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SUBALPINE PLANT COMMUNITIES OF THE WESTERN NORTH CASCADES, WASHINGTON

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ABSTRACT

This paper studies the structure, composition, and pattern of the vegetation in the subalpine zone of the western North Cascades. This 7,200-km^2 area is recognized as a relatively homogeneous ecological province. Ten major plant communities occur within three general habitat types. These plant communities are the *Carex nigricans, Luetkea pectinata* (residual or regosolic phase), *Cassiope mertensiana-Phyllodoce empetriformis, Vaccinium deliciosum, Tsuga mertensiana-Abies amabilis* (immature phase), *Tsuga mertensiana-Abies amabilis* (mature phase), and *Vaccinium membranaceum-Rhododendron albiflorum* communities in the typical meadow habitat; the *Saxifraga tolmiei* and *Luetkea pectinata* (rawmark phase) communities in the rawmark meadow habitat; and the *Rubus parviflorus-Epilobium angustifolium, Valeriana sitchensis-Veratrum viride,* and *Carex spectabilis* communities in the colluvial slope meadow habitat. Soils range from the immature profiles of the rawmark meadow habitat to the well developed podzols of the typical meadow habitat. Soil pH shows a marked decrease with advanced soil development.

INTRODUCTION

In many mountainous areas the composition, structure, and pattern of plant communities and their correlation with environmental factors are well known. The subalpine zone of the Pacific Northwest, however, has received relatively little attention from ecologists until recent years. Previously most of the botanical work consisted of floristic accounts of the vegetation. This lack of synecological study is probably due to the inaccessibility, short snow-free season, and frequently unfavorable climate of the region.

The only extensive studies of subalpine vegetation in northern Washington and British Columbia are by Fonda and Bliss (1969) and Kuramoto and Bliss (1970) in the Olympic Mountains of Washington and by Brooke *et al.* (1970) in the southwestern Coast Range of British Columbia. In the western North Cascades of Washington botanical research has been very limited. Localized floristic descriptions were written by Gorman (1907), St. John and Hardin (1929), and Muenscher (1941). Franklin and Trappe (1963), who made a reconnaissance of the region, gave a brief description of the plant communities. More recently, generalized community descriptions and floristic accounts have been provided by Douglas (1969, 1971) and Douglas and Taylor (1970).

The subalpine zone is defined in this study as that area above the montane (closed) forest and below the upper limit of conifers as an upright tree form; above this tree species occur only in a dwarfed or krummholz form. This definition, although not conforming to the recent definition put forth by Löve (1970), ap-

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pears more logical for this area since the majority of plant communities associated with the krummholz are clearly more closely related to the plant communities of the alpine zone. The inclusion of krummholz within the alpine zone has also been followed by many other North American ecologists (Clausen, 1965; Bliss, 1969; and others). On a local basis the subalpine and alpine zones may also be separated with relation to general habitats. Subalpine communities are associated mainly with cirque basins and adjacent slopes while alpine communities are associated mainly with upper slopes, ridge tops, and small high plateaus. Cirque basins at these higher elevations are always engulfed by glaciers or permanent snowfields.

The boundaries of the subalpine zone in the western North Cascades are extremely irregular due to the rugged physiography. Generally the continuous forest ends at 1,280 m on northern slopes and 1,580 m on southern slopes. The upper limits of the zone are often restricted due to precipitous rocky slopes, glaciers, and snowfields. This upper limit usually occurs at about 1,820 m although the highest communities encountered were at 1,980 m on a southern aspect.

DESCRIPTION OF THE STUDY AREA

The study area comprised the western North Cascades, an area of ca. 7,200 km^2. These mountains are bounded by the Cascade Crest and Ross Lake on the east, the Fraser River on the north, Glacier Peak and the South Fork of the Stillaguamish River on the south, and the lowlands on the west (Figure 1). This region is a relatively homogeneous ecological province with respect to vegetation, geology, topography, and climate. This province, except for the changes in the southern and northeastern boundaries, is similar to the Mt. Baker province described by Franklin (1965) for the true fir-hemlock forests of the Pacific Northwest.

The North Cascades of Washington are part of the Cascade Range which parallels the Pacific Coast from California to Canada. The steep rugged mountains of the North Cascades generally vary from 2,100 to 2,700 m elevation, although the two dormant volcanoes (Glacier Peak and Mt. Baker) tower above the main range.

Western Washington has a maritime climate, characterized by wet mild winters, cool relatively dry summers, and a long frost-free season (Franklin and Dyrness, 1969). The climate of the North Cascades, however, varies considerably from west to east. The prevailing flow of air into western Washington during the fall and winter is from southwest to west, while during spring and summer it is from the northwest. Since numerous peaks separate the mountains on the western edge from those on the east side, precipitation decreases measurably in an easterly direction.

The following weather data are based on the rather limited information available from climatic station records (U.S. Weather Bureau, no dates) in the North Cascades. In the study area mean annual precipitation ranges from 2,790 mm at the Mt. Baker station (the only subalpine meteorological station in the North Cascades—elevation 1,296 m) to 1,820 mm at Diablo Dam (elevation 267 m). The Diablo Dam station is 4 km south of Sourdough Mountain on the eastern boundary of the study area. Most of the precipitation at high elevations in the region falls as snow or sleet during the fall or winter with a relatively dry season during the summer. Showers, however, are quite frequent during the summer. The average summer (June, July, and August) rainfall at the Mt. Baker station is 274 mm, whereas at Diablo Dam it is 118 mm. The mean annual temperature is 4.4°C at Mt. Baker and 9.1°C at Diablo Dam. Using a lapse rate of 1.7°C per 305 m (U.S. Weather Bureau, no dates) the mean annual temperature at 1,525 m (lower subalpine zone) on Sourdough Mountain would be approximately 2.1°C. The July means are 12.1 and 18.2°C, at Mt. Baker and Diablo Dam, respectively, and approximately 11.2°C on Sourdough Mountain (elevation 1,525 m).

METHODS

A reconnaissance of the subalpine zone of the Cascade Range from the Goat Rocks and Mt. Rainier areas to the Canadian border was made during the summer of 1967. From this survey the western North Cascades was recognized as a relatively homogeneous ecological province and tentative plant community types were delimited. The methods used for vegetative sam-

