

CLASSIFICATION OF HIGH-ELEVATION NON-FORESTED PLANT COMMUNITIES IN COASTAL BRITISH COLUMBIA

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SUMMARY

This report expands and clarifies previous classifications of non-forested plant communities from upper subalpine and alpine locations in coastal British Columbia. A total of 80 plots (relevés) sampled specifically for this study were added to 202 relevés from published and unpublished studies conducted since 1963. We used tabular and multivariate methods to synthesize and classify plant communities according to the Braun-Blanquet approach. Plant communities were classified into 37 vegetation units (associations or subassociations) which served as the basis of the resulting hierarchical classification. We describe the habitat and species composition of these vegetation units and their relationship to units recognized elsewhere in the Pacific Northwest. We then present eight generalized habitat types which we propose as the basic units for future ecosystem mapping. Each of these habitat types includes a predictable mosaic of vegetation units whose pattern occurs at too fine a scale to map individually.

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COVER PHOTOGRAPH

The cover photograph shows a variety of non-forested plant communities in Brandywine Meadows, a hanging valley at the transition from subalpine to alpine elevations. Abundant water from melting snow and glaciers flows into the valley and results in a mosaic of braided streams, *Carex* fens and streamside communities consisting of such colourful herbs as *Epilobium latifolium* and *Mimulus lewisii*. Lower and middle slopes support heath communities, some tree islands and, especially on south-aspect slopes, lush subalpine meadow communities. Recently-deglaciated areas (shown in the background) have only a sparse vegetative cover and very little soil development. Unless indicated otherwise, all photos by Bob Brett.

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INTRODUCTION

Non-forested ecosystems dominate upper subalpine and alpine sites in coastal British Columbia, yet the classification of their plant communities remains relatively undeveloped compared to those within forested ecosystems. While high-elevation, non-forested ecosystems are included within the biogeoclimatic ecosystem classification (BEC) system (Krajina 1969; Pojar *et al.* 1987), e.g., the parkland Mountain Hemlock (MH) subzones and the Alpine Tundra (AT) zone, there has never been a comprehensive classification or mapping of all community types. The objective of this study is to collate and expand upon previous classifications, and thereby to increase our understanding of the habitats and composition of these plant communities.

Alpine and non-forested subalpine plant communities have been investigated throughout the Pacific Northwest by a number of workers (for a detailed account see Archer (1963), Brooke *et al.* (1970), Franklin and Dyrness (1973), and Viereck *et al.* (1992)). Klinka *et al.* (1997) included a provisional classification of these communities from the data collected by various researchers in coastal B.C. (Archer 1963; Wade 1965; Brooke *et al.* 1970; Ecological Program Staff of the BC Ministry of Forests; Prince Rupert Region, data on file). To expand and improve upon that initial classification, we sampled 80 additional relevés which were chosen with an emphasis on previously unsampled communities.

We define non-forested plant communities as those communities where trees are permanently absent, or where they can survive only as prostrate or stunted shrubs <3 m tall (krummholz). Similar criteria have been used to define timberline and the lower alpine limit (e.g., Arno 1966; Brooke *et al.* 1970), but we also use them to distinguish non-forested communities that form between tree islands in the upper subalpine (*i.e.*, parkland MH subzones). Within our region, non-forested communities generally dominate sites that are snow-free for <4 months (Brooke *et al.* 1970).

We developed this classification as a tool for further systematic studies and the mapping of high-elevation, non-forested plant communities, and as a means to relate them to communities elsewhere (e.g., Franklin and Dyrness 1973; Barbour and Major 1977; Pfister and Arno 1980; Ellenberg 1988; Rodwell 1991; Viereck *et al.* 1992). Different approaches within vegetation science means this classification may differ from others. We aimed to develop a classification that organizes communities into groups in a way which shows the greatest number of relationships, is easily retained in memory, and is easily conveyed through instructions.

After describing our methodology, we present the classification of plant communities into vegetation units that include (from lowest to highest hierarchical level): subassociations, associations, alliances, and orders. Diagnostic tables are used to show floristic affinities among the vegetation units and to interpret their relationships to climatic and edaphic gradients. We describe the habitat (environment) associated with the vegetation units, then discuss relationships between vegetation units and environmental gradients.

Combining previous studies and new sampling allowed us to prepare the most comprehensive classification of high-elevation, non-forested plant communities in coastal B.C. to date. Relating predictable patterns of plant communities to environmental gradients also allowed us to suggest eight habitat types (each containing a mosaic of plant communities) that may aid in the future mapping of high-elevation ecosystems. While we believe that the combined scope of this classification is an improvement on previous, uncollated classifications, we also recognize some weaknesses; e.g., the

2 INTRODUCTION

need for more data from the Central and North Coast, and from herbaceous and avalanche track communities.

This report has been updated from the 1998 version and is available in full colour or B&W printed versions or in electronic format on Scientia Silvica CD-ROM. For further information or to order a copy visit www.forestry.ubc.ca/klinka or contact Karel Klinka, Forest Sciences Department, University of British Columbia, 3036-2424 Main Mall, Vancouver BC V6T 1Z4 (e-mail: klinka@interchange.ubc.ca).

THE STUDY AREA

The study area is concentrated mostly in southern coastal British Columbia (including Vancouver Island, the coastal lowlands, windward and leeward slopes of the Coast Mountains, and windward slopes of the Cascade Mountains), but it also extends northward to the Central Coast near Prince Rupert. Its main elevational range is from the upper subalpine (parkland MH subzones) to the alpine (AT zone). The study area is subject to a strong maritime influence from the Pacific Ocean which, combined with colder temperatures at higher elevations, results in a maritime subalpine boreal climate (MH zone) and maritime alpine tundra climate (AT zone) (Köppen in Trewartha 1968). Further descriptions of these biogeoclimatic zones are included in Krajina (1969), Klinka *et al.* (1991) and Meidinger and Pojar (1991).

Glacial landforms and colluvium dominate the landscape. Granitic rocks, mainly quartz diorites and granodiorites, are most common and often occur as plutons. Metamorphic and volcanic rocks also occur, especially on Vancouver Island and the southernmost mainland. Glaciers still cover many high peaks and north-aspect cirques. Deglaciation on much of the adjoining terrain is too recent for extensive colonization by plants and soils remain mostly undeveloped (nonsoil to Regosols, CSSC 1978). On many vegetated sites, soil development ranges from peaty A/C soils (organic rankers, *sensu* Kubiěna 1953; = Orthic to Humic Regosols, CSSC 1978), especially in the alpine, to A/B/C soils (Melanic to Dystric Brunisols, CSSC 1978), especially on upper subalpine sites. Since soils are relatively young, they are usually less leached and acidified than forest soils and therefore tend to be more base-rich. Humus forms range widely: from no surface organic materials on uncolonized sites, to Mor humus forms (Green *et al.* 1993) under heath communities, to Moder (and even Mull) humus forms under herbaceous meadows. Late-lying snow results in soils that are commonly at field capacity for most or all of the growing season, though exposed sites can be subject to severe moisture deficits after snowmelt. Where drainage is impeded, semi-terrestrial organic soils develop (e.g., Fibrisols and Mesisols, CSSC 1978). More complete descriptions of the geology and soils of the study area are provided by Holland (1976), Valentine *et al.* (1978), Meidinger and Pojar (1991), and Monger and Journeay (1994).

Non-forested plant communities are characteristic of upper subalpine and alpine areas. Alpine ecosystems are non-forested by definition, since conditions are so harsh that tree species are unable to survive except as dwarf shrubs (krumholz). In contrast, upper subalpine environments contain a mosaic of non-forested and forested (tree-island) communities. The elevational progression from closed forest (at lower elevations), to tree islands, to treeless expanses is closely related to increasingly short growing seasons caused by later snowmelt. Deep winter snowpacks remain well into June on most sites in the study area, and may not melt before late August on sites protected from direct sunlight, e.g., bowls and cool-aspect slopes. Depending on how factors such as aspect and topography affect snowmelt, the transition from closed forest to alpine tundra can be gradual, abrupt, or even discontinuous. Very steep community gradients are often directly related to patterns of snowmelt (Brooke *et al.* 1970; Evans 1986). Increased snow and shorter growing seasons at alpine elevations result in a less continuous plant cover than at lower elevations.

MATERIALS AND METHODS

Our combined dataset of published and unpublished studies included 282 plots (relevés). All were sampled in non-forested plant communities that had not been disturbed by human activities..

Sources included studies by the students of Dr. V. J. Krajina (Archer 1963; Wade 1965; Peterson 1964 and Brooke 1966, collated in Brooke *et al.* 1970), unpublished survey results from the Prince Rupert Region of the B.C. Ministry of Forests (Ecological Program Staff, data on file), and additional relevés sampled specifically for this study.

Two datasets were from the southern mainland: Archer's (1963) data from Garibaldi Park and Brooke *et al.*'s (1970) data from Garibaldi Park and the North Shore Mountains. One dataset was from the Kimsquit area on the Central Coast north of Bella Coola (Ecological Program Staff, data on file). The Kimsquit plots were primarily in avalanche tracks located at mid-elevation sites (Coastal Western Hemlock, or CWH, zone) and lower subalpine sites (forested MH subzone). While data from higher elevations would be preferable for this study of upper subalpine and alpine plant communities, it is currently unavailable. As well, avalanche tracks commonly extend the range of subalpine vegetation into much lower elevations (Douglas 1970) and this was the first extensive dataset of avalanche track communities sampled in coastal B.C. Due to apparent floristic similarities between low-elevation and high-elevation wetlands, we also included 19 plots from Wade's (1965) *Carex pluriflora* association sampled near sea level in the Tofino area of western Vancouver Island.

Klinka *et al.* (1997) used these four datasets to classify non-forested, upper subalpine and alpine plant communities, but recognized their classification was incomplete. We therefore sampled additional plots to increase the geographic range of the classification and to include a greater representation of plant communities, particularly wetlands. All 80 new plots were in either the maritime or submaritime MH parkland subzones. Study locations included:

- i. Church Mountain and Mt. Maguire in the windward Cascade Range near Chilliwack;
- ii. Kwoiek Creek in the leeward Coast Mountains near Lytton;
- iii. Hurley Pass, Blackcomb Mountain, Brandywine Meadows, and the Black Tusk in the Coast-Interior transition near Whistler; and
- iv. on Vancouver Island, two sites near Nimpkish Lake, one site near Woss, and one site on Mt. Cain ([Figure 1](#)).

Vegetation data for all datasets were collected using standard phytosociological methods (Braun-Blanquet 1928; Mueller-Dombois and Ellenberg 1974). Each plot (usually square or rectangular) was placed in a portion of a community that was relatively uniform in floristic composition, structure, and site attributes (e.g., slope position, aspect, gradient, and ground cover). Depending on the character and areal extent of the selected community, the size of sample plots varied from 0.5 m² to 100 m². Plot size increased with increasing floristic diversity and structural complexity of vegetation, e.g., plots in *Sphagnum* bogs were relatively small while plots in herbaceous meadow communities were relatively large. All plant species present within the plot were identified and their cover was estimated using the ten-class (+ to 9) Domin-Krajina scale of species significance (Mueller-Dombois and Ellenberg 1974). We have standardized the taxonomic nomenclature from all studies by following Qian and Klinka (1998).

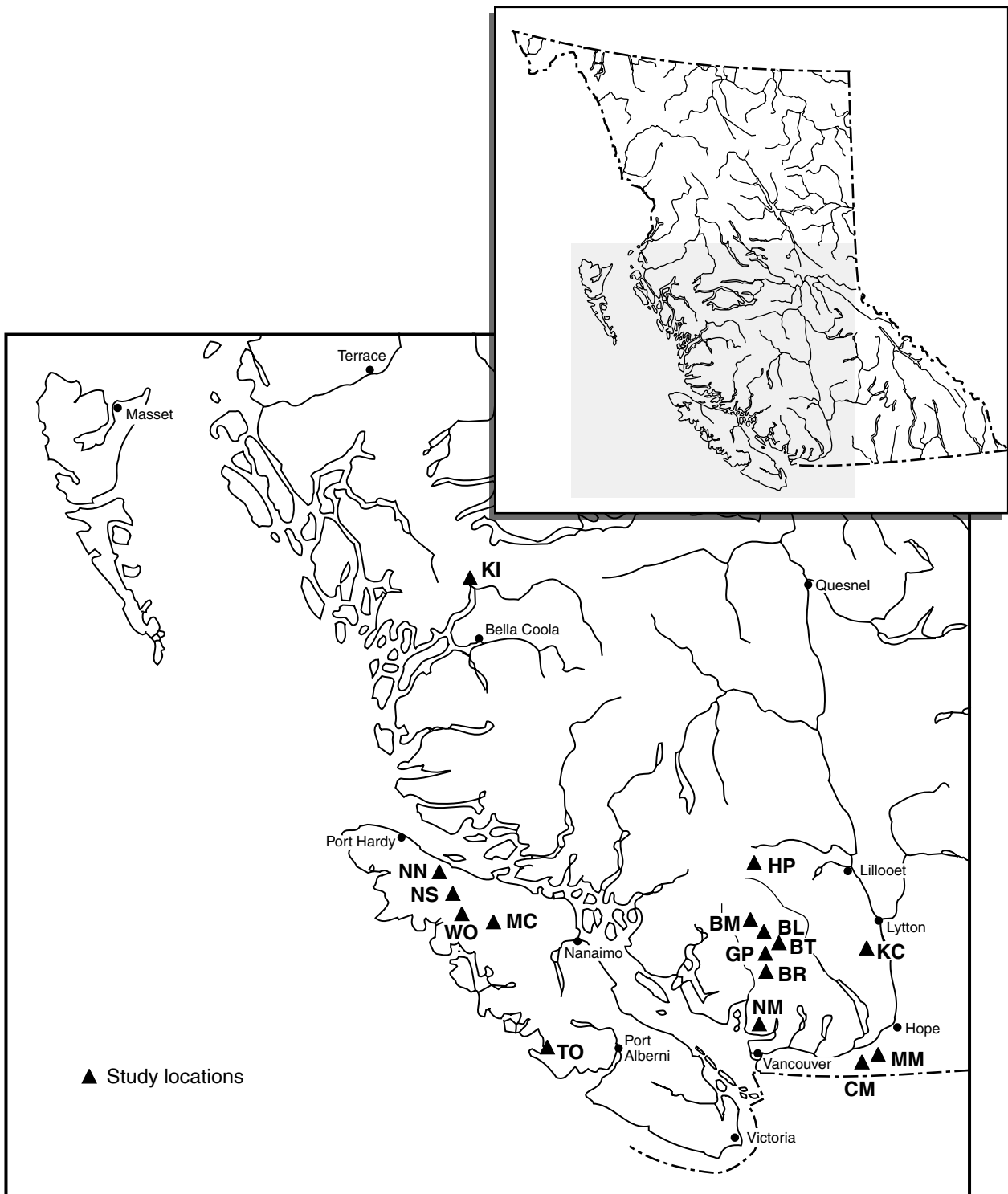


Figure 1. Map of study locations. Except where noted, the following abbreviations refer to study locations that were sampled specifically for this study: BL = Blackcomb Mountain; BM = Brandywine Meadows; BR = Brohm Ridge; BT = Black Tusk; CM = Church Mountain; GP = Garibaldi Park (Archer 1963; Brooke *et al.* 1970); HP = Hurley Pass; KC = Kwoiek Creek; KI = Kimsquit (Ecological Program Staff, data on file); MC = Mt. Cain; MM = Mt. Maguire; NS = Nimpkish South; NM = North Shore Mountains (Brooke *et al.* 1970); NN = Nimpkish North; TO = Tofino (Wade 1965); WO = Woss.

Somewhat different environmental data were collected for each dataset, though all recorded such site attributes as slope position, aspect, and gradient. A pit was dug at each plot and soils were described and identified. We translated the soil classification terms used in earlier studies to their closest equivalents according to the Canada Soil Survey Committee (CSSC 1978) but, since the Canadian system is limited in its description of alpine and wetland soils, we sometimes also included the original terminology of Kubiëna (1953). We estimated soil moisture and nutrient regimes for all studies using a heuristic procedure (Green and Klinka 1994). A more complete description of field methods is included in Archer (1963), Wade (1965), Brooke *et al.* (1970) and Luttmerding *et al.* (1990).

Data analysis and synthesis followed the Braun-Blanquet approach (Mueller-Dombois and Ellenberg 1974: 177-210; Westhoff and van der Maarel 1980: 287-399). Our objective was to produce ecologically-meaningful classes of plant communities that could be identified, mapped, and related to their environment. The major tool used to achieve this objective was a computer-aided tabular analysis program (Emanuel 1989). Consistent with previous studies, we used a hierarchy where each taxonomic unit: (1) could be floristically distinguished; (2) represented a group of communities that had affinities in floristic composition and physiognomy; and (3) occupied a floristically-defined segment of edaphic and local climatic gradients.

We classified vegetation units into four categorical levels (in order of increasing generalization): subassociation, association, alliance, and orders. Associations represented closely-related plant communities that could be easily recognized in the field. Subassociations represented two or more variations on the theme of their related associations, but the differences between units were not great enough to be recognized at the association level. Alliances and orders were built from associations and allowed us to note and describe characteristic vegetation and environmental conditions at a higher (more generalized) hierarchical level. We followed four analytical steps to synthesize the data:

Step 1 The groups of plots obtained in step 1 were tabulated and examined for similarities and differences within and among groups, using the presence class and species significance of each species. Relevés in different groups that were floristically and environmentally similar were eventually re-assigned within the same group. We inspected the tables for internal redundancies using the similarity of different species combinations as the criterion for re-assignments and mergers.

Step 2 A tentative hierarchy of groups was then proposed, where each group was named as either an association or a subassociation depending on its relationship to the hierarchy. Preliminary diagnostic tables were produced using the concept of differential- and dominant differential-species (e.g., Becking 1957) and the criteria as defined by Pojar *et al.* (1987):

differential-species:

- i. species that may be associated with more than one vegetation unit in a hierarchy;
- ii. presence class \geq III (Table 2) and
- iii. at least two presence classes greater than in other units of the same category and circumscription;

dominant differential-species:

- i. species that may be associated with more than one vegetation unit in a hierarchy;
- ii. presence class \geq III;
- iii. mean species significance \geq 5 (Table 2) and
- iv. two or more species significance classes greater than in other units of the same category and circumscription.

