Species List

Vascular plants

Abies amabilis (Dougl.) Forbes
Abies lasiocarpa (Hook.) Nutt.
Abies procera Rehder
Agoseris aurantiaca (Hook.) Greene
Agoseris glauca (Pursh) Raf.
Agrostis idahoensis Nash
Agrostis thurberiana A.S. Hitch.
Agrostis variabilis Rydb.
Alnus occidentalis Wats.
Anemone occidentalis Wats.
Anemone quinquefolia L. var lyallii Robins.
Antennaria alpina (L.) Gaertn.
Aquilegia formosa Fisch.
Arabis platysperma Gray
Arnica mollis Hook.
Aster alpigenus (T. & G.) Gray
Aster ledophyllus Gray
Aster occidentalis (Nutt.) T. & G.

Boykinia major Gray

Calamagrostis canadensis (Michx.) Beauv.
Calochortus subalpinus Piper
Caltha biflora DC.
Cardamine cordifolia Gray var. Lyalli (Wats.) Nels. & Macbr.
Carex illota L.
Carex interrupta Boeck.
Carex laeviculmis Meinsh.
Carex lenticularis Michx.
Carex luzulina Olney
Carex mertensii Prescott
Carex neurophora Mackenzie
Carex nigricans C.A. Mey.
Carex praeceptorium Mackenzie
Carex rostrata Stokes ex With.
Carex scopulorum Holm.
Carex sitchensis Prescott
Carex spectabilis Dewey
Carex stylosa C.A. Mey.

Carex subfusca W. Boott. in Wats.
Cassiope mertensiana (Bong.) G. Don
Castilleja parviflora Bond., var. oreopola (Greenm.) Ownbey
Castillja suksdorfii Gray
Cicuta douglasii (DC.) Coult.
Claytonia lanceolata Pursh
Clintonia uniflora (Schult.) Kunth.
Comandra umbellata (L.) Nutt.

Delphinium nuttallianum Pritz.
Deschampsia atropurpurea (Wahlenb.) Scheele
Deschampsia caespitosa (L.) Beauv.
Dicentra formosa (Andr.) Walpers
Dodecatheon jeffreyi Van Houtte

Eleocharis pauciflora (Lightf.) Link.
Epilobium alpinum L.
Equisetum arvense L.
Eriogonum pyrolaefolium Hook. ex. A. Murr.
Eriogonum umbellatum Torr.
Eriophorum polystachion L.
Erythronium grandiflorum Pursh

Gaultheria humifusa (Grah.) Rydb.
Gaultheria ovatifolia Gray
Glyceria elata (Nash) M.E. Jones

Habenaria saccata Greene
Hieracium albiflorum Hook.
Hieracium scouleri Hook.
Hieracium gracile Hook.
Hordeum jubatum L.
Hydrophyllum fendlerii (Gray) Heller
Hypericum anagalloides C. & S.

Juncus drummondii E. Meyer in Ledeb.
Juncus ensifolius Wiks.
Juncus filiformis L.
Juncus mertensianus Bong.
Juncus parryi Engelm.
Juniperus communis L.

Ligusticum grayi Coult. and Rose
Lilium washingtonianum Kell.
Lomatium martindalei Coult. and Rose
Luetkea pectinata (Pursh) Kuntze
Luina stricta (Greene) Rob.
Lupinus latifolius Agardh.

Lupinus lepidus Dougl. ex Lindl.
Luzula parviflora (Ehrh.) Desv.
Lycopodium sitchense Rupr.
Lysichitum americanum Hulten & St. John

Mertensia paniculata (Ait.) G. Don
Microseris alpestris (Gray) Q. Jones
Mimulus lewisii Pursh
Mimulus moschatus Dougl.
Mimulus tilingii Regel
Montia cordifolia (Wats.) Pax and K. Hoffm.
Montia sibirica (L.) Howell
Muhlenbergia filiformis (Thurb.) Rydb.