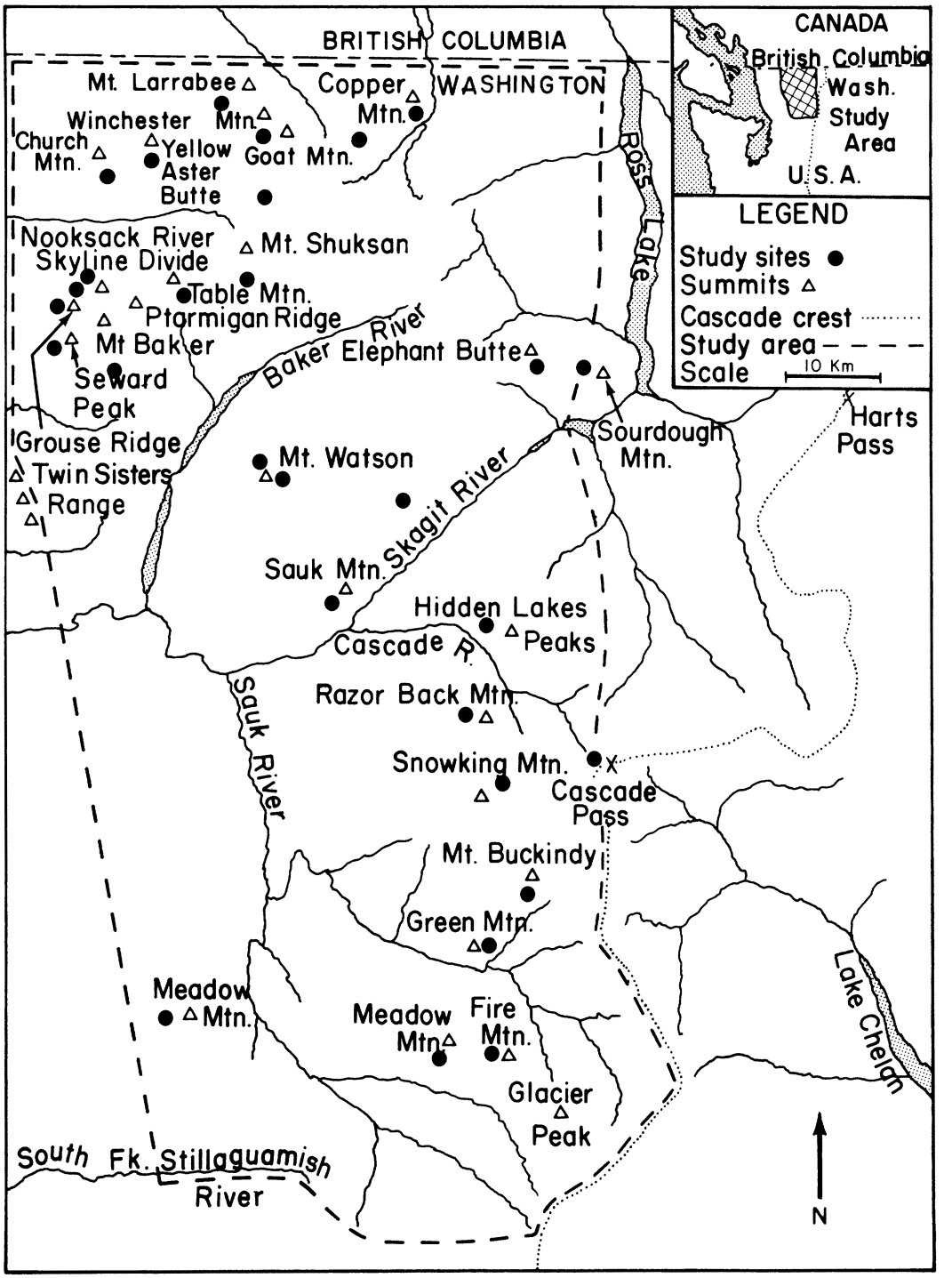

FIGURE 1. Map of the western North Cascades.

pling are similar to the "method of successive approximation" described by Poore (1962). The term "stand," in this study, refers to a particular example of vegetation which was sampled, and "community" or "community type" to a grouping of similar stands. A total of 69 stands were sampled on 28 mountains in the study area. The community types are represented by 4 to 14 sampled stands.

In examining the tree groups, or islands, the entire overstory was sampled. Circular sample plots were then placed systematically along one or more lines, depending on stand size, at 3-m intervals to obtain quantitative data on the understory vegetation. In the closed tree groups, where vegetation was sparse, 0.0001-ha plots were found to be of sufficient size based on the "minimal area" method (Cain, 1938). In more open tree groups and all other community types 0.0004-ha plots were the most adequate. The number of plots necessary, which ranged from 10 to 26, was also determined by the "minimal area" method, with the sampling being terminated well after the plateau in the species area curve had been reached.

Crown cover, using the methods of Daubenmire (1959), was estimated for all species of vascular plants, mosses, and lichens in each plot. Frequency and average percentage cover for each species were calculated and then converted to prominence values (PV) by multiplying the average percentage cover by the square root of the species frequency in each stand. This index is a modification of that used by Beals (1960). Similarity coefficients (C) between all stands were then calculated from the formula $C = 2w/(a + b) \times 100$ (Kulczyński, 1937) where w is the sum of the lowest prominence values of species common to both stands, and a and b are the total prominence values of all species in stands a and b. Species were not adjusted in relation to their maximum values of frequency and cover as in Bray and Curtis (1957). Dissimilarity values ($1 - C$) were then computed and used in the construction of a two-dimensional ordination (Bray and Curtis, 1957; Beals, 1960).

Soil pits were opened within each sampled stand and profiles described following the U.S.D.A. Soil Survey Manual (1951, 1962). Soil texture was evaluated in the field. Composite samples of each horizon were taken for later pH analysis. Soil pH was determined using the glass electrode method on 1:2 soil-to-water mixtures. Soil color was decribed for moist soil using the Munsell Color Charts in natural light.

Nomenclature follows that of Hitchcock *et al.* (1955, 1959, 1961, 1964, 1969) for the vascular plants, Lawton (1965) for mosses, and Hale and Culberson (1970) for lichens. In the text only the binomial is used for any plant having just one variant in the North Cascades. A full set of voucher specimens is in my private collection. Partial sets are in the New York Botanical Garden, U.S. Forest Service, and University of Washington herbaria.

RESULTS

Plant Communities

In the subalpine zone of the western North Cascades the major plant communities are usually sharply delineated and create a complex mosaic on the landscape. Ten major community types, decided upon by grouping of the stand tables, are described below for three general habitat types. Two of the community types (*Luetkea pectinata* and *Tsuga mertensiana-Abies amabilis*) have more than one phase.

A two-dimensional ordination was constructed to illustrate the pattern of distribution of the community types (Figure 2). Although the ordination is constructed from only dissimilarity values of species between sampled stands, the stand groupings do indicate some general environmental relationships.

Typical Meadow Habitat

This habitat occurs on all aspects and on hydric to mesic residual, regosolic, or lacustrine soils. Six of the major communities are found in this habitat type between 1,250 m and 1,950 m elevation.

Carex Nigricans *Community.* Filled-in or partially filled-in lakes, and relatively poorly drained depressions and level areas are typical sites of this community. These snowbed sites often remain covered with snow until late July or mid-August. In areas where there is abundant surface runoff from the slopes above, snow may disappear by June although surface water remains well into the summer. With the late snow melt and frequent rains, soils remain relatively moist for most of the summer.

An average of 14 species per stand (45 in total) occurs in this type. *Carex nigricans* C. A. Mey. forms a thick mat and is dominance is indicated by its high average cover (80%)