- Step 3** Step three was repeated iteratively for each group, in a process of successive approximation (Poore 1962) in which the production of tentative diagnostic tables for each group continued until exclusive diagnostic combinations of species were obtained for each unit of the hierarchy. This process occasionally required the grouping of tentative units lacking a diagnostic combination of species.
- Step 4** In the last step, the tentative units were tabulated together to determine whether the hierarchy and differentiation obtained separately for each group retained their integrity and stability. This procedure was repeated, as described for Step 3, until a logical hierarchy and exclusive diagnostic combination of species was obtained for each unit of the hierarchy.

Identifying and distinguishing vegetation units requires a diagnostic combination of species, but there is no universally accepted methodology (*cf.* Becking 1957; Mueller-Dombois and Ellenberg 1974; Westhoff and van der Maarel 1980). We used the principle of relative differentiation to identify and distinguish subassociations, associations, alliances, and orders. Relative differentiation allows the recognition of a unit by an exclusive diagnostic combination of species that must include at least one differential-species or dominant differential-species. Units that represent the central concept of a higher circumscribing unit can be recognized without a diagnostic combination of species, provided they are differentiated by the absence or low occurrence of species that characterize other units of the same category and circumscription (Pojar *et al.* 1987: 131-132). Two or more associations within the same alliance could therefore be distinguished when some species that are absent or rare in one association are abundant in the other association(s), e.g., the *Carex spectabilis* alliance in [Table 7](#).

Plant associations were named using the generic and specific names of one or two dominant species within the diagnostic combination of species for that association (e.g., the *Carex nigricans* association). Plant subassociations were named by adding a colon (:) to the association name, followed either by the term 'typic' (to represent what we believed to be the central concept of that association) or the name of one diagnostic species (e.g., the *Carex nigricans*: *Polytrichum alpinum* subassociation). We included citations for vegetation units that were recognized in previous studies and retained the original name except where our re-synthesis showed that another name was more appropriate. In the latter case, we labeled the new names with '*n.n.*' (*nomen novum*). All units based on <10 relevés were noted with an asterisk (*).

We applied two additional tabular tools to help compare plant orders. The first tool compared the spectrum of life-forms within each plant order (Emanuel 1989). Species were classified according to the following life-form types (Klinka *et al.* 1989): coniferous trees, evergreen shrubs, deciduous shrubs, ferns and fern-allies, graminoids, herbs, mosses, liverworts, and lichens. The second tool compared floristic similarities between pairs of plant orders using Sørensen's index (Magurran 1988). This index is a simple but effective measure of the number of species shared between two vegetation units, and allows the floristic similarity of different pairings to be compared. It is based on the following formula:

$$SI = \frac{2c}{(a + b)}$$

where a = the number of species in the first order,
 b = the number of species in the second order, and
 c = the number of species common to both.

RESULTS AND DISCUSSION

The Classification

Of 282 relevés, all but 14 were classified into a hierarchy of vegetation units that included 13 subassociations, 30 associations, 13 alliances, and 11 orders (Table 1). Tables showing diagnostic combinations of species are included for plant orders (Table 2) as well as for subordinate units of each order (Tables 6, 7, 8, 9). We also include summary tables listing all species with a presence class ≥ 3 for plant orders (Appendix 1), and for 37 vegetation units (Appendices 2, 3, 4, 5). These 37 vegetation units represent the lowest level within each branch of the hierarchy, *i.e.*, most are associations except where subassociations were also identified. They are numbered sequentially within each plant order (e.g., 1.1 refers to the first vegetation unit we describe in the *Rhizocarpon geographicum* order) and are more fully described in the next section.

Additional plant communities sampled for this study allowed us to identify three orders not included in Klinka *et al.* (1997): one which was entirely new (*Phlox diffusa*) and two from wetlands that were raised from the association to the order level (*Eriophorum angustifolium* and *Carex pluriflora*). We also identified five new associations (*Phlox diffusa*, *Oxyria digyna* – *Carex spectabilis*, *Warnstorffia exannulata* – *Eriophorum angustifolium*, *Fauria crista-galli* – *Eriophorum angustifolium*, and *Sphagnum* – *Carex pluriflora*) and three new subassociations, and strengthened the delineation of the remaining units.

Only one order, *Rhizocarpon geographicum*, remained unchanged from the classification of Klinka *et al.* (1997). The classification of four orders (*Marsupella brevissima*, *Carex nigricans*, *Cassiope mertensiana* – *Phyllodoce empetrifolmis*, and *Philonotis fontana*) remained virtually unchanged even with the addition of new plots. A number of vegetation units were re-named, due either to slightly different diagnostic species or to a revision of plant nomenclature (e.g., *Heracleum maximum* instead of *H. lanatum*). In other cases, the addition of new plots resulted in more significant changes. For example, Klinka *et al.*'s (1997) original *Carex mackenziei* association (*Valeriana sitchensis* order) was merged with the *Heracleum maximum* – *Valeriana sitchensis* association. Further discussion of how this classification differs from that presented in Klinka *et al.* (1997) is described in the next section.

Although tabular analysis produced groupings that differed floristically, the diagnostic combinations of species for seven of the eleven orders included only one or two species (Table 2). These orders included: *Rhizocarpon geographicum*, *Marsupella brevissima*, *Carex nigricans*, *Carex spectabilis*, *Valeriana sitchensis*, *Eriophorum angustifolium*, and *Carex pluriflora*. In most of these cases, the weak differentiation reflects species-poor or single-species dominated communities, tending in some cases towards monocoenoses (populations consisting of a single plant species). Within the species-rich *Valeriana sitchensis* order, however, the lack of additional diagnostic species likely means more sampling is needed to clarify the classification.

Table 1. Synopsis of vegetation units in the classification. Plant orders are numbered from 1 to 11. The lowest vegetation unit within each hierarchical branch is numbered sequentially within each plant order.

Habitat codes are defined in [Table 10](#) and [Figure 44](#). Diagnosis based on <10 relevés is indicated by an asterisk (*). Citations are included for vegetation units described in previous studies; '*n.n.*' (nomen novum) is added if the name has been changed.

Vegetation unit no.	Habitat code	Order
		Alliance
		Association
		Subassociation
1		Rhizocarpon geographicum
		Rhizocarpon geographicum
1.1	H	Sibbaldia procumbens*; Archer 1963
1.2	H	Silene acaulis*; Archer 1963
1.3	H	Penstemon davidsonii – Juniperus communis*; Archer 1963
1.4	A, H	Phyllodoce empetriformis – Abies lasiocarpa; <i>n.n.</i> ; Archer 1963
2		Phlox diffusa*
		Phlox diffusa*
2.1	A, H	Phlox diffusa*
3		Marsupella brevissima
		Marsupella brevissima
3.1	D	Polytrichum alpinum – Marsupella brevissima*; <i>n.n.</i> ; Archer 1963
3.2	D	Polytrichum piliferum – Marsupella brevissima*; <i>n.n.</i> ; Archer 1963
3.3	B	Luzula wahlenbergii – Saxifraga tolmiei*; <i>n.n.</i> ; Brooke <i>et al.</i> 1970
4		Carex nigricans
		Carex nigricans
		Carex nigricans; Archer 1963
4.1	D, E	Carex nigricans: typic*
4.2	D, E	Carex nigricans: Polytrichum alpinum
5		Cassiope mertensiana – Phyllodoce empetriformis
		Cassiope mertensiana
5.1	C	Carex spectabilis – Cassiope mertensiana; <i>n.n.</i> ; Archer 1963
		Cassiope mertensiana – Tsuga mertensiana
		Cassiope mertensiana – Phyllodoce empetriformis; <i>n.n.</i> ; Brooke <i>et al.</i> 1970
5.2	C	Cassiope mertensiana – Phyllodoce empetriformis: typic
5.3	C	Cassiope mertensiana – Phyllodoce empetriformis: Vaccinium deliciosum
		Cassiope mertensiana – Tsuga mertensiana; <i>n.n.</i> ; Brooke <i>et al.</i> 1970
5.4	C	Cassiope mertensiana – Tsuga mertensiana: typic*
5.5	C	Cassiope mertensiana – Tsuga mertensiana: Hippuris montana*
		Luetkea pectinata*
5.6	B, F	Luetkea pectinata*; Archer 1963
6		Carex spectabilis
		Carex spectabilis
6.1	F	Carex spectabilis*; Archer 1963
6.2	F	Anaphalis margaritacea – Lupinus arcticus; Archer 1963
6.3	F	Oxyria digyna – Carex spectabilis*
7		Philonotis fontana
		Philonotis fontana
7.1	G	Caltha leptosepala – Leptarrhena pyrolifolia; Brooke <i>et al.</i> 1970
7.2	G	Epilobium latifolium – Mimulus lewisii; Archer 1963

Vegetation unit no.	Habitat code	Order
		Alliance
		Association
		Subassociation
8		Valeriana sitchensis
		Valeriana sitchensis
8.1	G1, G2	Parnassia fimbriata – Valeriana sitchensis*
8.2	G1, G2	Heracleum maximum – Valeriana sitchensis
8.3	G1	Carex spectabilis – Valeriana sitchensis*; <i>n.n.</i> ; Archer 1963
8.4	G2	Sphagnum – Valeriana sitchensis*
9		Alnus viridis
		Alnus viridis
		Oplopanax horridus – Alnus viridis
9.1	G1, G2	Oplopanax horridus – Alnus viridis: Rubus parviflorus*
9.2	G1, G2	Oplopanax horridus – Alnus viridis: typic
9.3	G2	Phyllodoce empetriiformis – Alnus viridis*
9.4	F	Juncus ensifolius – Alnus viridis*
9.5	G2	Valeriana sitchensis – Alnus viridis*
10		Eriophorum angustifolium
		Eriophorum angustifolium
10.1	E	Warnstorfia exannulata – Eriophorum angustifolium*
		Fauria crista-galli – Eriophorum angustifolium
10.2	C, E	Fauria crista-galli – Eriophorum angustifolium: Empetrum nigrum*
10.3	E	Fauria crista-galli – Eriophorum angustifolium: typic*
10.4	E	Fauria crista-galli – Eriophorum angustifolium: Sphagnum*
10.5	E	Carex aquatilis – Eriophorum angustifolium*; <i>n.n.</i> ; Brooke <i>et al.</i> 1970
11		Carex pluriflora
		Carex pluriflora
		Sphagnum – Carex pluriflora
11.1	E	Sphagnum – Carex pluriflora: Vaccinium uliginosum*
11.2	E	Sphagnum – Carex pluriflora: typic

Table 2. Diagnostic combinations of species for plant orders.

Order number		1	2	3	4	5	6	7	8	9	10	11
Number of plots		25	5	21	16	53	21	23	21	38	25	20
Diagnostic												
Species	value ¹	Presence class ² and mean species significance ³										
Order 1: Rhizocarpon geographicum												
Rhizocarpon geographicum	d	IV 1	2	+			I	+				
Umbilicaria proboscidea	d	III 1					I	+				
Order 2: Phlox diffusa												
Paxistima myrsinites	d		3 2							I	+	
Penstemon procerus	d	I	+	3 1			I	+	I	+		
Phlox diffusa	d		4 5				I	+				
Saxifraga occidentalis	d		3 1									
Selaginella wallacei	d		3	+								
Tortella tortuosa	d		3 4									
Order 3: Marsupella brevissima												
Marsupella brevissima	d, cd			V 6	II 2	I 1		I	+			
Saxifraga tolmiei	d			IV 3	II 1	I	+			I	+	
Order 4: Carex nigricans												
Carex nigricans	dd, cd	II	+	2	+	IV 2	V 8	II 1	III 1	III 3	I 2	I 4
Order 5: Cassiope mertensiana												
Barbilophozia floerkei	d					I 1	III 4					I 3
Cassiope mertensiana	dd	I 1	1	+	II 1	III 3	IV 6	I	+	I	+	I 2
Cladonia bellidiflora	d				II 1	III 1	III 1				I	+
Dicranum fuscescens	d	I 1				I	+	III 4	I	+	I	1
Luetkea pectinata	d, cd	I 1	1	+	I	+	I 1	V 5	II 2	II 1	I	+
Lycopodium sitchense	d	I	+		II	+	I	+	III 2			I
Racomitrium heterostichum	d	I	+		I	+	I	+	III 3			I
Tsuga mertensiana	dd	I 1			I	+			III 5		II	+
Vaccinium delicosum	d								IV 5			
Vaccinium membranaceum	d								III 2			
Order 6: Carex spectabilis												
Carex spectabilis	d, cd	II	+		I 1	II 2	I	+	V 7	III 4	II 3	I 2
Lupinus arcticus	dd				I 1	I	+	I 2	III 5	I	+	II 1
Order 7: Philonotis fontana												
Caltha leptosepala	d						I	+		III 3		I 1
Leptarrhena pyrolifolia	d				I	+	I	+		IV 5	II	+
Philonotis fontana	d									IV 5		I 3
Order 8: Valeriana sitchensis												
Valeriana sitchensis	d, cd						I	+	I	+	III 1	V 6
Order 9: Alnus viridis												
Alnus viridis	d, cd								I	+	V 8	
Athyrium filix-femina	d							I	+	I	+	II 2
Rubus spectabilis	d									I	2	III 3
Salix sitchensis	d									I	3	IV 4
Order 10: Eriohorum angustifolium												
Eriophorum angustifolium	d, cd								I	+		V 6
Order 11: Carex pluriflora												
Carex pluriflora	d, cd											V 6
Sphagnum spp.	dd				I	+	I	+		I	2	II 5

1 Species diagnostic values: d - differential, dd - dominant differential, cd - constant dominant, c - constant (Pojar *et al.* 1987).

2 Presence classes as percent of frequency: I = 1-20, II = 21-40, III = 41-60, IV = 61-80, V = 81-100. If 5 plots or less, presence class is arabic value (1-5).

3 Species significance class midpoint percent cover and range: + = 0.2 (0.1 - 0.3), 1 = 0.7 (0.4 - 1.0), 2 = 1.6 (1.1 - 2.1), 3 = 3.6 (2.2 - 5.0), 4 = 7.5 (5.1 - 10.0), 5 = 15.0 (10.1 - 20.0), 6 = 26.5 (20.1 - 33.0), 7 = 41.5 (33.1 - 50.0), 8 = 60.0 (50.1 - 70.0), 9 = 85.0 (70.1 - 100).

Herbs and mosses represented more than half of all species (Table 3). Coniferous and evergreen shrubs were the least diverse life-form classes. While the proportion of herbs and moss species was relatively consistent across different plant orders, herb diversity was generally greatest in plant orders with richer soil nutrient regimes, and moss diversity was greatest in plant orders having poorer soil nutrient regimes (see Table 11). Deciduous shrubs were most diverse in the avalanche track communities of order 9 (*Alnus viridis*). The diversity of lichens was greatest in the xerophytic communities of order 1 (*Rhizocarpon geographicum*), but also high in the heath communities of order 5 (*Cassiope mertensiana* – *Phyllodoce empetrifomis*). Since the number of identified species increases with sampling effort (*i.e.*, more plots), Table 3 presents species diversity as percentages. Nonetheless, some observations can be made about the total number of species by plant order. Order 9 (*Alnus viridis*) had the most species and order 11 (*Carex pluriflora*) had the fewest species. While order 5 (*Cassiope mertensiana* – *Phyllodoce empetrifomis*) had the second-highest species richness, this result likely reflects that it was based on more than twice as many plots as most other plant orders. Given that only five plots were sampled, the *Phlox diffusa* order contained unexpectedly diverse communities.

Table 3. Species richness (percent number of species) of plant orders. Plant order numbers are defined in Table 1. To prevent counting shared species more than once, row totals were calculated using the combined dataset.

Order number	1	2	3	4	5	6	7	8	9	10	11	Total
Number of plots	25	5	21	16	53	21	23	21	38	25	20	268
Coniferous trees	5.1	0.0	2.5	2.0	2.9	0.0	2.4	1.5	3.1	0.0	0.0	1.8
Evergreen shrubs	8.5	4.9	7.5	8.2	3.6	4.5	1.6	0.8	1.5	5.7	8.3	2.0
Deciduous shrubs	1.7	0.0	5.0	2.0	5.8	1.5	5.6	6.9	15.5	1.9	8.3	7.7
Ferns and allies	1.7	4.9	5.0	2.0	2.2	4.5	4.0	8.4	7.2	3.8	0.0	5.1
Graminoids	15.3	14.8	17.5	14.3	7.3	15.2	16.0	16.0	16.0	21.0	16.7	13.2
Herbs	16.9	42.6	15.0	14.3	21.2	43.9	34.4	47.3	47.9	22.9	41.7	33.8
Mosses	27.1	23.0	30.0	32.7	24.8	18.2	25.6	14.5	6.7	31.4	25.0	21.0
Liverworts	0.0	0.0	12.5	16.3	13.9	4.5	9.6	1.5	0.5	7.6	0.0	7.3
Lichens	23.7	9.8	5.0	8.2	18.2	7.6	0.8	3.1	1.5	5.7	0.0	7.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total species	59	61	40	49	137	66	125	131	194	105	12	491

The number of species presented in Table 3 does not necessarily reflect the abundance of those species. For example, while evergreen shrubs represented only 2% of all species, their nearly-complete cover on many sites increased their average percent cover to almost 10% (Table 4). Deciduous shrubs and graminoids were also more abundant than diverse.

Table 4. Abundance (percent cover) of life-form classes by plant order. Plant order numbers are defined in Table 1.