Osmorhiza occidentalis (Nutt.) Torr.

Pachistima myrsinites (Pursh) Raf.
Parnassia fimbriata Konig.
Pedicularis contorta Benth.
Pedicularis groenlandica Retz.
Penstemon fruticosus (Pursh) Greene
Penstemon procerus Dougl. ex R. Grah.
Phleum alpinum L.
Phyllodoce empetriformis (Sm.) D. Don
Pinus albicaulis Engelm.
Pinus contorta Dougl.
Pinus monticola Dougl.
Poa sandbergii Vasey
Polemonium pulcherrimum Hook.
Polygonum bistortoides Pursh
Polygonum newberryi Small
Potentilla flabellifolia Hook. ex T. & G.
Puccinellia pauciflora (Presl) Munz

Raillardella argentea Gray
Ribes howellii Greene
Rubus lasiococcus Gray

Salix commutata Bebb
Salix sitchensis Sanson in Bong.
Saxifraga ferruginia Grah.
Saxifraga oregana Howell
Saxifraga punctata L.
Saxifraga tolmiei T. & G.
Scirpus congdonii Britt.
Scirpus microcarpus Presl
Senecio triangularis Hook.
Sorbus sitchensis Roemer

Spirea densiflora Nutt. ex T. & G.
Spraguea umbellata Torr. in Smith
Stellaria simcoae (Howell) C. L. Hitchc.
Stipa occidentalis Thurb.

Tofieldia glutinosa (Michx.) Pers.
Trisetum spicatum (L.) Richter
Tsuga mertensiana (Bong.) Carr.

Vaccinium deliciosum Piper
Vaccinium membranaceum Dougl. ex Hook.
Vaccinium scoparium Leib.
Vaccinium uliginosum L.
Valeriana sitchensis Bong.
Veronica wormskjoldii Roem. and Schult.
Veratrum californicum Durand
Viola glabella Nutt.
Viola macloskeyi Lloyd.

Xerophyllum tenax (Pursh) Nutt.

Bryophytes

Amblystegium serpens (Hedw.) B.S.G.
Amblystegium trichopodium var. trichopodium (Schultz) B.S.G.
Arctoa starkei (Web. & Mohr) Loeske
Aulacomnium palustre (Hedw.) Schwaegr.

Barbilophozia lycopodioides (Wallr.) Loeske
Bartramia ithyphylla Brid.
Bryum alpinum With.
Bryum creberrimum Tayl.
Bryum pseudotriquetrum (Hedw.) Gaertn.

Calliergon stramineum (Brid.) Kindb.
Cephalozia bicuspidata (L.) Dum.
Ceratodon purpureus (Hedw.) Brid.
Claopodium bolanderi Best
Cratoneuron filicinum (Hedw.) Spruce

Dicranella heteromalla (Hedw.) Schimp.
Dicranoweisia crispula var. contermina (Ren. & Card.) Grout
Drepanocladus exannulatus (B.S.G.) Warnst.
Drepanocladus uncinatus (Hedw.) Warnst.

Grimmia alpestris (Web. & Mohr) Schleich. ex Nees

Hygrohypnum ochraceum (Wils.) Loeske

Lescuraea atricha (Kindb.) Lawton

Marsupella brevissima (Dumort) Grolle

Philonotis americana (Dism.) Dism.
Philonotis fontana (Hedw.) Brid.
Pohlia drummondii (C. Muell.) Andr. in Grout
Pohlia gracilis (B.S.G.) Lindb.
Pohlia ludwigii (Schwaegr.) Broth
Polytrichum commune Hedw.
Polytrichum juniperinum Hedw.
Polytrichum norvegicum Hedw.
Polytrichum piliferum Hedw.

Rhacomitrium aciculare (Hedw.) Brid.
Rhacomitrium canescens (Hedw.) Brid.
Rhacomitrium sudeticum (Funck) B.S.G.
Rhizomnium nudum (Williams) Koponen