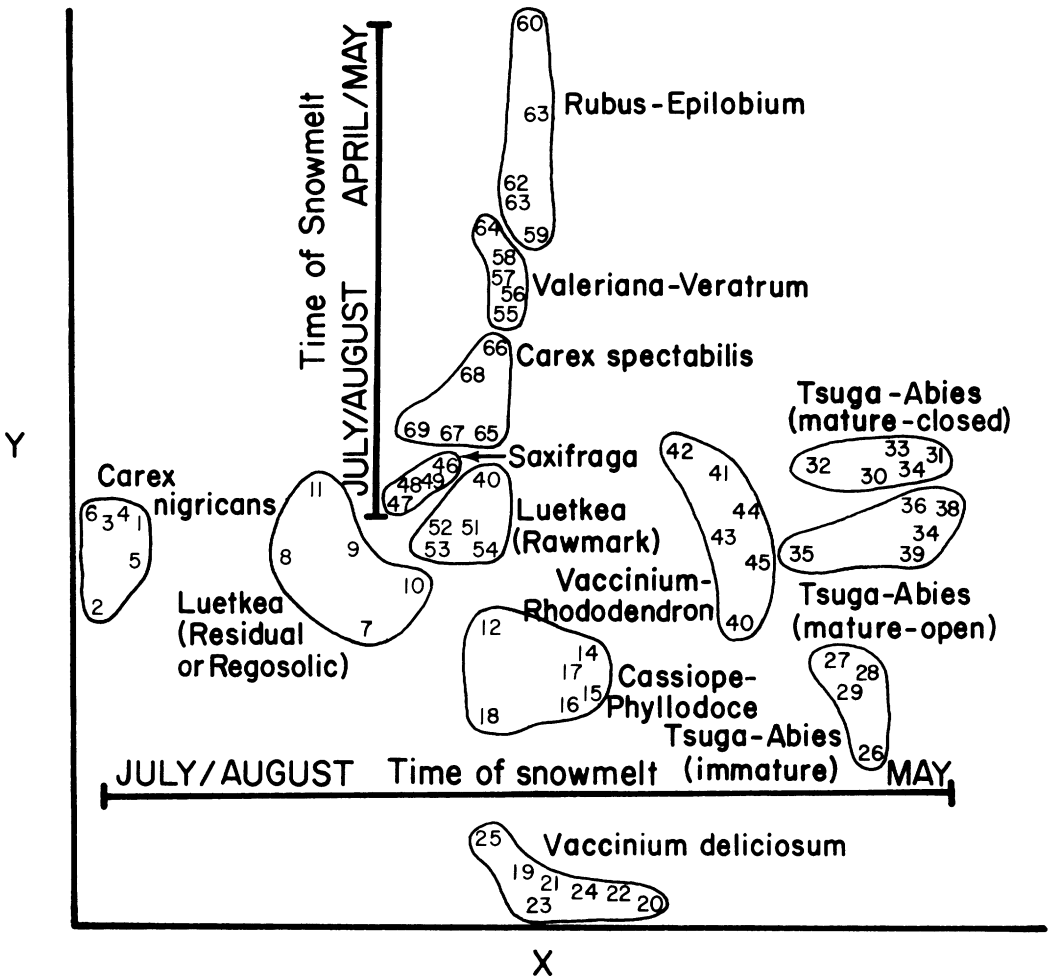

FIGURE 2. Ordination of 69 stands sampled in the subalpine zone. Lines delimit community types whose names are derived from the dominant species.

and frequency (100%). *Epilobium alpinum* L. var. *alpinum* and *Luetkea pectinata* (Pursh) Kuntze, while often present, are of low prominence (Table 1). Important bryophytes in the community are *Pogonatum alpinum* (Hedw.) Roel and *Polytrichadelphus lyallii* Mitt.

Luetkea Pectinata (*Residual or Regosolic Phase*) *Community*. This phase of the Luetkea community occurs on moist, relatively poorly drained slopes and flat areas. It reaches its best development adjacent to the *Carex nigricans* community type. Surface water usually does not accumulate on sites occupied by the *Luetkea* community and the snow-free season is from 1 to 4 weeks longer than that of the *Carex nigricans* community.

This community is floristically rich, with a total of 48 species and an average of 20 per stand. *Luetkea pectinata,* with a mean cover of 50% and a frequency of 100%, is the only dominant species in this type but has a large number of associates. Some of the more important are *Deschampsia atropurpurea* (Wahlenb.) Scheele, *Valeriana sitchensis* Bong., *Carex spectabilis* Dewey, *C. nigricans, Hieracium gracile* Hook., and *Vaccinium deliciosum* Piper. Frequent mosses in the community are *Polytrichadelphus lyallii, Pogonatum alpinum,* and *Dicranum* sp.

Cassiope Mertensiana-Phyllodoce Empetriformis *Community*. This community type is found on poor to fairly well drained moist slopes and ridges. The snow-free season may vary greatly, especially with regard to slope

and aspect. Steep southerly sites may be free of snow by early June, whereas sites with moderate slopes and northerly aspects may remain covered until late July.

Forty-six species (17 per stand) occur in this community. *Cassiope mertensiana* (Bong.) G. Don and *Phyllodoce empetriformis* (Sw.) D. Don form a dense overstory and are the most prominent species in the community with average cover values of 45 and 33%, respectively. *Vaccinium deliciosum* and *Luetkea pectinata* occur with high frequency and relatively low cover. In openings between the heath mat *Lycopodium sitchense* Rupr. and *Deschampsia atropurpurea* appear frequently. *Dicranum fuscescens* Turn., *Rhacomitrium* sp., and *Cladonia* sp. are conspicuous cryptogams in the community.

Vaccinium Deliciosum *Community*. The habitat or site preference and length of snow duration in this community are quite similar to that of the *Cassiope-Phyllodoce* community. The ecological differences, although markedly influencing the composition and structure of these types, were too subtle to detect at the level of the present study. Brooke *et al.* (1970), in the Coast Range of British Columbia, attributed the differences to a 1- to 3-week longer snow-free period for the *Vaccinium deliciosum* community. In the western North Cascades, however, instances were noted where *Cassiope-Phyllodoce* communities were snow-free earlier than adjacent *Vaccinium deliciosum* communities.

A total of 42 species (12 per stand) are found in this community type. The dominant species is *Vaccinium deliciosum,* which occurs with an average cover of 69% and a frequency of 100%. Frequent associates are *Phyllodoce empetriformis* and *Luetkea pectinata,* while *Dicranum fuscescens* is an important moss in most stands.

Tsuga Mertensiana-Abies Amabilis (*Immature Phase*) *Community*. This phase of the *Tsuga-Abies* community is most often found invading the *Cassiope-Phyllodoce* or *Vaccinium deliciosum* community types on ridges, mounds, or upper slopes. During the initial years of establishment snow duration is comparable to the latter units but as tree heights increase snow melt is initiated earlier, thus resulting in longer snow-free periods.

An average of 14 species per stand (32 in total) occurs in this community. *Tsuga mertensiana* (Bong.) Carr. forms a dominant upper (sapling) layer with a mean cover of 57% and a frequency of 100%. Typical associates persisting from the previous communities are *Vaccinium deliciosum, Phyllodoce empetriformis, Luetkea pectinata,* and *Cassiope mertensiana.* Probably because of the longer growing season and more favorable microenvironment, *Vaccinium membranaceum* Dougl. ex Hook., *Abies amabilis* (Dougl.) Forbes, *A. lasiocarpa* (Hook.) Nutt., *Sorbus sitchensis* Roemer var. *grayi* (Wenzig) C. L. Hitchc., and *S. sitchensis* var. *sitchensis* may be found invading the community. Important bryophytes in the community are *Dicranum fuscescens* and *D. pallidisetum* (Bailey) Irel.

Tsuga Mertensiana-Abies Amabilis (*Mature Phase*) *Community*. Communities of this type occur on the relatively mesic, well drained mounds, ridges, and upper slopes of the typical meadow habitat. Except for the *Rubus parviflorus-Epilobium angustifolium* community and ridges and rock outcrops of southerly aspects, this is the first major vegetation unit to become free of snow. The snow usually begins to disappear sometime in May.

The *Tsuga-Abies* (mature phase) community varies greatly with respect to composition and structure and may occur either as a small group of several specimens or larger groups covering areas up to 0.4 ha in size. It may form either closed or open communities, the closed having branches extending to the ground while the open are branchless for several meters above the ground.

Floristically, the mature phase of the *Tsuga-Abies* community is the poorest of the major plant communities in the western North Cascades with an average of 8 species per stand for both the open and closed groups (a total of 15 and 21, respectively). *Tsuga mertensiana* is usually the dominant species while *Abies amabilis* is a major associate. The former has an average overstory cover of 71% (open communities) and 41% (closed communities) while *A. amabilis* has an average overstory cover of 9% (open communities) and 10% (closed communities). *Abies lasiocarpa* and *Chamaecyparis nootkatensis* (D. Don) Spach occur infrequently in this community type throughout the study area. The understory differs immensely depending on the openness of the community. In open communities an understory resembling the *Vaccinium membrana-*

ceum-Rhododendron albiflorum community is found. In these open groups the most important tall shrubs and saplings are *Vaccinium membranaceum, Abies amabilis,* and *Tsuga mertensiana. Phyllodoce empetriformis* and *Luetkea pectinata* are frequent in the low shrub layer and *Dicranum fuscescens* is an important bryophyte. In the closed stands of tree islands the understory is much sparser, indicated by the low prominence value of the most abundant species *Luxula wahlenbergii* Rupr. (*PV* 40).

Vaccinium Membranaceum - Rhododendron Albiflorum *Community.* After the *Tsuga-Abies* community becomes established a number of tall shrubs usually develop around the periphery. This peripheral band, the *Vaccinium-Rhododendron* community, increases in size as the tree groups expand.