Order number	1	2	3	4	5	6	7	8	9	10	11	Total
Number of plots	25	5	21	16	53	21	23	21	38	25	20	268
Coniferous trees	25.0	0.0	0.3	0.1	11.8	0.0	0.3	0.4	0.5	0.0	0.0	2.5
Evergreen shrubs	36.6	29.3	1.5	3.6	34.1	1.5	0.2	0.1	8.1	3.5	0.1	9.4
Deciduous shrubs	0.2	0.0	0.1	0.1	8.2	0.1	2.8	28.9	53.1	4.6	2.6	13.6
Ferns and allies	0.1	0.5	0.4	0.1	2.1	0.1	2.5	8.9	7.1	0.3	0.0	2.8
Graminoids	3.4	1.2	8.0	52.5	1.9	42.0	12.4	6.0	10.4	38.8	30.5	19.3
Herbs	17.9	26.1	9.6	2.0	14.3	53.0	43.5	40.8	12.0	7.5	2.8	20.6
Mosses	9.0	34.1	41.1	36.6	19.0	1.7	35.5	14.0	8.1	37.8	64.0	26.4
Liverworts	0.0	0.0	38.7	4.7	6.1	1.3	2.7	0.1	0.1	2.6	0.0	3.6
Lichens	7.7	8.8	0.2	0.3	2.5	0.2	0.1	0.7	0.5	4.9	0.0	1.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Consistent with the trends shown in Table 3, the abundance of life-forms (Table 4) was related to edaphic conditions (see Table 11). Herbs, ferns, and deciduous shrubs were most abundant in wetter, more nutrient-rich orders: order 6 (*Carex spectabilis*), order 7 (*Philonotis fontana*), order 8 (*Valeriana sitchensis*), and order 9 (*Alnus viridis*). In contrast, evergreen shrubs and coniferous trees were most abundant in relatively dry and nutrient-poorer orders: order 1 (*Rhizocarpon geographicum*), order 2 (*Phlox diffusa*) and order 5 (*Cassiope mertensiana* – *Phyllodoce empetrifomis*). Mosses were apparently less affected by soil moisture than soil nutrients as they were most abundant in nutrient-poorer orders that included both drier and wetter sites: order 11 (*Carex pluriflora*), order 3 (*Marsupella brevissima*), order 10 (*Eriophorum angustifolium*), order 4 (*Carex nigricans*), and order 2 (*Phlox diffusa*). Graminoids were abundant in orders spanning a wide edaphic range. They dominated the wet, nutrient-poor order 11 (*Carex pluriflora*) and order 10 (*Eriophorum angustifolium*), the moist to very moist but still nutrient-poor order 4 (*Carex nigricans*), and the nutrient-medium order 6 (*Carex spectabilis*) on slightly dry to very moist sites. Liverworts were important only in order 3 (*Marsupella brevissima*), and lichens reached their greatest abundance in the two xerophytic orders: order 1 (*Rhizocarpon geographicum*) and order 2 (*Phlox diffusa*).

The floristic individuality of plant orders was reflected by the few Sørensen's Index values >0.40 (Table 5). The two most floristically-similar pairings were the two late-snowmelt orders, order 3 (*Marsupella brevissima*) and order 4 (*Carex nigricans*), and the two orders containing the greatest number of herbaceous species, order 8 (*Valeriana sitchensis*) and order 9 (*Alnus viridis*). All pairings with the species-poor and unique order 11 (*Carex pluriflora*) had Sørensen Index values ≥ 0.10 . The degree of floristic similarity appeared to be related to soil nutrient gradients (see Table 11). Values were all ≥ 0.30 for pairings between the four nutrient-poorest orders: order 1 (*Rhizocarpon geographicum*), order 3 (*Marsupella brevissima*), order 4 (*Carex nigricans*), and order 5 (*Cassiope mertensiana* – *Phyllodoce empetrifomis*). Similarly, values were all ≥ 0.28 for pairings in the nutrient-richest orders: order 7 (*Philonotis fontana*), order 8 (*Valeriana sitchensis*), and order 9 (*Alnus viridis*). The nutrient-medium order 6 (*Carex spectabilis*) occupied an intermediate position, with relatively high floristic similarities to both nutrient-poorer and nutrient-richer orders. Similar relationships between floristic similarity and soil nutrient regime could not be extended to order 2 (*Phlox diffusa*), order 10 (*Eriophorum angustifolium*), or order 11 (*Carex pluriflora*), nor could as strong a relationship be detected between floristic similarity and soil moisture regime.

Table 5. Matrix of floristic similarities for plant orders. Higher values of Sørensen's Index (Magurran 1988) indicate a greater number of shared species and greater floristic similarity. Plant order numbers are defined in Table 1.

Order no.	Sørensen's Index									
	1	2	3	4	5	6	7	8	9	10
2	0.20									
3	0.38	0.16								
4	0.30	0.13	0.56							
5	0.42	0.24	0.32	0.37						
6	0.38	0.27	0.36	0.30	0.36					
7	0.18	0.12	0.24	0.29	0.37	0.36				
8	0.17	0.18	0.13	0.18	0.27	0.31	0.37			
9	0.08	0.14	0.10	0.09	0.19	0.21	0.28	0.46		
10	0.15	0.10	0.12	0.25	0.26	0.13	0.37	0.16	0.13	
11	0.00	0.03	0.00	0.03	0.03	0.03	0.03	0.03	0.02	0.10

Description of Vegetation Units

This section expands upon the synopsis of vegetation units ([Table 1](#)) by describing their characteristic flora, habitats, and relationships to vegetation units recognized by previous researchers. The vegetation units are presented sequentially following the numbering in [Table 1](#). We begin each subsection with a brief description of the order, then describe the subordinate vegetation units. The units are usually associations except where an association has been subdivided into two or more subassociations. We only discuss alliances in this section when it helps clarify relationships between vegetation units.

Since this classification expands upon previous studies, the discussion of some vegetation units relies partly or completely on the source publications. We take care to note the nature of, and reasons for, any modifications to previously-recognized units. Where possible, we refer to similar vegetation units identified outside the study area. We also discuss the 14 relevés sampled for this study that remained unclassified because of their uniqueness; each is discussed after the vegetation unit to which it appears to have the greatest floristic and environmental affinities. We emphasize the habitat of each vegetation unit more than its vegetation for two reasons: the floristic information is presented in diagnostic and summary tables, and the presence of a plant community can often be inferred from its environmental surroundings, or habitat. We deal with more generalized vegetation-environment relationships and the pattern of different communities across changing landscapes in the next section.

At the end of this section we present the diagnostic combinations of species for the units. Units in orders 1-4 are presented in [Table 6](#); orders 5-7 in [Table 7](#); orders 8-9 in [Table 8](#), and orders 10-11 in [Table 9](#). The differentiated summary tables are presented in Appendices 1-5.

For best screen viewing of this section, hide the navigation pane (eg. bookmarks and thumbnails), select the “fit width” option found in the View menu of Adobe Acrobat, and advance one half page at a time using the page down button on your keyboard or the scroll bar.

1 *Rhizocarpon geographicum* order

(References: [Table 2](#), [Appendix 1](#))

Some of the driest alpine sites are inhabited by lichen- and bryophyte-dominated communities of the *Rhizocarpon geographicum* order. These rupicolous (exposed rock) communities are most common on acidic rock. With the exception of mosses and lichens which create their own environments, plants grow mostly on grits and organic material that accumulate in cracks between the rocks. Since unconsolidated material is <10 cm deep, it is considered ‘nonsoil’ (CSSC 1978). Typical species include two lichens, *Rhizocarpon geographicum* and *Umbilicaria proboscidea*, and one bryophyte, *Polytrichum piliferum*. The four associations remain unchanged from those described in Archer’s (1963) study of alpine plant communities. Viereck *et al.* (1992) consider such ‘crustose lichen’ communities to be the primary successional stage on xeric sites in Alaska, but suggested further succession may be prevented by harsh growing conditions. Similar communities were noted, but not sampled, in the western North Cascades (Douglas 1970) and in the Bella Coola area (McAvoy 1931).

1.1 *Sibbaldia procumbens* association

(References: [Table 6](#), [Appendix 2](#))

Archer (1963) included the *Sibbaldia procumbens* association within his 'snow patch' grouping, a grouping which also included snow basin communities of the *Marsupella brevissima* and *Carex nigricans* orders. The usually flat and exposed sites are snow-free for as little as 2.5 months and support almost-pure communities of *Sibbaldia procumbens* (Figure 2). Lesser species include *Antennaria alpina*, *Juncus drummondii*, *Luetkea pectinata*, and *Polytrichum piliferum*.



Figure 2. *Sibbaldia procumbens* colonizing rocky sites (*Sibbaldia procumbens* association).

1.2 *Silene acaulis* association

(References: [Table 6](#), [Appendix 2](#))

The *Silene acaulis* and *Penstemon davidsonii* – *Juniperus communis* associations were included by Archer (1963) in his 'rupicolous' grouping. While communities in these associations develop on similar microsites to those in the *Sibbaldia procumbens* association (above), snow melts up to 1.5 months earlier. The *Silene acaulis* association, based on only four plots, is found on recently-deglaciated ridges and colluvial slopes where soils retain a relatively high base status. These habitats are usually found in the lee of ridges and couloirs where late snowmelt prevents excessive moisture deficits. The vigorous tap-root system of *Silene acaulis* allows it to colonize both rock crevices and more open ground (Figure 3), and facilitates survival in unstable soils. Other species found on these harsh sites include *Phacelia sericea*, *Saxifraga bronchialis*, and (suggesting an affiliation with the next association) *Penstemon davidsonii*.

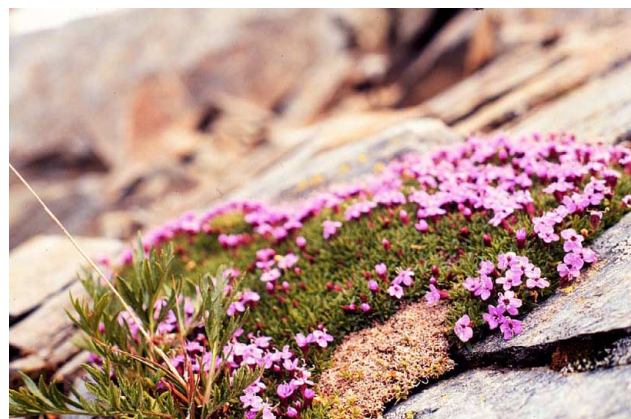


Figure 3. *Silene acaulis* inhabiting a rock pavement (*Silene acaulis* association).

1.3 *Penstemon davidsonii* – *Juniperus communis* association

(References: [Table 6](#), [Appendix 2](#))

Habitats supporting the *Penstemon davidsonii* – *Juniperus communis* association tend to be steeper, drier, and more exposed than those in the previous association. Moisture deficits in these rock outcrop and ridge-top habitats can be pronounced. Exposure to the wind severely stunts the height growth of *Juniperus communis* and *Penstemon davidsonii* and results in dwarf shrubs that are usually <10 cm tall (Figure 4). *Phyllodoce glanduliflora* is common on most sites, and the presence of some *Carex spectabilis* on moister microsites indicates an affinity to chomophytic (fragmented rock) communities.



Figure 4. *Juniperus communis* on a rock outcrop (*Penstemon davidsonii* – *Juniperus communis* association).

1.4 *Phyllodoce empetriflora* – *Abies lasiocarpa* association

(References: [Table 6](#), [Appendix 2](#))

The only krummholz communities described here were located on steep sites in the AT zone where snow melted as early as the end of June (Figure 5). The presence of such krummholz communities dominated by *Abies lasiocarpa* increases with greater continentality (though they may also occur on the highest peaks of the leeward mountains of Vancouver Island, e.g., Mt. Cain). Analogous, but more maritime-influenced, communities dominated by *Chamaecyparis nootkatensis* or *Tsuga mertensiana* have yet to be described. This is the only association of the Rhizocarpon geographicum order where A/C soils can develop (Ranker, *sensu* Kubišna 1953; = Orthic to Humic Regosol, CSSC 1978).

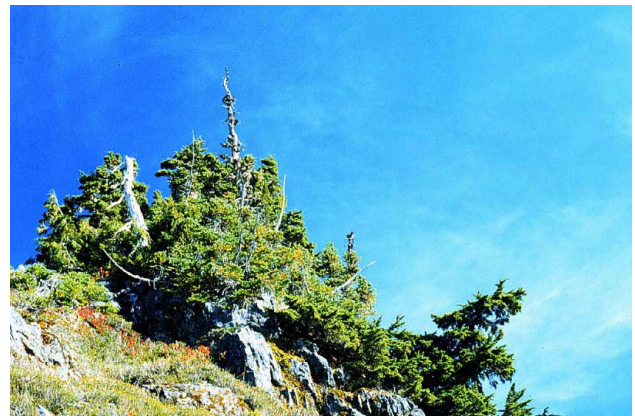


Figure 5. *Abies lasiocarpa* krummholz on a rock outcrop on Mt. Cain. (*Phyllodoce empetriflora* – *Abies lasiocarpa* association).

Four newly-sampled communities that did not fit into the classification shared characteristics with communities of the *Rhizocarpon geographicum* order. Two plots were on opposite sides (south- and north-aspects) of a 3 m-tall, steep-sided, granitic boulder. More extreme climatic conditions on the south-aspect plot were reflected in the >40% cover of lichens (primarily *Rhizocarpon geographicum*) and <0.1% cover of mosses. In contrast, the north-aspect plot had an 80% cover of mosses (primarily *Kiaeria starkei*, with less *Polytrichum piliferum* and *Racomitrium sudeticum*) and <10% cover of lichens (Figure 6). Similar communities were common throughout the study area on exposed rocks.

The effect of exposed, base-rich rock substrates was seen in one community on Mt. Maguire. It shared some species with the associations above, e.g., *Rhizocarpon geographicum* and *Penstemon davidsonii*, but was dominated by *Pseudoleskea* spp. mosses. We sampled only one plot almost exclusively populated (98% cover) by *Arctostaphylos uva-ursi* (Figure 7). It also had a minor cover of *Phlox diffusa* and stunted *Juniperus communis*, but no *Rhizocarpon geographicum*. This community was located on a south-aspect, convex slope on Church Mountain with rapidly-drained colluvial soil. These factors, and the site's upper slope position, undoubtedly caused severe growing season moisture stress. Similar (but unsampled) plant communities are common on warm-aspect sites with very early snowmelt in more continental (submaritime and subcontinental) climates. In contrast to soils on most subalpine sites, Douglas (1970) notes that soils under these communities can freeze solid to depths >25 cm.

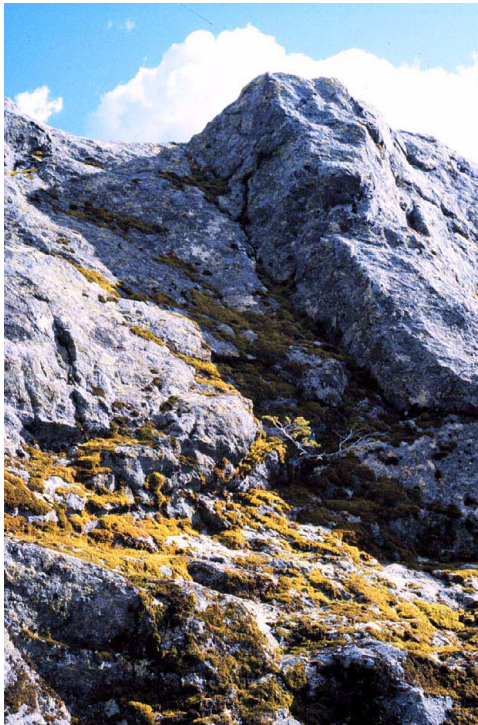


Figure 6. An unclassified community in Brandywine Meadows that is affiliated with the *Rhizocarpon geographicum* order. Mosses were abundant on this north aspect, while lichens dominated the south aspect of the same boulder.



Figure 7. An almost-pure community of *Arctostaphylos uva-ursi* on a south-aspect site on Church Mountain that has severe moisture deficits during the growing season.

2 *Phlox diffusa* order

(References: [Table 2](#), [Appendix 1](#))

2.1 *Phlox diffusa* association

(References: [Table 6](#), [Appendix 2](#))

The *Phlox diffusa* is a new order and association. Habitats are similar to those in the *Silene acaulis* and *Penstemon davidsonii* – *Juniperus communis* associations, but the growing season on these steep, south-aspect sites may be even longer and warmer. All five plots in this association also differed in that they were in the windward Cascades and on base-rich rock (Figure 8).



Figure 8. Rocky, south-aspect slopes containing species-rich communities of the *Phlox diffusa* association.

In addition to *Phlox diffusa*, common species include *Paxistima myrsinites* (on drier microsites) and *Penstemon procerus* (Figure 9). The floristic diversity of the five plots was shown by a total of 61 species, many of which were absent or rare in other vegetation units, e.g., *Lloydia serotina*, *Saxifraga occidentalis*, *Tortella tortuosa*, and *Selaginella wallacei*. Kuramoto (1968) described *Phlox diffusa*-dominated communities in the Olympic Mountains, but they contained only 13 species, a sparse plant cover, and unstable soils. Hamann (1972) also described *Phlox diffusa*-dominated communities near Mount Rainier, but they were on mostly flat, sandy sites and included a high cover of graminoids. Further sampling is required to determine the extent of this order in coastal B.C. and its relationship to the Rhizocarpon geographicum order.

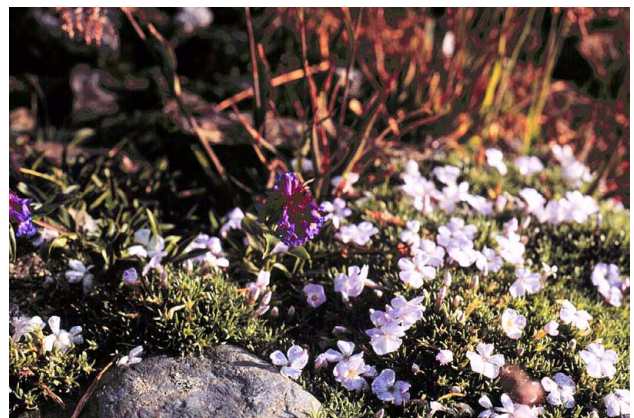


Figure 9. *Penstemon procerus* among *Phlox diffusa* on a lithic community of the *Phlox diffusa* association.

3 Marsupella brevissima order

(References: [Table 2](#), [Appendix 1](#))

The Marsupella brevissima order includes late-snowmelt, or chionophilous (literally, “snow-loving”), pioneer and snow basin communities that occur mostly in alpine and uppermost subalpine environments (Figure 10). These communities develop on sites with a very long-lasting snowpack with a nearly continuous saturation of cold melt water. We added three plots to the order described in Klinka *et al.* (1997), but the diagnosis was unaffected. Two species are characteristic of this order: the cushion-forming liverwort, *Marsupella brevissima* (= *Gymnomitrium varians*), and *Saxifraga tolmiei*.



Figure 10. A snow basin on Brohm Ridge inhabited by communities in the Marsupella brevissima and Carex nigricans orders. Upland microsites are occupied by heath communities (Cassiope mertensiana – Phyllodoce empetrifomis order). The tree island in the middle is the highest elevation reached by trees in the area.

3.1 Polytrichum alpinum – Marsupella brevissima association

(References: [Table 6](#), [Appendix 2](#))

Archer (1963) identified two similar community types in late-snowmelt basins in the AT zone: communities developing on the latest-snowmelt sites where *Polytrichum alpinum* (= *P. norvegicum*) is the dominant moss, and those that develop on sites where snow melts earlier and *Polytrichum piliferum* is the dominant moss. Communities of the Polytrichum alpinum – Marsupella brevissima association occur at the bottom of snow basins on protected slopes. Snowmelt as late as the end of August, cold and anaerobic conditions, and deposits of fine silt lead to the development of snow basin Rutmarks (*sensu* Kubiëna 1953; = Orthic or Gleyed Regosols, CSSC 1978). Vegetation is seldom taller than 1 cm and consists of pure cushion-like communities of *Marsupella brevissima* in the middle of depressions generally spanning 0.5 to 2 m. At the edges of these depressions, *Polytrichum alpinum* occurs on slight (*i.e.* 1 to 3 cm) prominences that form the transition to *Carex nigricans*-dominated communities (Figure 11).



Figure 11. With very small changes in elevation, dominant species change from *Marsupella brevissima*, to *Polytrichum alpinum*, to *Carex nigricans*. On prominences higher than *ca.* 50 cm, usually on rocks, the species change to *Phyllodoce empetrifomis* and *Cassiope mertensiana*.

3.2 *Polytrichum piliferum* – *Marsupella brevissima* association

(References: [Table 6](#), [Appendix 2](#))

Though also found in depressions, these communities are found on sites where snow melts up to three weeks earlier than in the previous association, and a coarser, sandy soil prevents the same degree of saturation from melting snow. As a result, the cover of the less water-tolerant *Polytrichum piliferum* increases. Loose stones and gravel (Hamada, *sensu* Kubiëna 1953) and freeze-thaw processes limit soil development (e.g., Orthic or Gleyed Regosols, CSSC 1978). The pioneer plants, *Luzula piperi* and *Saxifraga tolmiei*, are more common here than in the *Polytrichum alpinum* – *Marsupella brevissima* association, which may indicate a transition to sheet-wash communities of the *Luzula wahlenbergii* – *Saxifraga tolmiei* association. Two new plots have been added to Archer's (1963) original grouping that, though floristically similar, are on sheet-wash slopes rather than in basins.

3.3 *Luzula wahlenbergii* – *Saxifraga tolmiei* association

(References: [Table 6](#), [Appendix 2](#))

Pioneer communities dominated by *Saxifraga tolmiei*, *Luzula wahlenbergii*, and *Marsupella brevissima* occur where soil instability and cool temperatures restrict vegetation and soil development (Figure 12). Such communities inhabit north-aspect upper slopes that may be snow-free for only 2 to 3 months each year. Soil movement is promoted by the continuous saturation of the soil, frost heaving, and sheet-wash (the downslope movement of surface stones and gravels caused by heavy rain), and there is little or no accumulation of organic matter (Terrestrial Raw Soils, *sensu* Kubiëna 1953; = Regosols, CSSC 1978). The presence of *Phyllodoce empetrifomis* and dwarf *Tsuga mertensiana* on more stable soils at the edges of these communities signals a transition to communities of the *Cassiope mertensiana* – *Phyllodoce empetrifomis* order. Similar communities have been described elsewhere in the Pacific Northwest (Douglas 1970; Hamann 1972; Henderson 1974) on the latest-snowmelt sites where, in some years, snow never completely melts.



Figure 12. Vegetation cover is typically <10% in the pioneer *Luzula wahlenbergii* – *Saxifraga tolmiei* association. Snow from the previous winter was still present just below this Black Tusk site in the middle of September.

4 *Carex nigricans* order

(References: [Table 2](#), [Appendix 1](#))

The chionophilous sedge and bryophyte vegetation of semi-terrestrial, snow basin habitats is typified by the *Carex nigricans* order ([Figure 13](#)). Communities in this order develop below north-aspect slopes and other basin habitats. Cold -air ponding results in the retention of snow for ≥ 9 months each year (see [Figure 10](#)). *Carex nigricans* forms often-pure communities: (a) around small ponds; and (b) in semi-terrestrial snow basins surrounding pits usually dominated by *Marsupella brevissima* (see [Figure 11](#)). Vegetation development is limited by the late snowpack and the cold, usually water-saturated, root environment. Continuous mats of *Carex nigricans* cause turf-like surface soil horizons ([Figure 14](#)). Typical soils are fine-textured, laminated with deposits of fine organic and inorganic sediments from snowmelt, and are usually gleyed. Snow melts earlier and soils are drier on raised microsites and adjacent upland slopes. Resulting communities grade into heath communities of the *Cassiope empetriformis* – *Phyllodoce empetriformis* order. Most researchers in the Pacific Northwest have reported similar ‘dwarf sedge’ communities (Franklin and Dyrness 1973). Henderson (1974) suggested that communities in this order succeed communities dominated by *Marsupella brevissima*.

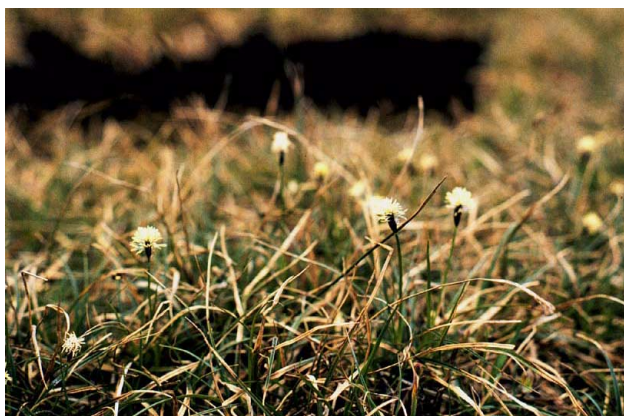


Figure 13. A pure community of flowering *Carex nigricans* (*Carex nigricans* order).

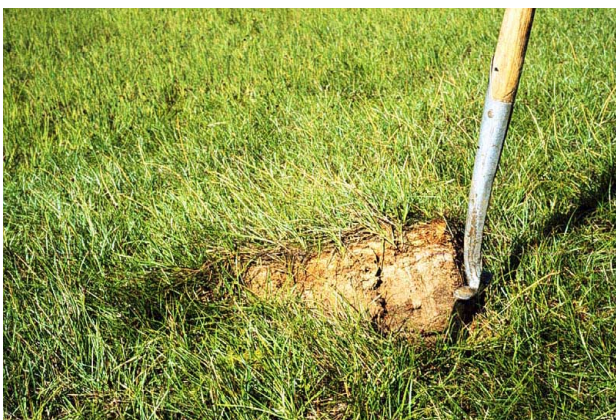


Figure 14. Laminated, turf-like soil in the *Carex nigricans* order.

4.1 *Carex nigricans*: typic subassociation

(References: [Table 6](#), [Appendix 2](#))

The five alpine plots that Archer (1963) classed into this vegetation unit were on flat sites with acidic rocks of both volcanic and plutonic origin. The snow-free period was 9 to 9.5 months and soils typically had a thin A horizon over an undeveloped C horizon (Rankers, *sensu* Kubiëna 1953; = Regosols, CSSC 1978). We have added one upper subalpine plot which, though floristically similar, was on a slightly raised microsite (*ca.* 20 cm above the surrounding ground) in a fen with abundant flowing water. The presence of flowing water very near the surface resulted in the development of a very deep (>1 m) organic soil with annual flood-deposited layers of silt over mostly-undecomposed sedge remains (Cumulo Fibrisol, CSSC 1978).

4.2 *Carex nigricans*: *Polytrichum alpinum* subassociation

(References: [Table 6](#), [Appendix 2](#))

The *Polytrichum alpinum* subassociation also occurs in late-snowmelt bowls with snow-free periods ≤ 3 months. All communities within this subassociation were located in upper subalpine environments and typical soils were Snow Basin Anmoors (*sensu* Kubiëna 1953; = Gleyed Dystric Brunisols intermixed with Terric Cumulo Fibrisols, CSSC 1978). Communities are more species-rich than in the previous subassociation and include more *Polytrichum alpinum*, *Phyllodoce empetrifomis*, and *Cassiope mertensiana*. All 10 plots were located in or near Garibaldi Park. Previously sampled plots from Garibaldi Park included *Polytrichum alpinum*. The three new plots instead included *P. sexangulare*. This change likely reflects taxonomic rather than ecological differences.

5 *Cassiope mertensiana* – *Phyllodoce empetrifomis* order

(References: [Table 2](#), [Appendix 1](#))

The *Cassiope mertensiana* – *Phyllodoce empetrifomis* order is the best-described of the classification with 53 plots. The three alliances and four associations of the order remain unchanged from Klinka *et al.* (1997), though the diagnostic combinations of species have been slightly modified with the addition of 9 plots. The *Cassiope mertensiana* alliance includes only heath communities from the AT zone. The *Cassiope mertensiana* – *Tsuga mertensiana* alliance includes only heath communities from the upper MH zone. The *Luetkea pectinata* alliance includes herb-dominated communities at a variety of elevations.

Communities related to this order have been described in Europe (Nordhagen 1937; McVean and Ratcliffe 1962; Dahl 1956; Rodwell 1991) and elsewhere in the Pacific Northwest (see Franklin and Dyrness 1973; Viereck *et al.* 1992). Henderson (1974) argued that the *Phyllodoce-Cassiope* communities identified by previous researchers should all be grouped in a *Phyllodoce empetrifomis* – *Vaccinium deliciosum* association, but the absence of *Vaccinium deliciosum* in two of three alliances in our region suggests otherwise.

The *Cassiope mertensiana* – *Tsuga mertensiana* alliance may also include dwarfed *Tsuga mertensiana*, prostrate *Chamaecyparis nootkatensis*, and scattered *Vaccinium deliciosum* and *V. membranaceum*, especially in transitions to krummholz or tree islands (Figure 15). Two species common to all alliances (between clumps of *Phyllodoce empetrifomis* and *Cassiope mertensiana*) are *Lycopodium sitchense* and, especially on wetter, peaty substrates, *Luetkea pectinata*.



Figure 15. Dwarfed *Tsuga mertensiana* and some *Chamaecyparis nootkatensis* scattered amidst a heath community of the *Cassiope mertensiana* – *Phyllodoce empetrifomis* order (Mt. Cain). Dwarf trees and a higher cover of *Vaccinium deliciosum* are common in transitional areas near tree islands.

Heath communities occupy zonal sites in the alpine and near-zonal sites in the upper subalpine, but their habitat changes with elevation. At higher elevations, they occupy relatively early-snowmelt sites and are slightly chionophobic (snow-avoiding). At lower elevations, they instead occupy sites where snow melts relatively late and they are moderately chionophilous (Brooke *et al.* 1970). Heath communities are widespread in alpine and upper subalpine environments, and may extend into the lower subalpine (*i.e.*, forested MH subzones) on benches and basins where snow melts late and growing conditions resemble those at higher elevations (Figure 16).

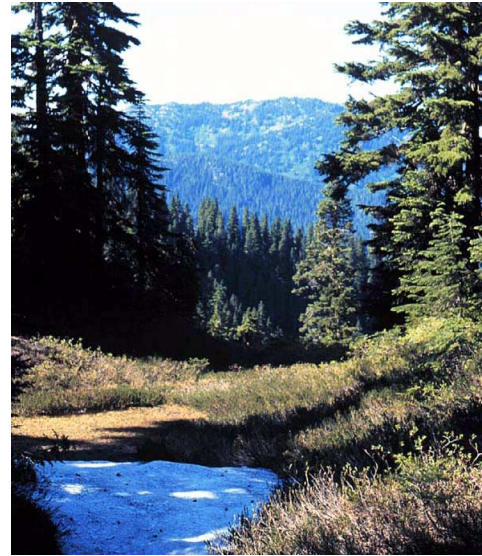


Figure 16. Late snowmelt on benches and cool-aspect slopes in the lower subalpine (forested MH subzones) result in growing conditions that are similar to high elevations. This late-snowmelt gap, near Yale Creek, is inhabited by heath communities of the *Cassiope mertensiana* – *Phyllodoce empetrifomis* order.

A number of researchers have speculated on the successional relationship of this order. McAvoy (1931) considered *Phyllodoce empetrifomis* (Figure 17) to be the climax alpine vegetation, though this contradicts the greater presence of *Cassiope mertensiana* at higher elevations. The approximate elevation at which the latter species becomes dominant has been reported at 1800 m both near Mount Rainier (Hamann 1972) and in Garibaldi Park (Archer 1963). Douglas (1970) suggested a successional trajectory from the typic to the *Vaccinium deliciosum* subassociations of the *Cassiope mertensiana* – *Phyllodoce empetrifomis* association, and eventually to the *Cassiope mertensiana* – *Tsuga mertensiana* association. Tree establishment and growth above the snowpack in the latter association is expected to result in earlier snowmelt, and eventually develop into a closed forest (Douglas 1972; Henderson 1974).



Figure 17. *Phyllodoce empetrifomis* (*Cassiope mertensiana* – *Phyllodoce empetrifomis* order)

5.1 *Carex spectabilis* – *Cassiope mertensiana* association

(References: [Table 7](#), [Appendix 3](#))

Though he was unable to distinguish between them, Archer (1963) believed that there were two variations of this association within the AT zone: one at lower elevations dominated by *Phyllodoce empetrifomis*, and the other at higher elevations dominated by *Cassiope mertensiana*. This association differs from others within the order by the higher cover of *Carex spectabilis*, *Antennaria alpina*, and *Erigeron peregrinus*. Other than being at higher elevations, it shared similar habitats, e.g., all aspects, a variety of slope gradients, and soil moisture regimes from fresh to wet. Soils are less developed than others in this order, usually consisting of peaty A/C soils (Organic Rankers; *sensu* Kubiëna 1953; = Orthic to Humic Regosols, CSSC 1978).

5.2 *Cassiope mertensiana* – *Phyllodoce empetrifomis*: typic subassociation

(References: [Table 7](#), [Appendix 3](#))

This subassociation includes typical heather communities on flatter sites where snow duration is slightly longer than in others of the *Cassiope mertensiana* – *Tsuga mertensiana* alliance. Its transitional location is reflected by a higher presence and cover of snow-basin species such as *Marsupella brevissima* and *Carex nigricans*. Soils are typically Dystric Brunisols (CSSC 1978).

5.3 *Cassiope mertensiana* – *Phyllodoce empetrifomis*: *Vaccinium deliciosum* subassociation

(References: [Table 7](#), [Appendix 3](#))

While *Vaccinium deliciosum* is present on most sites in the *Cassiope mertensiana* – *Tsuga mertensiana* alliance, it achieves its greatest extent in this subassociation where snow melts up to three weeks earlier than in the typic subassociation. These plant communities often occupy slope positions intermediate between those of the typic subassociation and tree islands (Figure 18; also Figure 58 in Brooke *et al.* 1970). Their greater affinity to forested communities (compared to other communities in the alliance) is reflected by a higher presence of *Rubus pedatus*, a thicker Mor humus layer, and greater leaching (Eluviated Dystric Brunisols to Ferro-Humic Podzols, CSSC 1978). With the addition of five new plots, the geographic range of this subassociation has been expanded to include Vancouver Island, Garibaldi Park, and the windward Cascades.



Figure 18. A typical sequence of upper subalpine communities from Mt. Washington. *Phyllodoce empetrifomis* dominates mesic microsites below the tree island, but is intermixed with an increasing presence of *Vaccinium deliciosum* closer to the tree island. (See also [Figure 45](#).)

5.4 *Cassiope mertensiana* – *Tsuga mertensiana*: typical subassociation

(References: [Table 7](#), [Appendix 3](#))

Compared to communities of the other three subassociations in the *Cassiope mertensiana* – *Tsuga mertensiana* alliance, these tend to occupy higher slope positions (ridges to mid-slopes), have earlier snowmelt, be drier, and have more podzolized soils (Dystric Brunisols to Humo-Ferric Podzols; CSSC 1978). As in the *Hippuris montana* subassociation (below), there are many dwarf ('nano-') *Tsuga mertensiana*, but also more dwarf *Chamaecyparis nootkatensis*.

We sampled a plot on Mt. Cain similar to those in the typical subassociation. The *Tsuga mertensiana* and *Chamaecyparis nootkatensis* present were <50 cm tall and restricted to a site beside a ridge populated by tree-sized individuals (see Figure 16). A slightly different plant community sampled near Nimpkish Lake was in a late-snowmelt basin at the base of a north-aspect slope and was between two tree islands. In addition to an almost complete cover of low ericaceous shrubs (primarily *Empetrum nigrum*), there was a 50% cover of strongly-curved *Chamaecyparis nootkatensis*, most of which were <1 m tall.

5.5 *Cassiope mertensiana* – *Tsuga mertensiana*: *Hippuris montana* subassociation

(References: [Table 7](#), [Appendix 3](#))

Compared to the previous subassociation, communities of the *Hippuris montana* subassociation occupy lower slope positions, including concave sites, and soils tend to have a coarser texture. The high presence and cover of the moisture-requiring *Hippuris montana*, resulting from more abundant seepage, distinguishes this subassociation from the previous subassociation.

5.6 *Luetkea pectinata* association

(References: [Table 7](#), [Appendix 3](#))

Identified by Archer (1963) within his 'chomophytic group' (see the *Carex spectabilis* order below), these are pioneer communities on unstable colluvial substrates (Figure 19).



Figure 19. Unstable (sheet-wash) slopes are often colonized by *Luetkea pectinata*.

28 RESULTS AND DISCUSSION

5 *Cassiope mertensiana* – *Phyllodoce empetrifomis* order

Rapid drainage is offset by moisture from melting snow. The *Luetkea pectinata* association, though consisting of herb-dominated communities, was grouped by Klinka *et al.* (1997) in the *Cassiope mertensiana* – *Phyllodoce empetrifomis* order to recognize its floristic affinity with adjacent heath communities. It likely represents the initial successional stage on alpine sites (Archer 1963; Henderson 1974) and, as organic material accumulates and the soil is stabilized by vegetation, is succeeded by zonal heath communities (Figure 20).



Figure 20. Some *Luetkea pectinata* communities represent a succession to zonal heath communities.

In addition to *Luetkea pectinata*, differential species include *Hieracium gracile*, *Luzula piperi*, and *Valeriana sitchensis*. Douglas (1970) recognized the wide ecological amplitude of *Luetkea pectinata* and distinguished two associations dominated by the species: a 'residual or regosolic phase' on flat, late-snowmelt sites adjoining *Carex nigricans* communities; and an 'alpine rawmark phase' which inhabit similar sites to those of the association we describe here.