Forty-one species (16 per stand) occur in this community type. *Vaccinium membranaceum,* which has a frequency of 95% and a mean cover of 39%, is the most prominent species. Although less frequent, *Rhododendron albiflorum* Hook. also has a relatively high average cover of 26%. Other characteristic tall shrubs are *Sorbus sitchensis* var. *grayi* and *Menziesia ferruginea* Smith. *Phyllodoce empetriformis* and *Vaccinium deliciosum,* major components of the communities which the *Vaccinium-Rhododendron* community invades, are important in the low shrub layer. The most abundant moss is *Dicranum fuscescens.*

Rawmark Meadow Habitat

The second habitat type within which major plant communities occur in the study area is the rawmark meadow habitat. Rawmark soils are poorly developed because of soil movement and were first described in Europe by Kubiena (1953). On northerly aspects in the study area these soils are often associated with recent glacial moraines. The habitat is characterized by short snow-free periods, moist soils, and the lack of a closed vegetative cover. The *Saxifraga tolmiei* and *Luetkea pectinata* (rawmark phase) communities occur in the habitat.

Saxifraga Tolmiei *Community.* This community is found on gentle to steep northerly slopes which are poorly to fairly well drained. These sites have an extremely short snow-free season, with snow usually remaining until sometime in late July or August. Meltwater from nearby snowbanks maintains constantly moist soils throughout the growing season.

An average of 11 species per stand (28 in total) occurs in this community. Total plant cover is low and averages only 20%. *Saxifraga tolmiei* T. & G. and *Luzula wahlenbergii* are the only constant species with frequencies of 98 and 82% and mean covers of 8 and 5%, respectively. *Polytrichadelphus lyallii,* with relatively low frequency and cover values, is the only important cryptogam. The plants of this community are often established on the downhill sides of rocks where soils are more stable.

Luetkea Pectinata (*Rawmark Phase*) *Community.* Northerly, fairly well drained, steep to moderate slopes are the typical site of this phase of the *Luetkea* community type in the western North Cascades. The short snow-free season is from 2 to 4 weeks longer than that of the *Saxifraga* community type.

The major floristic and structural differences between the two phases of the *Luetkea* community are the inclusion of many elements of the *Saxifraga* community type and the patches of bare ground or rocks typical of the rawmark phase. Total vegetative cover is 83% of which 46% is contributed by the sole dominant *Luetkea pectinata.* Other prominent associates are *Carex spectabilis* and *Luzula wahlenbergii.* Conspicuous mosses in the community are *Dicranella heteromalla* (Hedw.) Schimp., *Rhacomitrium canescens* Brid. var. *epilosum* (H. Muell.) Milde, and *Polytrichum norvegicum* Hedw.

Colluvial Slope Meadow Habitat

The third habitat type recognized in this study is the colluvial slope meadow habitat. The mesic residual or regosolic soils of these steep southerly slopes support a lush plant cover. Three of the major community types are typical of this habitat.

Rubus Parviflorus-Epilobium Angustifolium *Community.* In contrast to the relatively small stands of other subalpine community types the *Rubus-Epilobium* community may encompass extremely large areas. It may occur over horizontal distances of up to 2.5 km and altitudinal ranges of up to 600 m. The community is common on steep slopes and avalanche tracks between 1,500 and 1,800 m elevation. Snow duration is the shortest of all major community types with slopes becoming snow-free anytime from April to May. Soils in this community type are very well drained.

Floristically, this is the richest community type in the subalpine zone, with an average of 32 species per stand and a total of 70 tallied. Many of these species are major components and form a dense cover. Prominent species with *PV* values between 256 and 58 are *Rubus parviflorus* Nutt., *Epilobium angustifolium* L., *Valeriana sitchensis* Bong., *Pteridium aquilinum* (L.) Kuhn, *Veratrum viride* Ait., *Viola glabella* Nutt., *Heracleum lanatum* Michx., *Thalictrum occidentale* Gray, and *Hydrophyllum fendleri* (Gray) Heller var. *fendleri*. The presence of many species more typical of lower elevations in the *Rubus-Epilobium* community reflect the more favorable habitat in the subalpine zone.

This community shows distinctive periods of aspect dominance. Continuous snow creep during the winter removes virtually all of the aboveground parts of the numerous species and with the first disappearance of snow in the spring *Claytonia lanceolata* Pursh and *Erythronium grandiflorum* Pursh dominate the slopes. Shortly thereafter most of the final dominants begin to make their appearance. Several of the more important species such as *Epilobium angustifolium* and *Pteridium aquilinum* do not attain their full vegetative development until midsummer. Some plants (i.e., *Solidago canadensis* L., *Artemisia ludoviciana* Nutt. var. *latiloba* Nutt., and *A. norvegica* Fries) do not become conspicuous until later summer.

Valeriana Sitchensis-Veratrum Viride *Community*. This lush herbaceous community is physiognomically similar to the *Rubus-Epilobium* community although species richness, an average of 10 per stand (21 in total), is much lower. The soils are not as well drained and snow duration is longer, the snow not leaving until early May or late June. Individual stands are also smaller and extend to higher (1,900 m) elevations.

Valeriana sitchensis and *Veratrum viride*, the dominant species, are considerably more important in this community (average cover 32 and 29%, respectively) than in the *Rubus-Epilobium* community (average cover 14 and 6%, respectively). *Lupinus latifolius* Agardh var. *subalpinus* (Piper & Robbins) C. P. Smith, *Carex spectabilis*, *Mitella breweri* Gray, and *Polygonum bistortoides* Pursh are other prominent species in this community.

Carex Spectabilis *Community*. This community occurs on sites similar to those of the *Valeriana-Veratrum* community type, as well as on more level terrain near the base of colluvial slopes. Snow duration and soil drainage is also comparable.

Species richness is low with an average of 9 per stand (30 in total). *Carex spectabilis* is the sole dominant and occurs with 100% frequency and 78% mean cover. Other prominent species in the type are *Lupinus latifolius* var. *subalpinus* and *Polygonum bistortoides*.

Soils

The soils of the three general meadow habitats, as with the vegetation, are markedly different. These differences are described below for each habitat. Morphologic descriptions of some of the more important soils are presented in the Appendix.

Typical Meadow Habitat

In the typical meadow habitat soil development appears to be closely correlated with snow duration and the soil moisture gradient. The most poorly developed soils occur in the *Carex nigricans* community where snow duration is long and soils remain moist. Soils with more profile development are associated with the *Tsuga-Abies* community where snow release is early and soils are mesic.

The *Carex nigricans* community occurs on poorly drained residual, regosolic, or lacustrine soils. The upper horizons in these soil profiles consist of partially to well-decomposed mosses and herbs. B horizons are usually lacking and A-C profiles are common; lithological discontinuities consisting of volcanic ash and other depositional layers may also be present. In the description of a lacustrine soil (Profile 9 in Appendix) the XI C horizon was determined as Mt. Mazama ash (J. G. Bockheim and A. K. Schlichte, pers. comm., 1969) and previously dated at about 6,600 years BP by Rubin and Alexander (1960), Powers and Wilcox (1964), and Fryxell (1965). *Carex nigricans* soils are the least acid (pH 4.8 to 5.8) of the typical meadow habitat soils.

Increased depth of the A1 horizon and the appearance of a B horizon indicate that the soils in the *Luetkea* (residual or regosolic community) are better developed. Soil pH (4.6 to 5.6) is also lower in this type. Profile 10 (Appendix) was located on a slight slope about 6 m away and 3 m higher than Profile 9 (Appendix).

The soils of the *Cassiope-Phyllodoce*, *Vaccinium deliciosum*, and *Tsuga-Abies* (immature

phase) communities are quite similar. These residual or regosolic soils range from poor to relatively well drained. Well-developed A and B horizons are characteristic and are often superimposed over volcanic or other unconsolodated C horizons. A light, weakly developed A2 horizon may also be present in some profiles (*see* Profile 5 in Appendix). The soil pH (4.0 to 5.4) is lower in these community types than in the *Carex nigricans* or *Luetkea* (residual or regosolic phase) community types.