6 *Carex spectabilis* order

(References: [Table 2](#), [Appendix 1](#))

This order includes pioneer plant communities inhabiting recently deglaciated areas that are usually rockier than those of the previous association. These chomophytic (fragmented rock) communities are most common on colluvial alpine slopes, but also form on upper subalpine sites where coarse fragment debris has accumulated in late-snowmelt depressions. The coarse-textured soils are relatively base-rich because they have yet to be heavily leached or acidified, and receive abundant moisture from melting snow. There is little organic accumulation or soil development and Regosols (CSSC 1978) are most common. This order remains mostly unchanged from Klinka *et al.* (1997), except for the addition of the *Oxyria digyna* – *Carex spectabilis* association. *Carex spectabilis*-dominated communities in the U.S. Pacific Northwest were grouped with more nutrient-rich communities (including communities equivalent to those described in the *Philonotis fontana* and *Valeriana sitchensis* orders, below) and termed ‘lush herbaceous’ (Franklin and Dyrness 1973). While Douglas (1970) could not detect any ecological differences between the herbaceous groups, sites in our *Carex spectabilis* order were generally drier than in the following two orders, a result also reported by Kuramoto (1968).

6.1 *Carex spectabilis* association

(References: [Table 7](#), [Appendix 3](#))

The *Carex spectabilis* association can develop on a variety of bouldery sites (e.g., talus, rock outcrops, and glacial outwash slopes), as long as there is a source of moisture, usually melting snow (Figure 21). Plant communities are relatively species-poor and *Carex spectabilis* can form pure, continuous communities, especially on finer-textured soils. On talus slopes, where boulders and other large fragments restrict colonization, *Carex spectabilis* is more dispersed. The presence of *Lupinus arcticus* shows an affinity between this association and the following association.



Figure 21. This moist, colluvial site on Black Tusk supports a community of the *Carex spectabilis* association.

One unclassified plot, near the bottom of an active talus slope, contained only a sparse (<3%) cover of two xerophytes - *Saxifraga ferruginea* and *Grimmia* spp. A plot located near the top of this slope (and included in the *Carex spectabilis* association) had a 90% cover of *Carex spectabilis*, but also a minor cover of *Saxifraga ferruginea*. Soil instability apparently prevented the colonization of *C. spectabilis* on the otherwise similar habitat of the unclassified plot.

6.2 *Anaphalis margaritacea* – *Lupinus arcticus* association

(References: [Table 7](#), [Appendix 3](#))

Communities in the *Anaphalis margaritacea* – *Lupinus arcticus* association are characteristic of the initial successional stages on recently formed fluvial terraces, moraines, and boulder fields which have not been extensively leached of bases (Figure 22). *Lupinus arcticus* and *Anaphalis margaritacea* dominate the diverse communities that contain more herbaceous species than almost any other in this classification.



Figure 22. A successional sequence is obvious in this cool-aspect avalanche bowl on Church Mountain. Behind the distinct band of *Lupinus arcticus*-dominated communities is a band of krummholz next to a continuous forest.

6.3 *Oxyria digyna* – *Carex spectabilis* association

(References: [Table 7](#), [Appendix 3](#))

The single plot in this tentative association had a high cover of *Oxyria digyna* and *Carex spectabilis* and was located near Black Tusk in the middle of a moist, cool-aspect, colluvial slope (Figures 23).

The presence of *Petasites frigidus* indicated a constant flow of cold water. Pioneer plant communities containing *Oxyria digyna* (Figure 24) were also present on somewhat drier sites classified in the *Parnassia fimbriata* – *Valeriana sitchensis* association.



Figure 23. The only plot within the *Oxyria digyna* – *Carex spectabilis* association was located on Black Tusk. It occupied a very moist site on a convex lower slope comprised of colluvium.

Carex spectabilis association also shared some floristic similarities with stream-edge communities of the *Epilobium latifolium* – *Mimulus lewisii* association, e.g., the species mentioned above plus *Senecio triangularis* and *Cardamine oligosperma*. A somewhat similar community also containing *Oxyria digyna* and *Petasites frigidus* was reported by Douglas (1970), but it was dominated by *Saxifraga lyallii* and *S. nelsoniana* and contained no *Carex spectabilis*.



Figure 24. *Oxyria digyna* colonizes very rocky sites.

One unclassified plot was located on a steep, warm-aspect, colluvial slope on Blackcomb Mountain. The fresh to moist talus slope and the presence of *Carex spectabilis* and *Valeriana sitchensis* were consistent with plots in the *Carex spectabilis* order. None of the plots described above, however, had such a dense cover (70%) of ericaceous shrubs or an A/B/C soil (Orthic Dystric Brunisol, CSSC 1978). We therefore assume that this, and other shrub communities we saw on talus slopes between tree islands, represent intergrades to forest communities. Further sampling may clarify this relationship, and help determine if such communities will ultimately develop into a closed forest.

7 *Philonotis fontana* order

(References: [Table 2](#), [Appendix 1](#))

The floristically-diverse, herb-dominated plant communities of the *Philonotis fontana* order develop near flowing water, mostly on upland sites. They can form a narrow band on either side of streams and small rivulets, and also develop on seeps (flush habitats) with flowing surface water. In addition to herbs and graminoids, hygro- and hydrophytic bryophytes form a constant component of which the most striking feature is the yellow-green moss, *Philonotis fontana*. The order remains mostly unchanged from Klinka *et al.* (1997) in spite of the addition of 10 new plots. One small change is the addition of *Valeriana sitchensis* as a differential species, reflecting this order's affinity to the *Valeriana sitchensis* order. The two associations in the *Philonotis fontana* order can be distinguished by the degree of soil development: no or very little development in the *Epilobium latifolium* – *Mimulus lewisii* association, and somewhat greater development (especially the accumulation of organic material) in the *Caltha leptosepala* – *Leptarrhena pyrolifolia* association.

Floristically-similar communities developing in and beside cold, flowing water were noted, but not extensively sampled, in the western North Cascades (Douglas 1970) and the Bella Coola region (McAvoy 1931). *Epilobium latifolium*-dominated pioneer communities have been more extensively described on unstable flood plains and riverbanks in Alaska (see Viereck *et al.* 1992). The *Philonotis fontana* order (and the *Valeriana sitchensis* order) appear to be closely related to the Montio - Cardaminetalia grouping described in Europe (Krajina 1933; Poore 1953; Braun-Blanquet 1951; McVean and Ratcliffe 1962; Shimwell 1971; Ellenberg 1988; Rodwell 1991).

7.1 *Caltha leptosepala* – *Leptarrhena pyrolifolia* association

(References: [Table 7](#), [Appendix 3](#))

Five new plots have been added to the association first described by Brooke *et al.* (1970). Communities in this association are sharply demarcated by the influence of cold, flowing water which prevents the development of closed communities (Figure 25).



Figure 25. *Philonotis fontana* (middle of photo) signifies the presence of an active seepage area on Black Tusk.

Where the water's influence lessens there is an abrupt transition to zonal communities of the *Cassiope mertensiana* – *Phyllodoce empetrifolia* order or, on wetter slopes to meadows, of the *Valeriana sitchensis* order. Species that are more common than in other units include the two dominant species, *Leptarrhena pyrolifolia* and *Caltha leptosepala* (Figure 26), as well as *Parnassia fimbriata* and *Rhytidiadelphus squarrosus*. Compared to sites inhabited by *Epilobium latifolium* – *Mimulus lewisii* communities (below), *Caltha* – *Leptarrhena* communities develop where slower-moving water allows the accumulation of organic material. This accumulation raises the growing surface and results in slightly drier (but still very moist to wet, semi-terrestrial) growing conditions. Varying depths of organic material develop over the usually gleyed mineral soils on these sites (e.g., Rego Gleysols, CSSC 1978), and the snow duration is from 8 to 9 months.



Figure 26. *Caltha leptosepala* (in flower) and *Leptarrhena pyrolifolia* (leaves only) are characteristic of sites with slow-moving, cold water.

7.2 *Epilobium latifolium* – *Mimulus lewisii* association

(References: [Table 7](#), [Appendix 3](#))

This is the wetter of two alpine meadow associations identified by Archer (1963). Archer's suggestion that the *Epilobium latifolium* – *Mimulus lewisii* association is best expressed at lower alpine elevations is supported by the addition of five upper subalpine plots. Plant communities in this association develop on wet to very wet, base-rich sites where the scouring of water results in coarse-textured Regosols (CSSC 1978) with little or no accumulation of organic materials. They are common beside braided streams on glacial outwash plains, along fast-moving streams and rivulets, and in very vigorous seepage areas. *Mimulus lewisii* can establish where the water table is highest, while *Epilobium latifolium* is more common on slightly raised microsites (Figure 27).



Figure 27. Communities of the *Epilobium latifolium* – *Mimulus lewisii* association are initial colonizers of stream-edge sites with fast-flowing water (Brandywine Meadows).

Two unclassified plots from Brandywine Meadows occurred in habitats similar to those of the *Philonotis fontana* order, but were different floristically. The first plot (Figure 28) was at the base of a north-aspect, heath-dominated slope where seepage emerging from upslope caused a transition to open communities.



Figure 28. An unclassified community from Brandywine Meadows dominated by *Scapania undulata*, and surrounded by *Luetkea pectinata*.

This plot was in the middle of a small rivulet and contained an almost-pure community of *Scapania undulata*. Surrounding the plot, on slightly drier microsites, were communities dominated by *Luetkea pectinata* and *Leptarrhena pyrolifolia*. There was no soil development, only undecomposed plant remains and humic muck overlaying rock. The second plot (Figure 29) was in the middle of a fast-flowing rivulet bounded by an *Epilobium latifolium* – *Mimulus lewisii* community. Except where rounded rocks were exposed, this community consisted almost exclusively of the liverwort *Jungermannia exsertifolia*, growing over coarse sand.

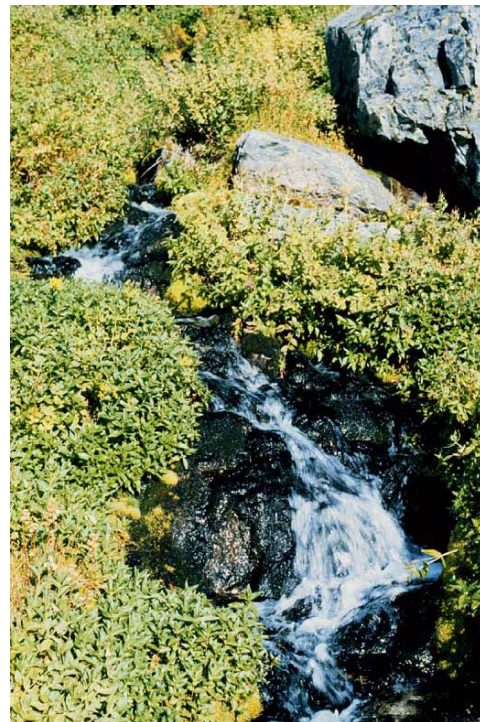


Figure 29. Most herbs are unable to survive in the middle of rivulets fed by snowmelt. This unclassified community in Brandywine Meadows is dominated by *Jungermannia exsertifolia*.

8 *Valeriana sitchensis* order

(References: [Table 2](#), [Appendix 1](#))

The lush herbaceous (Douglas 1970) meadow communities of the *Valeriana sitchensis* order, those most closely associated with colourful floral displays at high elevations, develop on fresh to very moist, nutrient-rich sites. The communities are commonly dominated by a great diversity of short and tall herbs (Figure 30), and usually also include an abundance of graminoids and mosses.



Figure 30. Herb-dominated communities in Kwoiek Creek. The most abundant species were *Epilobium angustifolium* and *Thalictrum occidentale*.

They typically occur on middle and lower slopes with plentiful moisture, usually from snowmelt, but also form in fresh to moist avalanche tracks. The addition of nine new plots has resulted in the clarification of associations and diagnostic combinations of species from Klinka *et al.* (1997). In particular, plots in Klinka *et al.*'s (1997) *Carex mackenziei* – *Valeriana sitchensis* association have been included in a revised *Heracleum maximum* – *Valeriana sitchensis* association, and five new plots form the new *Parnassia fimbriata* – *Valeriana sitchensis* association.

Similar communities reported in Europe (Krajina 1933; Poore 1953; Braun-Blanquet 1951; McVean and Ratcliffe 1962; Shimwell 1971; Ellenberg 1988; Rodwell 1991) and throughout the U.S. Pacific Northwest (Kuramoto 1968; Douglas 1970; Hamann 1972; Henderson 1974) develop on different habitats depending on location. For example, Kuramoto (1968) reported that they occupied cool-aspect slopes and Hamann (1972) associated them with lower avalanche slopes. Meanwhile, Douglas (1970) found them to be most common on steep (30-60% grade), south-aspect, colluvial slopes with snowmelt as soon as early May. Lush herbaceous communities may be favoured over heath communities on these sites because they are less damaged by snow creep (Douglas 1970; Franklin and Dyrness 1973). Within our region, the occurrence of lush herbaceous communities of the *Valeriana sitchensis* order increases with greater continentality.

8.1 *Parnassia fimbriata* – *Valeriana sitchensis* association(References: [Table 8](#), [Appendix 4](#))

This new association is based on five plots from the easternmost portions of the MH zone (Church Mountain and Kwoiek Creek). The three Church Mountain plots contained pioneer communities on a north-aspect talus slope, while the two Kwoiek Creek plots contained species-rich communities on deep Eutric Brunisols (CSSC 1978). The Kwoiek Creek plots were on the lower slope of an avalanche track (Figure 31) and included one plot with a closed-canopy of *Salix commutata*. Plant communities in this association share floristic similarities with both the *Oxyria digyna* – *Carex spectabilis* and the *Heracleum maximum* – *Valeriana sitchensis* associations, and clarifying the relationships between these three associations will require further sampling.



Figure 31. mosaic of lush herbaceous meadows (*Valeriana sitchensis* order), with tree islands on ridges in Kwoiek Creek.

8.2 *Heracleum maximum* – *Valeriana sitchensis* association(References: [Table 8](#), [Appendix 4](#))

Most communities within this association inhabit moist to wet, active slide slopes (Figure 32). The main floristic link between these wide-ranging communities (high elevations at Hurley Pass and Black Tusk, and low elevations at Kimsquit) was the presence of *Heracleum maximum* (= *H. lanatum*). Most sites were dominated by such herbs as *Valeriana sitchensis*, *Veratrum viride* and, on Kimsquit plots only, *Sanguisorba canadensis*. Two plots, however, were dominated by *Salix* spp. The base-rich soils were shallow to deep, Eutric to Melanic Brunisols (CSSC 1978).



Figure 32. A slide slope near Hurley Pass sampled after the first snowfall in mid-September. The herb-dominated community has been flattened by snow.

8.3 *Carex spectabilis* – *Valeriana sitchensis* association

(References: [Table 8](#), [Appendix 4](#))

We have added no plots to the second of two alpine meadow associations (with the *Mimulus lewisii* – *Epilobium latifolium*) identified by Archer (1963). Communities in this association occur in sheltered, well-drained locations that are more dependent upon moisture from snowmelt and have greater soil development than those in the *Mimulus lewisii* – *Epilobium latifolium* association. Common herbaceous species in addition to *Valeriana sitchensis* and *Carex spectabilis* include *Pulsatilla occidentalis* (= *Anemone occidentalis*) and *Lupinus arcticus*. These communities are associated with thick, peaty A horizons over acidic volcanic rock (Organic Rankers, *sensu* Kubiëna 1953; = Humic Regosols, CSSC 1978).

8.4 *Sphagnum* – *Valeriana sitchensis* association

(References: [Table 8](#), [Appendix 4](#))

The single plot in this tentative association, located in a moist to very moist seepage gully near Kimsquit, included a species combination unseen on any other plot: *Valeriana sitchensis* with *Sphagnum* spp. In addition, there was a dense cover of *Elliottia* (= *Cladothamnus*) *pyroliflorus*.

9 *Alnus viridis* order

(References: [Table 2](#), [Appendix 1](#))

Plant communities in this order are most floristically similar to those in the *Valeriana sitchensis* order (Table 5) in abundance of herbaceous species. Shrub-dominated communities, however, are common only in this order. The order is retained from Klinka *et al.* (1997), with some revision in the nomenclature. Communities are dominated by *Alnus viridis* and *Salix* spp., and associations increase in plant vigour from *Phyllodoce empetriformis* – *Alnus viridis* < *Juncus ensifolius* – *Alnus viridis* < *Valeriana sitchensis* – *Alnus viridis* < *Oplopanax horridus* – *Alnus viridis*.

These communities occur in a complex pattern that is related to variations in substrate, soil moisture conditions, duration of snowpack, and frequency of disturbance. With the exception of the new plot from Kwoiek Creek, most plots in this order are from lower elevations and vegetation units (other than the *Oplopanax horridus* – *Alnus viridis* association) are based on a small number of sample plots. Since avalanche tracks can span 600 to over 1200 m of vertical relief (Fonda 1967; Douglas 1970; Figure 33), we expect that further sampling will reveal similar plant communities at higher elevations.

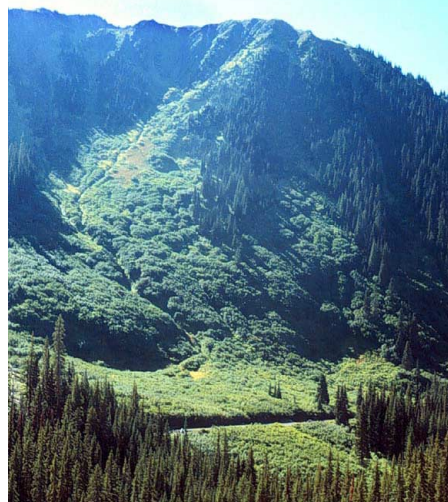


Figure 33. An avalanche slope near Kwoiek Creek containing herb and deciduous shrub-dominated communities of the *Alnus viridis* order. Avalanche tracks can span up to 1200 m of elevation.

The avalanche track communities are more or less frequently disturbed by snow avalanches and thus represent a disclimax (disturbance-maintained climax) vegetation. The shrub layer of *Alnus viridis* can be extremely dense, often forming impenetrable thickets, with the stems deformed by the heavy weight of snow (Figure 34).



Figure 34. The dense canopy of *Alnus viridis* typical of avalanche tracks. Note the deformation of stems caused by snow creep.

Scattered individuals or clumps of *Tsuga mertensiana* and *Chamaecyparis nootkatensis* (Fonda 1967) may also be present in canopy gaps and on the edges of boulders or small topographic prominences. The associated soils are typically moist to very moist, skeletal Regosols or Brunisols (CSSC 1978) with Moder or Mull humus forms (Green *et al.* 1993), and have a high proportion of coarse fragments intermixed throughout the soil profile.

9.1 *Oplopanax horridus* – *Alnus viridis*: *Rubus parviflorus* subassociation

(References: [Table 8](#), [Appendix 4](#))

Communities in this subassociation include a wider range of shrubs (e.g., *Rubus parviflorus*, *Acer glabrum*, and *Salix sitchensis*) than the typic subassociation, and have greater soil development than most vegetation units within this order (Dystric Brunisols to Ferro-Humic Podzols; CSSC 1978). They develop on moist, usually steep and warm-aspect, avalanche slopes in the CWH zone near Kimsquit. *Athyrium filix-femina*, common throughout communities within this order, reaches its greatest extent here. Douglas (1970) described very species-rich avalanche track communities dominated by *Rubus parviflorus* and *Epilobium angustifolium* from lower subalpine elevations in the western North Cascades. Snow melted as early as April, even at elevations from 1350-1500 m. Though the communities sampled by Douglas (1970) shared many species and similar habitats (other than elevation) with communities in this subassociation (and to a lesser extent, the following subassociation), tall shrubs were not present as they were here. Still, floristic and environmental similarities support the contention that the linear nature of avalanche track communities (e.g., up to 2 km of slope distance; Douglas 1970) results in subalpine elements being extended into montane, or even submontane, elevations.

9.2 *Oplopanax horridus* – *Alnus viridis*: typic subassociation

(References: [Table 8](#), [Appendix 4](#))

In contrast to the previous subassociation, these communities are dominated by *Alnus viridis*, and also have more *Sambucus racemosa*. They are also found on steep avalanche slopes in the CWH zone near Kimsquit, but are more likely to be on cool aspects. The fresh to moist soils are relatively undeveloped and range from shallow Orthic Regosols to Dystric Brunisols (CSSC 1978).

9.3 *Phyllodoce empetrifomis* – *Alnus viridis* association

(References: [Table 8](#), [Appendix 4](#))

Based on only one plot, this plant community was unique, with an almost complete cover of both *Phyllodoce empetrifomis* and *Alnus viridis*, as well as an extensive cover of mosses (*Dicranum* spp., *Racomitrium* spp., and *Polytrichum juniperinum*). It was located on a convex, well-drained, fluvial fan in the forested MH subzone near Kimsquit. Rapid drainage resulted in slight moisture deficits (slightly dry to fresh moisture regime), and soil development was limited to an Orthic Regosol (CSSC 1978).

9.4 *Juncus ensifolius* – *Alnus viridis* association

(References: [Table 8](#), [Appendix 4](#))

This community, also based on only one plot in the CWH zone near Kimsquit, supported another unusual combination of species. It was located on a moist floodplain with a fluctuating water table that resulted in the development of a Gleyed Orthic Regosol (CSSC 1978). The community consisted of a closed-canopy of *Alnus viridis* and an understory with abundant *Juncus ensifolius* and numerous other graminoids.

9.5 *Valeriana sitchensis* – *Alnus viridis* association

(References: [Table 8](#), [Appendix 4](#))

Communities of this association were located on moist avalanche tracks with a closed-canopy of *Alnus viridis*, some *Salix* spp., and an understory consisting of an extensive cover of such nitrophilous species as *Valeriana sitchensis*, *Veratrum viride*, *Heracleum maximum*, and *Athyrium filix-femina*. The presence of these and other shared species suggests an affinity of these communities with those of the *Heracleum maximum* – *Valeriana sitchensis* association in the previous order. Six of the plots were located in the forested MH subzone near Kimsquit, and one was from Kwoiek Creek. Soil development on these sites was unexpectedly poor (most soils were Orthic Regosols; CSSC 1978) given the closed-cover of soil-stabilizing shrubs and <20% surface cover of coarse fragments. The change in species composition from the *Oplopanax horridus* – *Alnus viridis*: *Rubus parviflorus* subassociation (sampled in the CWH zone) to this subassociation (sampled in the lower and upper MH subzones) supports Franklin and Dyrness' (1973) assertion that lower-elevation *Rubus parviflorus*-*Epilobium angustifolium* communities (discussed in [section 9.1](#)) grade into *Valeriana sitchensis*-*Veratrum viride* communities at higher elevations.

10 *Eriophorum angustifolium* order

(References: [Table 2](#), [Appendix 1](#))

Sedge- and bryophyte-dominated communities of the *Eriophorum angustifolium* order commonly form in and around small, stagnant ponds in the upper MH zone (Figure 35). This is one of two new wetland orders (with the *Carex pluriflora* order). It includes three associations: one (*Carex aquatilis* – *Eriophorum angustifolium*) retained from the classification of wetlands by Klinka *et al.* (1997), and the other two based on newly-sampled plots.



Figure 35. *Eriophorum angustifolium* (cotton grass) in flower.

10.1 *Warnstorfia exannulata* – *Eriophorum angustifolium* association

(References: [Table 9](#), [Appendix 5](#))

Communities in this association consist almost solely of *Eriophorum angustifolium* and, on the wettest microsites, *Warnstorfia exannulata*. It occupies microsites in water-collecting subalpine basins that are transitional from standing water to more mesic microsites inhabited by, e.g., *Carex nigricans* (Figure 36).

Organic substrates prevail (Fbrisols, Mesisols, and sometimes Humisols; CSSC 1978). One unclassified community within a *Carex*-dominated fen in Brandywine Meadows contained an almost complete cover of *Warnstorfia exannulata* and a minor cover of *Carex lenticularis*.



Figure 36. *Eriophorum angustifolium* inhabits water-collecting sites (middle). Increasingly dry sites are occupied by communities from the *Carex nigricans* order and communities from the *Cassiope mertensiana* – *Phyllodoce empetrifomis* order. Also see [Figure 45](#).

10.2 *Fauria crista-galli* – *Eriophorum angustifolium*: *Empetrum nigrum* subassociation(References: [Table 9](#), [Appendix 5](#))

Empetrum nigrum is especially common on more maritime sites in coastal B.C., e.g., Vancouver Island. All six plots identified in this subassociation were near Nimpkish Lake, where *Empetrum nigrum* appears to occupy an ecological niche equivalent to *Phyllodoce empetriformis* in more easterly locations. These moist to wet, nutrient-poor sites included typical bog species (e.g., *Fauria crista-galli*, *Vaccinium uliginosum*, and *Kalmia microphylla*) intermixed with species usually associated with mesic sites, (e.g., *Empetrum nigrum*, *Vaccinium caespitosum*, and *Pleurozium schreberi*). This diversity of species types was reflected in a mix of organic and mineral soils (Folisols and Eluviated Dystric Brunisols, respectively; CSSC 1978; Figure 37).



Figure 37. A Mesisol (CSSC 1978) from an *Eriophorum angustifolium*-dominated bog on Black Tusk.

Two plots may represent a separate *Cladina*-dominated subassociation. The water table on these plots was within 30 cm of the ground surface (Figure 38) but, in addition to the species mentioned above, there was an 80% cover of lichens (*Cladina rangiferina* and *C. mitis*). There were also similar, unsampled communities nearby on small boulders. *Empetrum nigrum* dominates different habitats outside of our region. For example, it forms pioneer alpine communities near Mount Rainier (Hamann 1972) and can dominate the tundra vegetation in southern Alaska and the Aleutian Islands (Viereck *et al.* 1992).



Figure 38. Two plots classified in the *Fauria crista-galli* – *Eriophorum angustifolium*: *Empetrum nigrum* subassociation contained an 80% cover of *Cladina* spp., in spite of a water table only 30 cm below the ground surface.

10.3 *Fauria crista-galli* – *Eriophorum angustifolium*: typic subassociation

(References: [Table 9](#), [Appendix 5](#))

The typic subassociation was restricted to a fen on a bench below a limestone bluff near Woss (Figure 39). The moisture regime varied from very moist to wet depending on proximity to the network of small streams flowing through the middle of the bench.

Compared to the other two subassociations in the *Fauria crista-galli* – *Eriophorum angustifolium* association, the communities here are relatively species-poor. Except for the limited presence and cover of *Vaccinium caespitosum*, upland species are absent. These were the only communities (other than the *Sphagnum* bogs sampled near sea level) that included *Sanguisorba officinalis*. The very deep (>1 m) soils (Typic and Cumulo Mesisols; CSSC 1978) consisted of thick organic soils over a very fine-textured, base-rich, mineral soil.



Figure 39. A bench near Woss supports communities of the *Fauria crista-galli* – *Eriophorum angustifolium*: typic subassociation.

10.4 *Fauria crista-galli* – *Eriophorum angustifolium*: *Sphagnum* subassociation

(References: [Table 9](#), [Appendix 5](#))

These plant communities formed on wet to very wet sites at the edges of shallow ponds in the two locations near Nimpkish Lake (Figure 40).

The organic soils varied from thin to thick (15 cm to >100 cm) Mesic Fibrisols (CSSC 1978). This subassociation shares a floristic affinity with the *Sphagnum* – *Carex pluriflora*: *Vaccinium uliginosum* subassociation (*Carex pluriflora* order), particularly in the high presence of *Sphagnum* spp. and *Fauria crista-galli*, but *Carex pluriflora* replaces *Eriophorum angustifolium* in the latter subassociation. Similar communities have been described near Mount Rainier (Henderson 1974) and in Alaska (Viereck *et al.* 1992).



Figure 40. Communities of the *Fauria crista-galli* – *Eriophorum angustifolium*: *Sphagnum* subassociation were located at the edges of ponds near Nimpkish Lake.

10.5 Carex aquatilis – Eriophorum angustifolium association

(References: [Table 9](#), [Appendix 5](#))

Most of the *Eriophorum-Carex aquatilis* communities described by Brooke *et al.* (1970) inhabited water-collecting basins in the forested MH zone, but similar communities may also form at elevations extending into the AT zone. Accumulations of dead *Sphagnum subnitens* form deep (60-120 cm) peats over gleyed mineral soils (Low Moor Peats, *sensu* Kubiěna 1953; = Fibrisols; CSSC 1978). A number of typical wetland species are present only within this unit, including *Carex aquatilis*, *Drepanocladus aduncus*, and *Calliergonella cuspidata*. Species common to the *Caltha leptosepala* – *Leptarrhena pyrolifolia* association emerge on better-drained sites with a higher base status. Brooke *et al.* (1970) infer a successional pattern to the vegetation: with *Carex aquatilis* colonizing sites with a high water table and *Eriophorum angustifolium* and *Sphagnum subnitens* succeeding after the accumulation of organic material raises the growing surface above the water. A similar but unclassified community was in a fen in Brandywine Meadows and, though containing some *Carex* spp. (primarily *C. illota*) and a minor cover of *Sphagnum* spp., it was dominated by *Calliergonella cuspidata*.

11 Carex pluriflora order

(References: [Table 2](#), [Appendix 1](#))

Low-elevation *Carex pluriflora* communities were described by Wade (1965) in the hypermaritime region of West Vancouver Island. This second wetland order contains only 12 species, 6 of which are unique in this classification: *C. pluriflora*, *C. obnupta*, *Sphagnum fallax*, *S. papillosum*, *Agoseris glauca*, and *Gentiana sceptrum*. As one of our high-elevation plots showed a distinct affinity to these communities, we included them into the classification. The addition of this plot resulted in the identification of a tentative subassociation containing *Vaccinium uliginosum*.

11.1 Sphagnum – Carex pluriflora: Vaccinium uliginosum subassociation

(References: [Table 9](#), [Appendix 5](#))

Occupying a seep on a slight slope (3% grade) between two tarns, the only plot in this tentative unit was completely covered by *Sphagnum* spp. that rose above the water table (Figure 41).

In addition to *Carex pluriflora*, there was also a minor cover of *Vaccinium uliginosum*, apparently extending from adjacent, drier microsites. This community was on a plutonic plateau (near Nimpkish Lake) with bedrock-restricted drainage. The organic soil (Cumulic Mesisol; CSSC 1978) was 70 cm thick over bedrock.



Figure 41. This *Sphagnum*-dominated community was located between two small tarns on the Nimpkish North site. A small cover of *Vaccinium uliginosum* suggests a transition to more upland sites.

11.2 *Sphagnum* – *Carex pluriflora*: typical subassociation

(References: [Table 9](#), [Appendix 5](#))

Although described near sea-level, the typical *Carex pluriflora* communities probably inhabit depressions in submontane, montane, and subalpine peat bogs. These communities are floristically simple, with a very high cover of *C. pluriflora* and a lesser cover of *Sphagnum fallax* and *S. papillosum*. The only other common species is *Sanguisorba officinalis*. Periods where standing water does not cover these communities occur in only the driest parts of summers that are drier than average. The organic soils, seldom deeper than 40 cm (but unclassified), are underlain by an impervious hardpan that restricts drainage.

Plots in this subassociation are the only ones from such a low elevation, but they share many species and a similar spectrum of life-forms with wetland communities sampled at upper subalpine elevations. They may therefore be relicts of the subarctic or boreal conditions that prevailed after the last glaciation (Wade 1965). Our additional sampling did not locate any communities that were floristically-similar enough to be classified with Wade's (1965) communities, but one community in a small pond near Nimpkish Lake shared a similar habitat (Figure 42). It consisted of only two plants, *Carex saxatilis* and *Sphagnum* spp., which dominated Wade's communities.



Figure 42. An open-cover community at the edge of a small bog pond on the Nimpkish North site. Total cover was approximately 25%.

Another unclassified plot was located in the middle of a stagnant pond near Nimpkish Lake. The community, consisting of *Nuphar luteum* ssp. *polysepalum* and *Menyanthes trifoliata* (Figure 43) resembled low-elevation plots classified in Klinka *et al.* (1997).



Figure 43. An open water community on the Nimpkish South location consisting of *Nuphar luteum* ssp. *polysepalum* and *Menyanthes trifoliata*.

Table 6. Diagnostic combinations of species for vegetation units 1.1 to 4.2. Vegetation units described in the text are numbered sequentially within each plant order.

Vegetation unit number		1.1	1.2	1.3	1.4	2.1	3.1	3.2	3.3	4.1	4.2
Number of plots		5	4	6	10	5	9	8	4	6	10
Vegetation units and species		Diagnostic value ¹	Presence class ¹ and mean species significance ¹								
Rhizocarpon geographicum order and alliance											
Rhizocarpon geographicum	d	3	1	3	1	V	2	IV	2	2	+
Umbilicaria proboscidea	d	2	1	3	1	IV	2	III	1		
Sibbaldia procumbens association											
Antennaria alpina	d	4	2							I	2
Juncus drummondii	d	3	1					III	2	III	+
Luetkea pectinata	d	3	3					II	3	II	1
Polytrichum piliferum	d, c	5	3	2	+	III	1	III	2	1	+
Sibbaldia procumbens	d, cd	5	5					II	+	II	1
Silene aucalis association											
Carex pyrenaica	d		3	1	I	+		I	1	II	+
Luzula piperi	d	1	+	3	1				IV	3	
Phacelia sericea	d		3	1							II
Polytrichum alpinum	d	1	1	3	1			V	5	II	1
Silene aucalis	d, c		5	4	I	1				3	1
Penstemon davidsonii – Juniperus communis association											
Juniperus communis	d, cd			V	7	III	3	2	5		
Penstemon davidsonii	d, c		3	1	V	2		1	+		
Solorina crocea	d			III	1						
Stereocaulon alpinum	d			III	1	1	+		I	+	I
Phyllodoce empetriformis – Abies lasiocarpa association											
Abies lasiocarpa	d, cd				V	6					
Brachythecium reflexum	d				III	1					
Cassiope mertensiana	d			I	1	III	2	1	+	II	+
Dicranum fuscescens	d				IV	2				I	1
Phyllodoce empetriformis	d, c	2	3		V	3		II	1	II	1
Pseudoleskea baileyi	d				III	1				4	+
Rhytidiopsis robusta	d				IV	3				II	1
Phlox diffusa order, alliance and association											
Paxistima myrsinites	d					3	2				
Phlox diffusa	d					4	5				
Saxifraga occidentalis	d					3	1				
Selaginella wallacei	d					3	+				
Tortella tortuosa	d					3	4				

Vegetation unit number	1.1	1.2	1.3	1.4	2.1	3.1	3.2	3.3	4.1	4.2
Number of plots	5	4	6	10	5	9	8	4	6	10
Vegetation units and species	Diagnostic value ¹	Presence class ¹ and mean species significance ¹								
Marsupella brevissima order and alliance										
Marsupella brevissima	d, cd					IV 6	IV 4	5 6	I +	II 3
Saxifraga tolmiei	d					II 1	IV 3	5 4	I 1	II 1
Polytrichum alpinum – Marsupella brevissima association										
Polytrichum alpinum	d, cd	1 1	3 1			V 5	II 1	3 1	IV 2	IV 6
Polytrichum piliferum – Marsupella brevissima association										
Luzula piperi	d	1 +	3 1				IV 3		II 1	
Polytrichum piliferum	d	5 3	2 +	III 1	III 2	1 +	II +	IV 5		
Luzula wahlenbergii – Saxifraga tolmiei association										
Kiaeria blyttii	d				II +			3 2		III 4
Luzula wahlenbergii	d					1 +		4 2		I +
Oligotrichum hercynicum	d							4 2		
Phyllodoce empetriformis	d	2 3			V 3		II 1	II 1	4 +	II 1
Tsuga mertensiana	d				I 3			4 1		I +
Carex nigricans order, alliance and association										
Carex nigricans	dd, cd	3 1	3 1			2 +	IV 2	IV 2	3 +	V 8
Carex nigricans: typic subassociation										
Carex nigricans: Polytrichum alpinum subassociation										
Cassiope mertensiana	d			I 1	III 2	1 +	II +	I 1	3 +	I +
Cephalozia bicuspidata	d								3 +	III 1
Kiaeria blyttii	d				II +				3 2	III 4
Phyllodoce empetriformis	d, c	2 2			V 3		II 1	II 1	4 +	II 1
Polytrichum alpinum	dd	1 1	3 1				V 5	II 1	3 1	IV 2
Vahlodea atropurpurea	d	1 +				1 +	I +	I +	2 +	II +

¹ Species diagnostic values, presence and species significance classes as defined in [Table 2](#).

Table 7. Diagnostic combinations of species for vegetation units 5.1 to 7.2. Vegetation units described in the text are numbered sequentially within each plant order.