On the more mesic sites where the *Tsuga-Abies* (mature phase) community is found soil differences become quite marked. Deep O horizons, consisting mainly of undecomposed forest litter, are present. A well-developed A2 horizon appears in most soil profiles (*see* Profile 13 in Appendix). It should be recognized, however, that the A2 horizons encountered in the podzolic profiles may be, in some instances, actually recent depositions of volcanic ash that have the general characteristics of A2 horizons and appear in the same position in the soil profile (Franklin, 1965). The soils of the *Tsuga-Abies* community are the most acid (pH 3.7 to 5.2) of all soils examined in the subalpine zone.

Rawmark Meadow Habitat

Soils of the rawmark meadow habitat are characterized by poorly drained immature profiles and are less acid (pH 5.0 to 5.6). Only C horizons are present except where the sparse vegetation enables a thin surficial A1 horizon to form. In the *Luetkea* (rawmark phase) community, where vegetative cover is greater, the A1 horizon is usually thicker than that found beneath vegetation in the *Saxifraga* community. Profile 14 (Appendix) was described from a nonvegetated area in a *Saxifraga* community.

Colluvial Slope Meadow Habitat

Deep, moist, well drained residual or regosolic soils are typical of the colluvial slope meadow habitats. The continuous snow-creep on these steep slopes and avalanche tracks often prevent O or A horizons from reaching full development. These colluvial slopes, however, usually attain enough stability for soil formation to take place, with A-B-C profiles being characteristic. B horizons are usually deep with poorly defined subhorizons. Soil pH (5.0 to 5.6) is higher here than in the typical meadow habitat. A pH inversion in some of these soil profiles (*see* Profile 1 in Appendix) is probably attributed to meltwater bearing bases leached from the more acid soils on the higher slopes.

Soil profiles are usually quite similar in the *Rubus-Epilobium, Valeriana-Veratrum,* and *Carex spectabilis* communities. The most notable difference is the greater depth of root penetration in the *Rubus-Epilobium* community. In some instances the *Carex spectabilis* community occurs on relatively shallow soils.

TABLE 1

Mean prominence values of species in the major community types of the subalpine zone[a,b]

Layer and Species	Community Type[c]												
	CM (6)	LP (5)	CP (7)	VD (7)	TY (4)	TC (5)	TO (5)	VR (6)	ST (5)	LR (4)	RE (5)	VV (5)	CS (5)
Trees—dominant													
Tsuga mertensiana (Bong.) Carr.						271	687						
Abies amabilis (Dougl.) Forbes						51	43						
Chamaecyparis nootkatensis (D. Don) Spach							61						
Trees—intermediate													
Tsuga mertensiana						351	140						
Abies amabilis						271	15						
Chamaecyparis nootkatensis							5						
Tall Shrubs and Saplings													
Tsuga mertensiana					451	1	54	16					
Abies amabilis					4	3	37	6					

TABLE 1 (cont.)

Layer and Species	Community Type[c]												
	CM (6)	LP (5)	CP (7)	VD (7)	TY (4)	TC (5)	TO (5)	VR (6)	ST (5)	LR (4)	RE (5)	VV (5)	CS (5)
Tall Shrubs and Saplings (cont.)													
Vaccinium membranaceum Dougl. ex Hook					1	4	272	377					
Sorbus sitchensis Roemer var. *grayi* (Wenzig) C. L. Hitchc.					1	1	3	53					
Rhododendron albiflorum Hook.						2	3	210					
Ribes howellii Greene						T		7					
Menziesia ferruginea Smith var. *ferruginea*							22	45					
Vaccinium ovalifolium Smith								17					
Low Shrubs and Herbs													
Carex nigricans C. A. Mey.	803	13	2	4	2	T			1	6			16
Epilobium alpinum L. var. *alpinum*	32	10						T	3	6		T	T
Luetkea pectinata (Pursh) Kuntze	21	502	73	71	42	1	23	2		462			2
Deschampsia atropurpurea (Wahlenb.) Scheele var. *latifolia* (Hook.) Scribn.	15	44	9	5	6	T		T	1	6		T	T
Cassiope mertensiana (Bong.) G. Don var. *mertensiana*	11	11	441	8	37	T		1	T	1			
Carex spectabilis Dewey	6	41	1	4	T	T		1	2	80	5	52	782
Juncus drummondii E. Meyer var. *subtriflorus*	5	6							1	11			
Leptarrhena pyrolifolia (D. Don) R. Br. ex Ser.	4	T								9			
Hieracium gracile Hook.	3	36	3	8	T				4	16			1
Phyllodoce empetriformis (Sw.) D. Don	2	15	386	78	135	T	78	41	1	1			
Luzula wahlenbergii Rupr.	2	10			T	40			47	29			
Potentilla flabellifolia Hook. ex T. & G.	1	13		1				1		T		4	7
Vaccinium deliciosum Piper	T	21	92	689	193		3	35	T	1		T	
Saxifraga tolmiei T. & G. var. *tolmiei*	T								78	15			
Lycopodium sitchense Rupr.	T	16	16	2	1			4					
Castilleja parviflora Bong. var. *albida* (Penn.) Ownbey	T	16	T	2	T				4	5			
Polygonum bistortoides Pursh	T	9	1	10							8	27	30
Valeriana sitchensis Bong.		47	5	14	T	2		7	T	2	127	305	15
Anemone occidentalis Wats.		11	T						T				2
Erythronium grandiflorum Pursh var. *grandiflorum*		2									9	6	5
Mitella breweri Gray		1		1		T		T			4	32	T
Ranunculus eschscholtzii Schlect. var. *suksdorfii* (Gray) Benson		1								8			
Veronica wormskjoldii Roem. & Schult.		1								5			
Veratrum viride Ait.		T		T							58	290	2
Abies lasiocarpa (Hook.) Nutt.		6	T										
Lupinus latifolius Agardh var. *subalpinus* (Piper & Robbins) C. P. Smith			4			T		1			25	59	42
Epilobium angustifolium L.				T				6			161	12	8
Rubus lasiococcus Gray						6		5					
Rubus pedatus J. E. Smith							6	24					

TABLE 1 (cont.)

Layer and Species	Community Type[c]												
	CM (6)	LP (5)	CP (7)	VD (7)	TY (4)	TC (5)	TO (5)	VR (6)	ST (5)	LR (4)	RE (5)	VV (5)	CS (5)
Low Shrubs and Herbs (cont.)													
Juncus mertensianus Bong.										10			
Athyrium distentifolium Tausch ex. Opiz var. *americanum* (Butters) Cronq.										7	T		
Saxifraga lyallii Engl. var. *lyallii*										7			
Rubus parviflorus Nutt. var. *parviflorus*											256	1	
Pteridium aquilinum (L.) Kuhn ssp. *aquilinum* var. *pubescens* Underw.											154		
Viola glabella Nutt.											105	5	7
Heracleum lanatum Michx.											80	6	T
Thalictrum occidentale Gray											78		
Hydrophyllum fendleri (Gray) Heller var. *fendleri*											71		
Lathyrus nevadensis Wats. ssp. *lanceolatus* (Howell) C. L. Hitchc. var. *pilosellus* (Peck) C. L. Hitchc.											27		
Elymus hirsutus Presl.											24		
Aster engelmannii (Eat.) Gray											23		
Disporum smithii (Hook.) Piper											21		
Angelica arguta Nutt.											15		
Saussurea americana Eat.											15		
Bromus carinatus Hook. & Arn. var. *carinatus*											13		
Galium triflorum Michx.											11		
Arenaria macrophylla Hook.											10		
Aruncus sylvester Kostel											8		
Tellima grandiflora (Pursh) Dougl.											8		
Aquilegia formosa Fisch.											7		
Anaphalis margaritacea (L.) B. & H.											6		
Smilicina stellata (L.) Desf.											6		
Lilium columbianum Hanson											5		
Fragaria virginiana Duncesne var. *platypetala* (Rydb.) Hall											5		
Senecio triangularis Hook.											T	6	
Aster foliaceous Lindl. var. *foliaceous*													7
Mosses and Lichens													
Polytrichadelphus lyallii Mitt.	17	44		4				T	7	3			
Pogonatum alpinum (Hedw.) Roël	16	22											
Polytrichum norvegicum Hedw.	13	T								14			
Dicranum sp.	13	22							3				
Lecidia granulosa (Ehrh.) Ach.	2	1	7					T					
Cladonia chlorophaea (Flörke ex Somm.) Spreng.	2	2	5		T			2					
Rhacomitrium canescens Brid. var. *epilosum* (H. Muell.) Milde	1	1	1					1		16			
Rhacomitrium sp.	1		37						4				
Dicranum fuscenscens Turn.		1	41	50	28	5	40	40					
Cladonia sp.			37										
Solorina crocea (L.) Ach.			6						T				
Rhytidiopsis robusta (Hook.) Broth.			1	T	T		73	2		T			

TABLE 1 (cont.)