Vegetation unit number		5.1	5.2	5.3	5.4	5.5	5.6	6.1	6.2	6.3	7.1	7.2
Number of plots		10	12	12	7	5	7	8	12	1	13	10
Vegetation units and species	Diagnostic value ¹	Presence class ¹ and mean species significance ¹										
Cassiope mertensiana – Phyllodoce empetriformis order												
Cassiope mertensiana	d	IV 6	V 7	IV 5	V 5	4 6	II +	I +	I +		I +	
Luetkea pectinata	d, cd	II 1	V 4	V 5	V 3	5 6	V 7	II 2	IB 3		III 1	I +
Lycopodium sitchense	d	II 1	IV 3	I 1	IV 3	2 2	I +					
Phyllodoce empetriformis	d, cd	IB 5	V 8	V 6	V 5	4 6	III 2	II 1	I +		III 1	I +
Racomitrium heterostichum	d	I +	IV 3	II 2	III 4	3 3	II +					
Cassiope mertensiana alliance; and Carex spectabilis – Cassiope mertensiana association												
Antennaria alpina	d	III 2							I 1			
Carex spectabilis	d	IV 2	I +	I +	I +			V 8	V 4	5 7	III 2	III 4
Cassiope mertensiana – Tsuga mertensiana alliance												
Barbilophozia floerkei	d		V 5	III 4	V 4	4 5						
Cladonia bellidiflora	d		III 1	IV 2	III 2	3 1						
Dicranum fuscescens	d		IV 5	III 5	V 4	4 4			I +		I 1	
Rhytiadopsis robusta	d		II 2	IV 3	III 1	3 2						
Tsuga mertensiana	d		III 3	III 3	V 8	5 7					I +	
Vaccinium delicosum	d, cd	I +	V 3	V 7	V 4	5 3					II +	
Vaccinium membranaceum	d	I +	III 2	III 3	III 2	4 1	II 1				I +	
Cassiope mertensiana – Phyllodoce empetriformis association												
Cassiope mertensiana – Phyllodoce empetriformis: typic subassociation												
Gaultheria humifusa	d		III 1		II +	1 +						
Marsupella brevissima	d	I 1	III 3		I +							I 1
Cassiope mertensiana – Phyllodoce empetriformis: Vaccinium delicosum subassociation												
Cetraria islandica	d	I +		III 1	I +	1 1					I +	
Rubus pedatus	d			III 1	I +						I +	
Vaccinium delicosum	dd	I +	V 3	V 7	V 4	5 3					II +	
Cassiope mertensiana – Tsuga mertensiana association												
Tsuga mertensiana	d, cd		III 3	III 3	V 8	5 7					I +	
Cassiope mertensiana – Tsuga mertensiana: typic subassociation												
Chamaecyparis nootkatensis	d		II 2	II 2	III 1	1 1					II 1	
Cladonia squamosa	d			I +	IV 1							
Hieracium gracile	d	I +	II +	I +	III +	1 +	IV 1	I +	IV 1			I +

Vegetation unit number		5.1	5.2	5.3	5.4	5.5	5.6	6.1	6.2	6.3	7.1	7.2
Number of plots		10	12	12	7	5	7	8	12	1	13	10
Vegetation units and species		Diagnostic value ¹	Presence class ¹ and mean species significance ¹									
Cassiope mertensiana – Tsuga mertensiana: Hippuris montana subassociation												
Hippuris montana	d, cd		II 1			5 5					II 1	
Lophozia wenzelii	d			I +		3 1					I +	
Luetkea pectinata alliance and association												
Hieracium gracile	d	I +	II +	I +	III +	1 +	IV 1	I +	IV 1			I +
Luzula piperi	d		I +				III 1	I +	II 1			I +
Valeriana sitchensis	d	I 2					III 1		II 1		III 1	II +
Carex spectabilis order and alliance												
Carex spectabilis	d, cd	IV 2	I +	I +	I +			V 8	V 4	5 7	III 2	III 4
Carex spectabilis association												
Anaphalis margaritacea – Lupinus arcticus association												
Anaphalis margaritacea	d								IV 5			I +
Juncus drummondii	d		I +	I +	I +				III 1		III +	V 1
Lupinus arcticus	dd, cd	II 2	I 2	I 4			III 2	IV 3	V 6		I +	
Oxyria digyna – Carex spectabilis association												
Cardamine oligosperma	d, c							I +		5 +		I +
Oxyria digyna	d, cd									5 8		I +
Philonotis fontana order and alliance												
Philonotis fontana	d										IV 6	IV 5
Valeriana sitchensis	d	I 2					III 1		II +		III 1	II +
Caltha leptosepala – Leptarrhena pyrolifolia association												
Caltha leptosepala	d, c		I +								V 4	
Drepanocladus aduncus	d										III 5	
Equisetum palustre	d										IV 4	
Erigeron peregrinus	d	III 1		I +	II +		II 1	II +	I +		IV 4	I +
Leptarrhena pyrolifolia	d, cd		I +								V 6	III 1
Mitella pentandra	d										III 1	I +
Parnassia fimbriata	d										IV 4	
Rhytiadelphus squarrosus	d										III 5	
Epilobium latifolium – Mimulus lewisii association												
Epilobium latifolium	d						I +		II 1			IV 5
Juncus drummondii	d,c		I +	I +	I +				III 1		III +	V 1
Mimulus lewisii	d										I +	IV 5
Saxifraga nelsoniana	d										I +	III 1

1 Species diagnostic values, presence and significance classes as described in [Table 2](#).

Table 8. Diagnostic combinations of species for vegetation units 8.1 to 9.5. Vegetation units described in the text are numbered sequentially within each plant order.

Vegetation unit number		8.1	8.2	8.3	8.4	9.1	9.2	9.3	9.4	9.5							
Number of plots		5	10	5	1	8	21	1	1	7							
Vegetation units and species		Diagnostic value ¹															
		Presence class ¹ and mean species significance ¹															
Valeriana sitchensis order and alliance																	
Valeriana sitchensis	d, cd	5	4	V	5	5	7	5	7		II	2	5	2		V	4
Parnassia fimbriata – Valeriana sitchensis association																	
Epilobium anagallidifolium	d	3	+	I	+					I	+						
Parnassia fimbriata	d	4	1	I	+												
Ranunculus eschscholtzii	d	3	+			1	+			I	+					I	+
Salix commutata	d	3	5														
Heracleum maximum – Valeriana sitchensis association																	
Heracleum maximum	d	2	2	IV	4			III	3	II	4					III	2
Sanguisorba canadensis	d			III	3					I	1			5	1	I	1
Carex spectabilis – Valeriana sitchensis association																	
Carex nigricans	d			I	+	3	4										
Carex spectabilis	d, c	1	+	II	4	5	4										
Luetkea pectinata	d			I	1	3	3			I	+	5	3			I	+
Lupinus arcticus	d, c	2	+	I	+	5	2										
Pulsatilla occidentalis	d					4	3										
Sphagnum – Valeriana sitchensis association																	
Elliottia pyroliflorus	d, cd					5	7			I	+					I	1
Rhizoplaca glaucophana	d, c					5	3	I	1	I	2						
Rubus pedatus	d, c					5	3	I	+								
Sphagnum spp.	d, cd					5	8									I	1
Vaccinium ovalifolium	d, c					5	4	II	1								
Alnus viridis order and alliance																	
Alnus viridis	d, cd			I	1			II	5	IV	8	5	9	5	9	V	9
Oplopanax horridus – Alnus viridis association																	
Aruncus dioicus	d			I	3			II	3	III	4					I	+
Oplopanax horridus	d							IV	5	III	3					I	3

Vegetation unit number		8.1	8.2	8.3	8.4	9.1	9.2	9.3	9.4	9.5
Number of plots		5	10	5	1	8	21	1	1	7
Vegetation units and species		Diagnostic value ¹ Presence class ¹ and mean species significance ¹								
Oplopanax horridus – Alnus viridis: Rubus parviflorus subassociation										
Acer glabrum	d					IV 5	I 3			
Calamagrostis canadensis	d		I 3			III 2	I 1			
Dryopteris expansa	d					III 2	I 1			
Pteridium aquilinum	d					IV 5	I 3			
Rubus parviflorus	d, cd					V 5	II 4			
Salix sitchensis	d		I 4			III 5	I 3	5 1	5 2	III 5
Streptopus roseus	d		I 2		5 4	IV 2	II 2			II 4
Oplopanax horridus – Alnus viridis: typic subassociation										
Alnus viridis	d		I 1			II 5	IV 8	5 9	5 9	V 9
Phyllodoce empetriformis – Alnus viridis association										
Dicranum spp.	d, cd							5 6		
Phyllodoce empetriformis	d, cd		I +	1 1			I +	5 8		
Polytrichum juniperum	d, c							5 3		
Juncus ensifolius – Alnus viridis association										
Agrostis scabra	d, cd								5 5	
Carex lenticularis	d, c								5 4	I +
Equisetum variegatum	d, c								5 2	
Juncus ensifolius	d, cd								5 7	
Valeriana sitchensis – Alnus viridis association										
Mitella pentandra	d	2 4	II 3		5 1					III +
Salix barclayi	dd								5 1	III 5
Senecio triangularis	d	3 +	IV 4				I +			III +
Tiarella trifoliata	d		I +		5 1	II +	I 1			III 1
Valeriana sitchensis	d	5 4	V 5	5 7	5 7		II 2	5 2		V 4

¹ Species diagnostic values, presence and significance classes as defined in Table 2.

Table 9. Diagnostic combinations of species for vegetation units 10.1 to 11.2. Vegetation units described in the text are numbered sequentially within each plant order.

Vegetation unit number		10.1	10.2	10.3	10.4	10.5	11.1	11.2						
Number of plots		5	6	5	4	5	1	19						
Vegetation units and species	Diagnostic value ¹	Presence class ¹ and mean species significance ¹												
Eriophorum angustifolium order and alliance														
Eriophorum angustifolium	d, cd	4	7	V	2	5	6	4	6					
Warnstorfia exannulata – Eriophorum angustifolium association														
Warnstorfia exannulata	d	4	6				2	+						
Fauria crista-galli – Eriophorum angustifolium association														
Fauria crista-galli	d			III	3	5	3	4	6		5	1		
Tofieldia glutinosa	d			I	1	4	1	3	+	2	1			
Vaccinium caespitosum	d			III	3	4	1	3	+					
Fauria crista-galli – Eriophorum angustifolium: Empetrum nigrum subassociation														
Cassiope mertensiana	d			III	4									
Cladonia mitis	d			III	5									
Cladonia rangiferina	d			IV	5									
Empetrum nigrum	dd			IV	5			3	+					
Pleurozium schreberi	d			IV	6									
Vaccinium uglinosum	d, cd			V	6			2	+		5	4	I	+
Fauria crista-galli – Eriophorum angustifolium: typic subassociation														
Leptarrhena pyrolifolia	d					3	+							
Sanguisorba officinalis	d					3	3						IV	3
Fauria crista-galli – Eriophorum angustifolium: Sphagnum subassociation														
Fauria crista-galli	dd			III	3	5	3	4	6		5	1		
Sphagnum spp.	d							3	6		5	9		
Carex aquatilis – Eriophorum angustifolium association														
Calliergonella cuspidata	d								3	1				
Carex aquatilis	d								4	6				
Drepanocladus aduncus	d								4	5				
Polytrichum commune	d								3	3				
Rhizomnium nudum	d								3	2				
Scapania uliginosa	d								3	3				
Sphagnum subnitens	d								3	5				
Vahlodea atropurpurea	d								3	2				
Veratrum viride	d								3	+				

Vegetation unit number	10.1	10.2	10.3	10.4	10.5	11.1	11.2
Number of plots	5	6	5	4	5	1	19
Vegetation units and species	Diagnostic value ¹	Presence class ¹ and mean species significance ¹					
Carex pluriflora order and alliance; and Sphagnum – Carex pluriflora association							
<i>Carex pluriflora</i>	d, cd					5 6	V 7
Sphagnum – Carex pluriflora association: Vaccinium uglinosum subassociation							
<i>Erigeron peregrinus</i>	d, c	1 +	I +	2 +	2 +	5 2	
<i>Sphagnum</i> spp.	d, cd				3 6	5 9	
<i>Vaccinium uglinosum</i>	d, c		V 6		2 +	5 4	I +
Sphagnum – Carex pluriflora association: typic subassociation							
<i>Sanguisorba officinalis</i>	d			3 3			IV 3
<i>Sphagnum fallax</i>	d						IV 6
<i>Sphagnum papillosum</i>	d						IV 3

1 Species diagnostic values, presence and significance classes as defined in [Table 2](#).

Vegetation-Environment Relationships

One of the premises of plant ecology is that there are predictable, if inexact, relationships between vegetation patterns and environmental gradients. These relationships can be used to infer certain environmental conditions from the presence of a given plant community or, conversely, to predict the presence or development of plant communities given certain environmental conditions. The relationship between vegetation patterns and environmental gradients in non-forested upper subalpine and alpine communities is possibly stronger than in forested communities, since the gradients tend to be steeper. The steepest gradients develop in relation to time of snowmelt (Brooke *et al.* 1970; Franklin and Dyrness 1973; Evans 1986), distance from standing or flowing water, and time elapsed since deglaciation or disturbances such as avalanches or fire. Other environmental factors that affect plant communities (and can be used to predict their presence) include: aspect, slope gradient, slope position, parent material, soil texture, and drainage patterns.

The suite of environmental factors associated with a plant community can thus be used to describe its habitat. Following previous researchers of upper subalpine and alpine communities (Archer 1963; Brooke *et al.* 1970; Klinka *et al.* 1997), we distinguished eight generalized habitat types that are associated with the vegetation units described in the previous section (Table 10, Figure 44). Habitat types are identified by alpha-numeric codes that are also listed in Table 1.

Table 10. Habitat types and characteristic communities. These habitat codes are also included in Table 1 and Figure 44.

Habitat code	Habitat description and characteristic communities
A	Exposed cliffs and ridges - habitats of <i>krummholz</i> (dwarf tree) communities
B	Unstable slopes - habitats of pioneer <i>sheet-wash</i> communities
C	Mesic, well-drained sites (zonal in the AT zone, and near-zonal in the upper MH zone) - habitats of <i>heath</i> (low shrub) communities
D	Late-snowmelt patches and basins - habitats of <i>snow basin</i> (chionophilous) communities
E	Fens and bogs - habitats of <i>wetland</i> communities
F	Talus slopes, moraines, and rubble fields - habitats of <i>fragmented rock</i> (chomophytic) communities
G	Moist to wet slopes, stream edges, seeps, and avalanche tracks - habitats of <i>lush herbaceous</i> communities (G1 = herb-dominated, and G2 = shrub-dominated)
H	Exposed rock walls and outcrops - habitats of <i>lithic</i> (rupicolous) communities

Two loose groupings of habitat types are shown in Figure 44: the first group is represented by habitat types on the left half of the diagram (codes A to D), and the second group is represented by habitat codes on the right half of the diagram (E to H). On comparable slope positions, habitat types in the first group are more likely to be located on cool-aspect slopes, have later snowmelt, be drier, and have a lower nutrient status. On a regional scale, the prevalence of habitat types from the second group (particularly lush herbaceous communities) increases from west to east, *i.e.*, with increasing continentality.

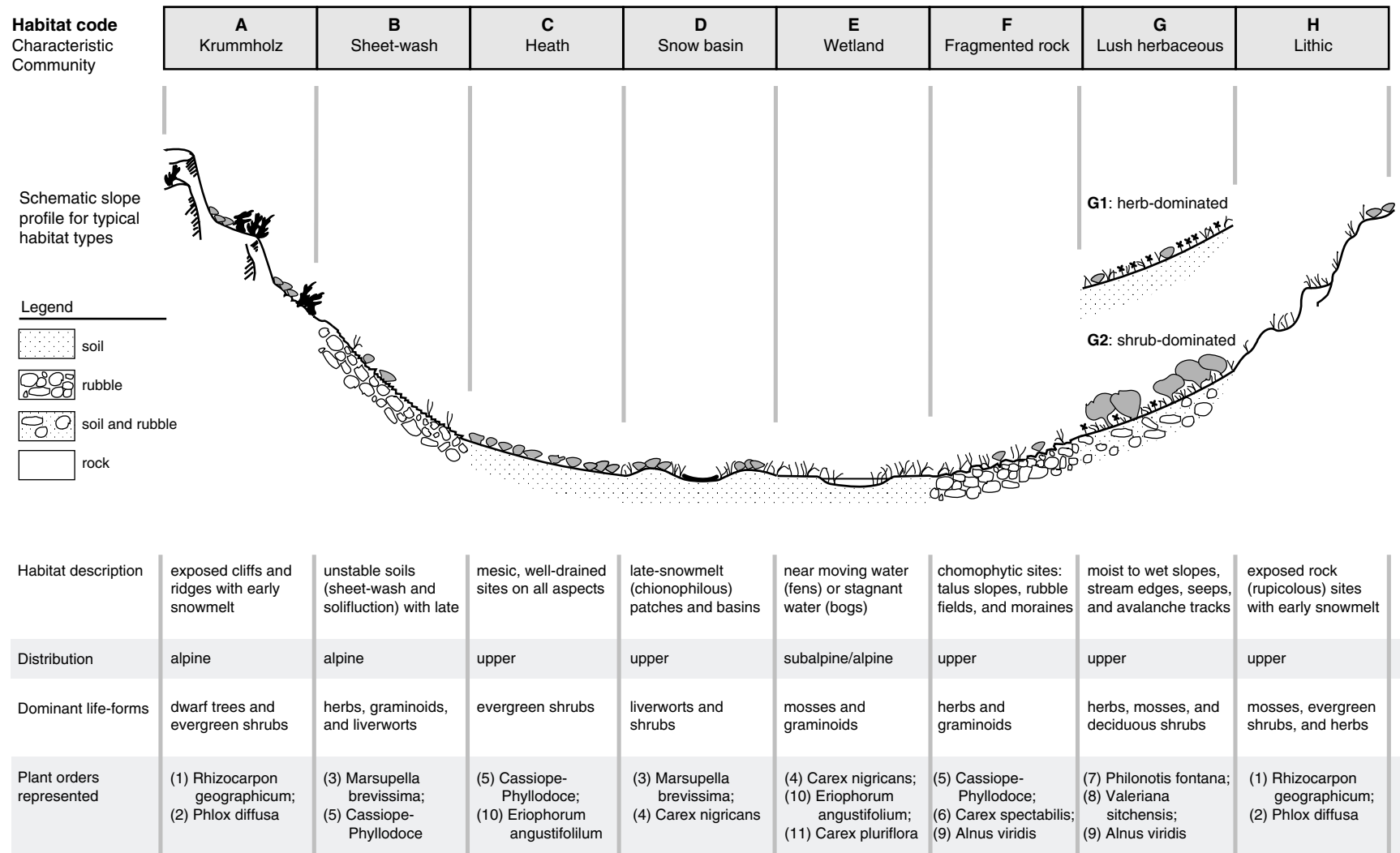


Figure 44. Generalized vegetation-environment relationships. Habitat codes are also included in the synopsis of vegetation units presented in Table 1.