Layer and Species	Community Type[c]												
	CM (6)	LP (5)	CP (7)	VD (7)	TY (4)	TC (5)	TO (5)	VR (6)	ST (5)	LR (4)	RE (5)	VV (5)	CS (5)
Mosses and Lichens (cont.)													
Brachythecium asperrimum (Mitt.) Sull.				3							22	1	
Dicranum pallidisetum (Bailey) Irel.					40								
Dicranella heteromalla (Hedw.) Schimp.										24			
Cover (%)													
Trees—dominant						51	85						
Trees—intermediate						55	21						
Tall Shrubs and Saplings					57	2	49	91					
Low Shrubs and Herbs	96	88	102	94	46	7	14	16	17	76	160	84	98
Mosses and Lichens	11	13	18	10	8	1	14	3	3	7	2	1	

[a]Only species with a prominence value of five, or more, in at least one community type are included in this table.

[b]Abbreviations: CN—*Carex nigricans,* LP—*Luetkea pectinata* (residual or regosolic phase), CP—*Cassiope mertensiana-Phyllodoce empetriformis,* VD—*Vaccinium deliciosum,* TY—*Tsuga mertensiana-Abies amabilis* (immature phase), TC—*Tsuga mertensiana-Abies amabilis* (mature phase—closed groups), VR—*Vaccinium membranaceum-Rhododendron albiflorum,* ST—*Saxifraga tolmiei,* LR—*Luetkea pectinata* (rawmark phase), RE—*Rubus parviflorus-Epilobium angustifolium,* VV—*Valeriana sitchensis-Veratrum viride,* CS—*Carex spectabilis*; T (trace) indicates a prominence value of less than 0.5.

[c]Number of stands sampled are enclosed in parentheses.

DISCUSSION

COMMUNITY PATTERN

The patterns of plant communities are dependent on a complexity of environmental factors and environmental gradients. In the subalpine zone of the western North Cascades community pattern is regulated in large part by snow depth, time of snow release, and summer soil moisture.

In the plant communities of the typical meadow habitat the importance of these factors is readily evident. The abrupt changes in species composition, however, which results in the recognition of the various communities in this habitat, would infer a steeper environmental gradient than appears to exist. The pattern of these community types is one which is repeated continuously throughout the study area.

On concave or level sites high snow accumulation, length of snow-free season, and the moist soils favor only the *Carex nigricans* community. Gentle slopes with earlier snow release and moist but seldom saturated soils, are characteristic of the *Luetkea* community. Heath-dominated communities (*Cassiope-Phyllodoce* and *Vaccinium deliciosum*) prevail on steeper slopes, mounds, and ridges. The *Cassiope-Phyllodoce* community is the most widespread community in the western North Cascades. The *Vaccinium deliciosum* community occurs mainly as large bands around the *Tsuga-Abies* (mature phase) community. Within the heath communities, on relatively well drained sites, the *Tsuga-Abies* (immature phase) community may become established. This establishment may be due to the occurrence of several consecutive years of low snow accumulation and longer growing seasons (Franklin *et al.,* 1971). Another possibility might be the occurrence of moderate early-season temperatures, favoring seedlings that may otherwise be killed by lethal soil temperatures (as high as 49°C [Ballard, 1972]) attained on exposed areas during the early part of the growing season. The *Tsuga-Abies* community occupies the most mesic sites within the typical meadow habitat and because of the lower snow depths and "black body" effect of the trees has the longest snow-free season (5 to 6 months). The immediate periphery of the tree groups provides a more favorable microenvironment thus enabling a number of tall shrubs (*Vaccinium-Rhododendron* com-

munity) to become established. Slope aspect and local topography in the typical meadow habitat not only influences snow accumulation but also results in varying dates of snow release for communities of the same type.

The two remaining habitat types, the rawmark meadow habitat and the colluvial slope meadow habitat, are dependent on slope aspect to a greater degree than in the typical meadow habitat. On northerly slopes, where snow accumulation is high and snow-free periods are extremely short, the rawmark meadow habitat supports a relatively sparse plant cover. The *Saxifraga* community is characteristic of these harsh sites. With earlier snow release and better drainage communities in this habitat are dominated by *Luetkea pectinata.*

The community types of the colluvial slope meadow habitat are markedly different than those found in other subalpine habitat types. The lower snow depth and earlier snowmelt on these steep southerly slopes and avalanche tracks result in a dense herbaceous cover. The *Rubus-Epilobium* community, which has the longest snow-free period in the subalpine zone is also the richest floristically, the result of a habitat that enables a number of lower elevation species to become established. With greater snow accumulation, later snow release, and an increase in soil moisture *Valeriana-Veratrum* and *Carex spectabilis* communities predominate in this habitat.

Community-Soil Relationships

The pattern of subalpine soil types occurring in the western North Cascades is closely correlated with the pattern of the plant communities. This reflects the dependence of the soils, to a large degree, on the composition and structure of the vegetation. In the typical meadow habitat the poorly drained soils of the *Carex nigricans* community are the least developed, with A-C profiles being typical. On better drained sites supporting the *Luetkea* (residual or regosolic phase), *Cassiope-Phyllodoce, Vaccinium deliciosum,* and *Tsuga-Abies* (immature phase) communities A-B-C profiles develop. The well drained podzolic soils of the *Tsuga-Abies* (mature phase) community illustrate the greatest profile development in the zone. In contrast the colluvial slope meadow habitat supports communities with soils having similar profile development. These soils usually attain only enough stability for weak A-B-C profiles to develop. In the rawmark meadow habitat the sparse plant cover results in a shallow surficial A horizon beneath the vegetation. Soils of this habitat are the most poorly developed of any in the subalpine.

Comparisons with Other Studies in the Pacific Northwest

Community pattern and floristic relationships, in many instances, are quite similar between the North Cascades and the Coast Range Mountains of British Columbia, the Olympic Mountains of Washington, and the Cascade Range of Oregon and southern Washington. These affinities, as well as those with the montane and alpine zones of the North Cascades (from the work of Douglas [1969, unpublished]), are discussed below.

Carex Nigricans *Community*

Carex nigricans is a widespread species on the Pacific Coast, occurring from the Sierra Nevada Mountains in central California (Munz, 1959) to southeast Alaska (Hultén, 1968). In the western North Cascades the *Carex nigricans* community is a frequent and conspicuous vegetation unit in both the subalpine and alpine zones. Major differences between the community in the two zones are the longer snow-free season and the substitution of subalpine elements with alpine elements in the alpine zone.

An almost identical community has been reported from the subalpine and alpine regions of the Coast Range in southern British Columbia (Archer, 1963; Brooke *et al.,* 1970). Bliss (1969) and Kuramoto and Bliss (1970) described similar alpine and subalpine communities in the Olympic Mountains. A wet meadow type dominated by *Carex nigricans* was also documented in the Three Sisters area of Oregon (Van Vechten, 1970). The most northern occurrence of this type is probably that described by Cooper (1942) in the Prince William Sound region of southeastern Alaska although *Carex limosa* L. and *Sphagnum* sp. were also important species.

Luetkea Pectinata *Community*

Luetkea pectinata is one of the most prevelant of all subalpine species in the western North Cascades. It occurs in various habitats, ranging from hydric to relatively xeric. It is also a component of almost all other community types in the subalpine zone (Table 1) as well as many in the alpine zone.

The two phases of the *Luetkea* community

type, although found throughout the study area, are one of the less common plant communities in the western North Cascades. The only other area on the Pacific Coast where a similar vegetation unit has been described is the Bella Coola region of British Columbia where McAvoy (1931) gave accounts of a *Spiraea pectinata* (*Luetkea pectinata*) community established in wet areas of both the subalpine and alpine zone. Many workers, from Alaska to Oregon, report the species as a frequent component of numerous subalpine and alpine communities (Brink, 1959; Heusser, 1960; Van Vechten, 1960; Archer, 1963; Hickman, 1968; Brooke *et al.*, 1970; Kuramoto and Bliss, 1970).

Cassiope Mertensiana-Phyllodoce Empetriformis *Community*

This is one of the most widespread communities in the study area. In the alpine zone of the western North Cascades this vegetation unit as well as other closely related communities (dominated mainly by *Phyllodoce glanduliflora* (Hook.) Colville) are also important.

The *Cassiope-Phyllodoce* community is one of the most far-ranging communities on the Pacific Coast. Similar heath communities have been reported from the Bella Coola region (McAvoy, 1931), the Coast Range of southern British Columbia (Brink, 1959; Archer, 1963; Brooke *et al.*, 1970), the Olympic Mountains (Kuramoto and Bliss, 1970), Mt. Rainier (Franklin *et al.*, 1971), and the Oregon Cascades (Van Vechten, 1960).

Vaccinium Deliciosum *Community*

The geographical range of *Vaccinium deliciosum* is relatively limited, known only from southern British Columbia to northern Oregon (Hitchcock *et al.*, 1959). This community type has previously been reported only from the Coast Range of British Columbia (Brooke *et al.*, 1970). In the alpine zone of the western North Cascades *V. deliciosum* occurs as a major associate of *Cassiope mertensiana* and *Phyllodoce empetriformis* in heath communities (Douglas and Ballard, 1971).

Tsuga Mertensiana-Abies Amabilis (*Immature Phase*) *Community*

Tsuga mertensiana and *Abies amabilis* are extremely important species in the western North Cascades. They are the dominant species in the upper montane forests and the subalpine tree groups. In the alpine zone *Tsuga mertensiana* and, less frequently, *Abies amabilis* form krummholz although *A. lasiocarpa* is usually more prominent.

Meadow invasion by trees in subalpine regions of the Pacific Coast has been observed from Alaska to central Oregon (Cooper, 1942; Brink, 1959; Van Vecten, 1960; Swedberg, 1961; Franklin and Mitchell, 1967; Fonda and Bliss, 1969; Brooke *et al.*, 1970; Kuramoto and Bliss, 1970; Franklin, *et al.*, 1971). Although less common than most other community types in the western North Cascades, the *Tsuga-Abies* (immature phase) is a conspicuous unit. Most of the trees are 25 to 45 years old, although several stands contained trees up to 120 years old. This same general age group (25 to 45 years) was noted by Brink (1959) in the Coast Range of British Columbia and Franklin *et al.* (1971) in the Cascade Range of Washington.

Tsuga Mertensiana-Abies Amabilis (*Mature Phase*) *Community*

The occurrence of the *Tsuga-Abies* community throughout the western North Cascades, western Olympics, and the Coast Range of British Columbia reflects a similar maritime type climate. In drier subalpine regions *A. lasiocarpa* is often the sole species or a major component (Franklin and Mitchell, 1967; Fonda and Bliss, 1969; Kuramoto and Bliss, 1970). In the western North Cascades tree groups (often consisting of *A. lasiocarpa*) are infrequent on dry southerly slopes.

Vaccinium Membranaceum-Rhododendron Albiflorum *Community*

Most of the major components of this vegetation unit are major understory dominants in the upper montane zone. The community is common throughout the subalpine zone of the western North Cascades. A similar unit has also been described by Brooke *et al.* (1970) in the Coast Range of British Columbia.

Saxifraga Tolmiei *Community*

In the subalpine and alpine zones of the western North Cascades the *Saxifraga* community is a frequent unit in rawmark meadow habitats. In contrast to the subalpine community, the alpine community occurs mainly on southerly aspects. A similar unit occurs less commonly in the Coast Range of British Columbia (Brooke *et al.*, 1970). McAvoy (1931) described a *Saxifraga tolmiei*-dominated community on wet alpine talus slopes in the Bella Coola region of British Columbia.

Rubus Parviflorus-Epilobium Angustifolium *Community*

Many of the components of this unit are common to openings, avalanche tracks, and creek sides in the upper montane zone of the region. Although the *Rubus-Epilobium* community type occurs throughout the study area it has been reported from only one other region. Hickman (1968) described a comparable community in the western Cascades of Oregon.

Valeriana Sitchensis-Veratrum Viride *Community*

The *Valeriana-Veratrum* community type, although common in the western North Cascades, has been documented in only two other regions. Hickman (1968) described a similar community in the western Cascades of Oregon which is comparable both floristically and edaphically. In the Olympic Mountains Kuramoto and Bliss (1970) also recognized a *Valeriana-type* community. Both *Valeriana sitchensis* and *Veratrum viride* have been reported as important components of communities in British Columbia and Alaska but data is lacking for them (Brink, 1959; Hultén, 1968).

Carex Spectabilis *Community*

This community is especially common in the subalpine and alpine zones of the western North cascades. A similar community ("Tall Sedge") has also been described in the Olympic Mountains (Kuramoto and Bliss, 1970). (For the "Tall Sedge" community described for the Olympic Mountains, *Carex albonigra* Mackenzie is equal to *C. spectabilis* [L. C. Bliss, pers. comm., 1971].)

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APPENDIX

LACUSTRINE PROFILE

Profile 9

Vegetation:	*Carex nigricans* community.
Parent Material:	Mica schist, volcanic ash.
Topography:	Level, southeast basin, 1,645 m elevation.
Drainage:	Very poor.

Depth (cm)	Horizon	Description
3-1	O1	Undecomposed to partly decomposed organic matter; thickness, 2 cm.
1-0	O2	Mixed, partly decomposed organic matter and mineral material; clear, wavy boundary; thickness, 1 cm.
0-3	A1	Dark brown (10 YR 3/3) silty loam; many fine to medium roots; abrupt smooth boundary; thickness, 3 cm; strongly acid (pH 5.0).
3-5	C	Brown (7.5 YR 4/2) silty loam; many fine roots; abrupt, smooth boundary; thickness, 3 cm; strongly acid (pH 5.2).
5-10	II C	Brown (10 YR 5/3) silty loam; many fine roots; clear, smooth boundary; thickness, 5 cm; medium acid (pH 5.5).

10-18	III C	Grayish-brown (10 YR 5/2) loamy sand; many fine roots; abrupt, smooth boundary; thickness, 8 cm; medium acid (pH 5.5).
18-22	IV C	Dark brown (10 YR 3/3) silty loam; many fine roots; abrupt, smooth boundary; thickness, 4 cm; very strongly acid (pH 4.8).
22-30	V C	Yellowish-brown (10 YR 5/4) sand; many fine roots; abrupt, smooth boundary; thickness, 9 cm; strongly acid (pH 5.2).
30-36	VI C	Dark brown (10 YR 3/3) silty loam; few fine roots; abrupt, smooth boundary; thickness, 5 cm; medium acid (pH 5.5).
36-43	VII C	Grayish-brown (10 YR 5/2) silty loam; few fine roots; abrupt, smooth boundary; thickness, 8 cm; medium acid (pH 5.5).
43-46	VIII C	Dark brown (10 YR 3/3) sandy loam; abrupt, smooth boundary; thickness, 3 cm; medium acid (pH 5.5).
46-51	IX C	Grayish-brown (10 YR 5/2) sandy loam; abrupt, smooth boundary; thickness, 5 cm; strongly acid (pH 5.3).
51-52	X C	Dark brown (10 YR 3/3) sandy loam; abrupt, smooth boundary, thickness, 1 cm; medium acid (pH 5.8).
52-66	XI C	Yellowish-brown (10 YR 6/6) loam; ash (Mazama); abrupt, smooth boundary; thickness, 14 cm; strongly acid (pH 5.1).
66+	XII C	Dark yellowish-brown (10 YR 4/4) loam; strongly acid (pH 5.0).

REGOSOL PROFILE

Profile 10

Vegetation: *Luetkea pectinata* (residual or regosolic soil phase) community.
Parent Material: Mica schist, volcanic ash.
Topography: 10% slope, straight, lower .25, southwest aspect, 1,648 m elevation.
Drainage: Poor.

Depth (cm)	Horizon	Description
1-0.5	O1	Undecomposed herbaceous litter; thickness, 0.5 cm.
0.5-0	O2	Mixed, partly decomposed organic matter and mineral material; clear, wavy boundary; thickness, 0.5 cm.
0-5	A1	Dark reddish-brown (5 YR 3/3) loam; many fine to medium roots; abrupt, smooth boundary; thickness, 5 cm; very strongly acid (pH 4.6).
5-10	B	Dark brown (7.5 YR 3/2) loam to sandy loam; many fine to medium roots; abrupt, smooth boundary; thickness, 5 cm; strongly acid (pH 5.1).
10-15	C	Dark reddish-brown (5 YR 4/3) loamy sand; many fine roots; clear, smooth boundary; thickness, 5 cm; strongly acid (pH 5.1).
15-22	II C	Dark reddish-brown (5 YR 3/2) silty loam; many fine roots; clear, smooth boundary; thickness, 6 cm; strongly acid (pH 5.0).
22-28	III C	Dark reddish-brown (5 YR 4/2) silty loam; few fine roots; abrupt, smooth boundary; thickness, 6 cm; strongly acid (pH 5.1).
28-32	IV C	Dark reddish-brown (5 YR 2/1) silty loam; very few fine roots; abrupt, smooth boundary; thickness, 4 cm; strongly acid (pH 5.1).
32-37	V C	Yellowish-brown (10 YR 5/6) loam; ash (Mazama); abrupt, smooth boundary; thickness, 5 cm; strongly acid (pH 5.1).
37-48	VI C	Dark reddish-brown (5 YR 2/1) silty loam; abrupt, smooth boundary; thickness, 9 to 11 cm; medium acid (pH 5.5).
48-91	VII C	Dark yellowish-brown (10 YR 4/4 loam; 30% coarse material, 3 to 13 cm across; strongly acid (pH 5.1).

RESIDUAL PROFILE

Profile 5

Vegetation: *Cassiope mertensiana-Phyllodoce empetriformis* community.
Parent Material: Andesite.
Topography: 60% slope, straight, base of slope, west aspect, 1,585 m elevation.
Drainage: Fair.

Depth (cm)	Horizon	Description
0.5-0	O1	Mixed, partly decomposed organic matter and mineral material; abrupt, smooth boundary; thickness, 0.5 cm.
0-3	A1	Black (10 YR 2/1) loam; many fine to medium roots; abrupt, smooth boundary; thickness, 3 cm; extremely acid (pH 4.0).
3-5	A2	Very dark gray (10 YR 3/1) silty loam; many fine to medium roots; abrupt, smooth boundary; thickness, 1 to 3 cm; extremely acid (pH 4.3).
5-10	B2	Very dark brown (10 YR 2/3) silty loam; many fine to medium roots; abrupt, smooth boundary; thickness, 5 to 6 cm; very strongly acid (pH 4.7).
10-20	C1	Olive brown (2.5 Y 4/4) silty loam; many fine roots; gradual, wavy boundary; thickness, 10 to 11 cm; very strongly acid (pH 4.9).
20-30	C2	Olive brown (2.5 Y 4/3) silty loam; many fine roots; clear, wavy boundary; thickness, 9 to 11 cm; strongly acid (pH 5.0).
30-43	II C	Olive (5 Y 4/3) sandy loam; gradual, smooth boundary; 5 percent coarse fragments, 1 to 3 cm across; thickness, 11 to 13 cm; strongly acid (pH 5.3).
43-58	III C	Olive gray (5 Y 4/2) sandy loam; clear, smooth boundary; 20% coarse fragments, 1 to 4 cm across; thickness 15 cm; medium acid (pH 5.4).
58+	IV C	70% coarse fragments.

PODZOL PROFILE

Profile 13

Vegetation: *Tsuga mertensiana-Abies amabilis* (mature phase—closed group) community.
Parent Material: Mica schist.
Topography: 15% slope, on mound, southeast aspect, 1,652 m elevation.
Drainage: Good.

Depth (cm)	Horizon	Description
13-8	O1	Heavy mat of undecomposed forest litter; thickness, 5 to 6 cm.
8-0	O2	Mixed, partly decomposed organic matter and mineral material; gradual, wavy boundary; thickness, 6 to 8 cm.
0-5	A1	Dark reddish-brown (5 YR 2/2) sandy loam; many fine to large roots; abrupt, clear boundary; thickness, 5 to 6 cm; extremely acid (pH 3.7).
5-17	A2	Very dark gray (10 YR 3/1) loamy sand; few fine to large roots; abrupt, smooth boundary; thickness, 10 to 11 cm; extremely acid (pH 4.4).
17-27	B 21	Dark brown (7.5 YR 3/2) sandy loam; few fine roots; gradual, wavy boundary; thickness, 10 to 13 cm; very strongly acid (pH 4.9).

27-52	B 22	Dark reddish-brown (5 YR 3/4) sandy loam; few fine roots; abrupt, wavy boundary; thickness, 25 to 28 cm; strongly acid (pH 5.2).
52-56	C	Dark reddish-brown (5 YR 3/3) sandy loam; 40% coarse fragments, 3 to 15 cm across.

RAWMARK PROFILE

Profile 14

Vegetation: *Saxifraga tolmiei* community.
Parent Material: Andesite.
Topography: 15% slope, straight, base of slope, north aspect, 1,600 m elevation.
Drainage: Poor.

Depth (cm)	Horizon	Description
0-9	C1	Dark gravish-brown (2.5 Y 3/2) gravelly sandy loam; clear, wavy boundary; thickness, 8 to 9 cm; medium acid (pH 5.4).
9-28	C2	Grayish-brown (2.5 Y 2/0) gravelly sandy loam; clear, wavy boundary; thickness, 17 to 20 cm; medium acid (pH 5.6).
28+	II C	90% coarse fragments.

RESIDUAL PROFILE

Profile 1

Vegetation: *Rubus parviflorus-Epilobium angustifolium* community.
Parent Material: Mica schist.
Topography: 60% slope, straight, upper .5, southwest aspect, 1,525 m elevation.
Drainage: Very good.

9-8	O1	Undecomposed herbaceous litter, thickness, 1 cm.
8-0	O2	Mixed, partly decomposed organic matter and mineral material; gradual, wavy boundary, thickness, 8 to 9 cm.
0-9	A1	Dark reddish-brown (5 YR 3/2) loam, many fine to large roots; abrupt, smooth boundary; 1% coarse fragments, 1 to 3 cm across; thickness, 9 to 10 cm; medium acid (pH 5.6).
9-23	B21	Dark reddish-brown (5 YR 2/2) loam; many fine to large roots; gradual, wavy boundary; 1% coarse fragments, 1 to 5 cm across; thickness, 14 to 15 cm; strongly acid (pH 5.3).
28-84	B22	Dark reddish-brown (5 YR 3/3) loam to sandy loam; few fine roots extending to 76 cm; clear, wavy boundary; 7% coarse fragments, 1 to 8 cm across; thickness, 38 to 61 cm; strongly acid (pH 5.2).
84+	C	Dark reddish-brown (5 YR 3/4) sandy loam; 25% coarse fragments, 3 to 15 cm across; strongly acid (pH 5.0).

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