Additional understanding of the relationship between vegetation patterns and environmental gradients can be gained by ranking the plant orders by duration of snow, soil moisture regime, and soil nutrient regime (Table 11). Though inconsistent methodology between researchers means these rankings are inexact, some general patterns can be inferred. For example, growing seasons are shortest in habitat types B, C, and D, and longest in habitat types H, A, and G. Consistent with Figure 44, soils are wetter and richer (on comparable slope positions) in habitat types E, F, G, and H.

Table 11. Approximate ranking of plant orders by environmental conditions. Plant orders are ranked so that snow duration, relative soil moisture regime, and soil nutrient regime decrease from top to bottom. Snow duration was measured by Archer (1963), Brooke *et al.* (1970), and Evans (1986) and their data has been augmented with observations by Kuramoto (1967), Douglas (1970), Hamann (1972), and Henderson (1974). Where no data were available, we used site factors and relationships to other plant orders to estimate snow duration. Soil moisture regimes were recorded by all data sources and are ranked accordingly. We based the soil nutrient regime for each order on the composition of indicator species (Klinka *et al.* 1989). Full plant order names are included in Table 1.

Approximate snow duration (months)		Relative soil moisture regime ¹		Soil nutrient regime ¹	
(3) Marsupella brev.	9.5 - 11	(10) Eriophorum ang.	5 - 8	(9) Alnus viridis	R - (VR)
(4) Carex nigricans	9.2 - 9.9	(11) Carex pluriflora	7	(8) Valeriana sitchensis	R
(6) Carex spectabilis	8.3 - 9.3 ²	(7) Philonotis fontana	6 - 8	(7) Philonotis fontana	(M) - R
(5) Cm - Pe	8.1 - 9.3	(9) Alnus viridis	5 - 7	(6) Carex spectabilis	M
(7) Philonotis fontana	7.7 - 9.1	(8) Valeriana sitchensis	5 - 7	(2) Phlox diffusa	P - M
(10) Eriophorum ang.	7.6 - 8.6 ²	(4) Carex nigricans	5 - 6	(5) Cm - Pe	P
(11) Carex pluriflora ³	7.6 - 8.6 ⁴	(3) Marsupella brev.	3 - 7	(3) Marsupella brev.	P
(8) Valeriana sitchensis	7.0 - 9.3 ²	(6) Carex spectabilis	3 - 6	(4) Carex nigricans	P
(1) Rhizocarpon geog.	6.0 - 9.3 ²	(5) Cm - Pe	3 - 5	(10) Eriophorum ang.	P
(9) Alnus viridis ⁴	6 - 9 ³	(1) Rhizocarpon geog.	0 - 3	(11) Carex pluriflora	P
(2) Phlox diffusa	6 - 7 ³	(2) Phlox diffusa	0 - 1	(1) Rhizocarpon geog.	VP - P

1 Klinka *et al.* (1989) and Luttmerding *et al.* (1990). Soil nutrient regime classes: VP = very poor; P = poor; M = medium; R = rich; VR = very rich.

2 Estimates based on partial data.

3 Estimates based on no data.

4 High-elevation sites only.

Sequences of Communities

Mapping upper subalpine and alpine communities can be hampered by the great variability within a small area. Grouping communities by habitat types, however, recognizes the mosaic of communities in a given environment, and habitat types may thus be the most appropriate units for mapping these areas. For example, the snow basin described in Sequence 2 (below) includes two basic habitat types. The first, habitat type D, includes three or four different communities found in snow basins. The second, habitat type C, contains a mosaic of heath communities. Given the scale of this pattern, mapping the habitat types is more feasible than mapping individual vegetation units. To further elucidate some of the characteristic mosaic of plant communities, we present three sequences that are common at high elevations. Where vegetation units have been identified, we include their number (from Table 1) in square brackets.

Sequence 1: bog communities → heath communities → tree island communities

The first sequence is typical of late-snowmelt basins in upper and sometimes lower subalpine sites where standing water is present throughout the growing season (Figure 45). The concentric pattern is especially evident in fall when these basins take on the appearance of a multi-coloured ‘bulls-eye’. The following sequence of communities developed in a small bowl on Mount Washington where the vertical rise from middle to edge was *ca.* 2 m.

- [10.1] Orange-tipped stems of *Eriophorum angustifolium* inhabited microsites where standing water was no deeper than about 10 cm.
- [4.1 or 4.2] Yellowish *Carex nigricans* dominated the transition to upland communities on very moist microsites that were *ca.* 5 cm above the level of standing water.
- [5.2] On mesic microsites above the influence of standing water, there were evergreen communities dominated by *Cassiope mertensiana* and *Phyllodoce empetrifomis*, with some *Luetkea pectinata*.
- [5.3] At an elevation approximately 1 to 1.5 m above the standing water, there was an increased presence of reddish *Vaccinium deliciosum* intermixed with the heath (see Figure 18).

The transition to a tree island began at the lip of the bowl, *ca.* 2 m above the standing water. These unclassified communities consisted of tall ericaceous shrubs such as *Vaccinium membranaceum* and *Rhododendron albiflorum* at the tree-island edge. The tree island contained *Tsuga mertensiana*, *Rhododendron albiflorum*, and a lesser presence of *Abies amabilis* and *Chamaecyparis nootkatensis*. Soils changed within the same sequence from Fibrisols (CSSC 1978) in *Eriophorum angustifolium* and *Carex nigricans* communities; to Orthic or Eluviated Dystric Brunisols (CSSC 1978) in the heath communities; to Podzols (CSSC 1978) in the tall shrub and tree-island communities. In a similar sequence from Nimpkish Lake, *Empetrum nigrum* replaced *Phyllodoce empetrifomis* and *Cassiope mertensiana* as the dominant heath vegetation, and *Vaccinium uliginosum* and *V. caespitosum* replaced *V. deliciosum*.

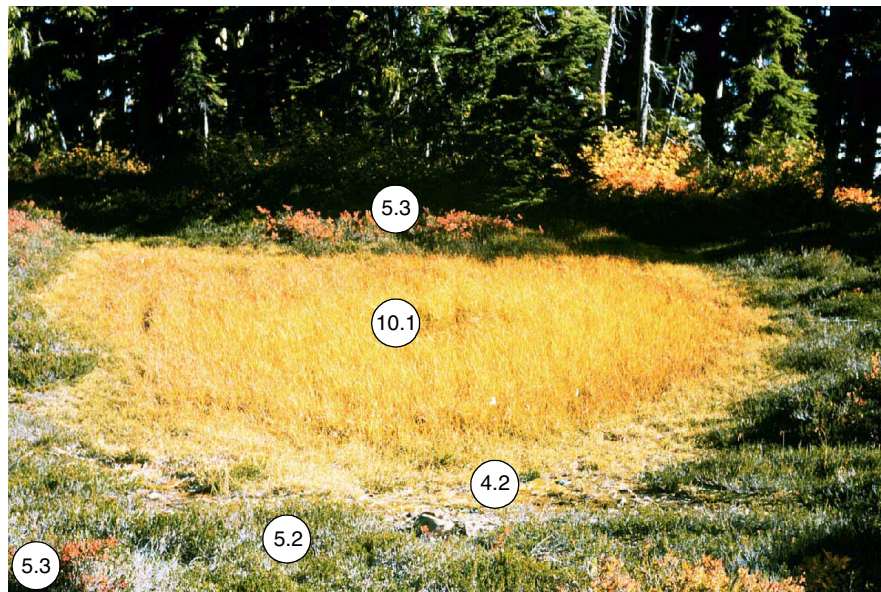


Figure 45. A typical snow basin sequence (from Mt. Washington). At the edge of standing water (centre of photo), *Eriophorum angustifolium* dominates. The almost perfectly symmetrical pattern of vegetation units from the standing water at the middle of the photo includes: the *Warnstorfia exannulata* – *Eriophorum angustifolium* association [10.1], communities of the *Carex nigricans* order [4.2]; first typic [5.2], then *Vaccinium deliciosum* subassociations [5.3], of the *Cassiope mertensiana* – *Phyllodoce empetrifomis* order; and finally tall shrub and forested communities in adjacent tree islands.

Sequence 2: snow basin communities → heath communities

Another late-snowmelt sequence is more characteristic of late-snowmelt bowls at slightly higher elevations, *i.e.*, into lower portions of the alpine (Figure 46 and 47). The sequence we describe here was located at the alpine - upper subalpine transition on Brohm Ridge. The uphill side of the bowl consisted of a mosaic of heaths and pioneer alpine communities, while the highest-elevation tree island in the area inhabited the downhill side of the bowl (see Figure 10). Instead of being convex, the lowest part of this bowl was flat, with topographic variations generally <50 cm in elevation. Even within this small elevational range, there were four distinct community types (from lowest to highest).

- [3.1] *Marsupella brevissima* formed almost-pure communities in the middle of areas usually no larger than *ca.* 1-3 m².
- [4.2] *Polytrichum sexangulare* was the dominant species on slight (*ca.* 1-3 cm) prominences that graded away from the *Marsupella brevissima* cushion.
- [4.2] Approximately 10 cm above the *Marsupella brevissima*, but still within the same vegetation unit, the community consisted almost entirely of *Carex nigricans* and *Polytrichum sexangulare*.
- [5.2] On even higher prominences, usually over rocks, communities were dominated by *Cassiope mertensiana* and *Phyllodoce empetriformis*, though there were still many elements of the previous three communities

These snow basin elements diminished at the edges of the bowl at slightly higher elevations (> *ca.* 100 cm) and were replaced by typical mesic heath communities. Soils were deep (>70 cm) throughout this particular sequence and ranged from deep Orthic Gleysols (CSSC 1978) under the *Marsupella brevissima* and *Polytrichum sexangulare*-*Marsupella brevissima* communities, to Gleyed Dystric Brunisols under the *Carex nigricans*- and heath-dominated communities. This sequence of plant communities repeated itself across an area of approximately 500 m².



Figure 46. Snow basin communities support a repeating pattern of plant communities that is related to elevation. Lowest elevations in the basins are dominated by *Marsupella brevissima*, intermediate elevations are dominated by *Carex nigricans*, and highest elevations (most still only 50 cm above the lowest elevation) are dominated by *Phyllodoce empetriformis* and *Cassiope mertensiana*. See Figure 47 for more detail.



Figure 47. Close-up of the relationship between microtopographic variation and changes in plant communities. From bottom left to the top right of the photograph, the sequence of communities changes with increasing elevation above the snow basin: from *Marsupella brevissima*-dominated communities [3.1]; to *Polytrichum sexangulare*-dominated *Carex nigricans* communities [4.2]; to *Carex nigricans* communities [4.1]; and finally on slight prominences, to heath communities dominated by *Phyllodoce empetrifomis* and *Cassiope mertensiana* [5.2].

Sequence 3: mid-stream communities → stream-edge communities

Fast-moving rivulets draining heath-covered slopes are easily visible because of the thin band of lush herbaceous communities of the *Philonotis fontana* order on either side of the water (Figure 48 and 49). In this sequence, from Black Tusk, we describe three communities that are characteristic of wet to very wet sites and whose composition is related to distance from fast-flowing water:

- [unclassified] Coarse sands in the middle of the rivulet supported an unclassified, almost-pure community of the black liverwort, *Jungermannia exsertifolia*.
- [7.2] At the edges of the rivulet and extending onto its bank, there were communities dominated by *Mimulus lewisii* and *Epilobium luteum*.
- [7.1] Farther from the scouring of fast-flowing water (>ca. 1 m from the middle of the rivulet), but on microsites that were still wet, there were communities dominated by *Philonotis fontana*, *Leptarrhena pyrolifolia*, and *Arnica latifolia*.

Coarse-textured Orthic Regosols (CSSC 1978) underlay each of these communities, but organic horizons were present only on the two herbaceous communities. The depth of the organic horizons increased with distance from the rivulet.



Figure 48. Rivulets draining heath-covered slopes are easily visible from the band of herbaceous species (*Philonotis fontana* order) on either side of the stream.



Figure 49. Fast-flowing water prevents extensive colonization by herbaceous species. The edges of such rivulets support communities of the *Epilobium latifolium* – *Mimulus lewisii* association. Farther from the rivulet, but where soils are still wet, communities of the *Caltha leptosepala* – *Leptarrhena pyrolifolia* association develop. Outside the direct influence of flowing water, there is often an abrupt transition to zonal heath communities (*Cassiope mertensiana* – *Phyllodoce empetrifomis* order)

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APPENDICES

Appendix 1. Differentiated summary table (by presence) for plant orders. Only species with a presence class \geq III in at least one plant order are included.

Order number		1	2	3	4	5	6	7	8	9	10	11
Number of plots		25	5	21	16	53	21	23	21	38	25	20
Species	Diagnostic value ¹	Presence class ¹ and mean species significance ¹										
<i>Polytrichum piliferum</i>		III 2.1	I +.0	II 4.1		I 2.0	I +.3		I +.0			
<i>Rhizocarpon geographicum</i>	d	IV 1.9	2 +.0			I +.0						
<i>Umbilicaria proboscidea</i>	d	III 1.6				I +.0						
<i>Paxistima myrsinites</i>	d		3 2.6							I +.0		
<i>Penstemon procerus</i>	d	I +.0	3 1.1			I +.0	I +.0					
<i>Phlox diffusa</i>	d		4 5.0			I +.0						
<i>Saxifraga occidentalis</i>	d		3 1.5									
<i>Selaginella wallacei</i>	d		3 +.5									
<i>Tortella tortuosa</i>	d		3 4.4									
<i>Phyllocladus empetriformis</i>	cd	II 2.5		III 1.1	IV 2.0	V 6.4	I +.5	II +.2	I +.1	II 5.2	I +.0	
<i>Carex nigricans</i>	dd, cd	II +.6	2 +.0	IV 2.0	V 8.4	II 1.5	III 1.1	III 3.7	I 2.3		I 4.2	
<i>Juncus drumondii</i>		I +.0		III 2.1	III 1.7	I +.0	I +.5	IV 1.0	I +.0	I +.0		
<i>Polytrichum alpinum</i>		I +.7		III 3.9	IV 5.5	I +.0						
<i>Marsipella brevissima</i>	d, cd			V 6.0	II 2.2	I 1.3		I +.5				
<i>Saxifraga tolmiei</i>	d			IV 3.5	II 1.0	I +.0				I +.0		
<i>Vahlodea atropurpurea</i>		I +.0	1 +.0	I +.0	III 2.9	IV 2.3	III +.1	II +.5	I 1.5	II 1.6	I +.8	
<i>Cassiope mertensiana</i>	dd	I 1.2	1 +.0	II 1.0	III 3.3	IV 6.0	I +.0	I +.0		II 1.1	I 2.2	
<i>Luetkea pectinata</i>	d, cd	I 1.4	1 +.0	II 1.7	III 1.6	V 5.4	II 2.4	II 1.0	I 1.9	II 1.8	I +.0	
<i>Barbilophozia floerkei</i>	d				I 1.1	III 4.2					I 3.1	
<i>Cladonia bellidiflora</i>	d					III 1.5				I +.1		
<i>Dicranum fuscescens</i>	d	I 1.0				III 4.5	I +.0	I +.2				
<i>Lycopodium sitchense</i>	d	I +.0			I +.0	III 2.6			I +.0		I +.0	
<i>Racomitrium heterostichum</i>	d	I +.0		I +.0	I 1.6	III 3.3					I +.0	
<i>Tsuga mertensiana</i>	dd	I 1.5		II +.3	I +.0	III 5.6		I +.0		II +.1		
<i>Vaccinium deliciosum</i>	d			I +.0	I +.2	IV 5.0		I +.0				
<i>Vaccinium membranaceum</i>	d			I +.0		III 2.1		I +.0				
<i>Carex spectabilis</i>	d, cd	II +.8		I 1.0	II 2.1	I +.7	V 7.0	III 4.0	II 3.5		I 2.1	
<i>Epilobium angallidifolium</i>			1 +.0	I +.0	I 1.1	I +.0	III +.6	IV 3.7	I +.0	I +.0		
<i>Lupinus arcticus</i>	dd			I 1.1	I +.0	I 2.5	III 5.1	I +.0	II 1.3			
<i>Valeriana sitchensis</i>	d, cd					I +.9	I +.8	III 1.1	V 6.4	III 3.1		
<i>Erigeron peregrinus</i>			2 +.0			II +.1	I +.0	III 3.6	I +.0	II +.1	II +.0	III 1.2
<i>Caltha leptosepala</i>	d					I +.0		III 3.8			I 1.4	
<i>Leptarrhena pyrolifolia</i>	d					I +.0		IV 5.5	II +.3	II 1.0	I +.0	
<i>Mimulus lewisii</i>								III 4.9		II +.2		
<i>Philonotis fontana</i>	d				I +.0			IV 5.8			I 3.3	
<i>Mitella pentandra</i>								II +.2	III 3.3	I +.0	I 1.1	
<i>Veratrum viride</i>						I +.0		I 1.3	III 4.0	II 2.0	I +.0	
<i>Alnus viridis</i>	d, cd								I +.0	V 8.9		
<i>Athyrium filix-femina</i>	d						I +.0	I +.2	II 2.9	IV 4.8		
<i>Rubus spectabilis</i>	d								I 2.2	III 3.4		
<i>Salix sitchensis</i>	d								I 3.0	IV 4.0		
<i>Fauria crista-galli</i>											III 4.0	III +.7
<i>Eriophorum angustifolium</i>	d, cd							I +.0			V 6.4	
<i>Carex pluriflora</i>	d, cd											V 6.7
<i>Sphagnum</i> spp.	dd				I +.7	I +.0		I 2.5	II 5.5	I +.0	I 3.9	III 7.9
<i>Vaccinium uliginosum</i>											II 4.1	III 3.1

¹ Diagnostic values, species presence and significance classes as defined in Table 2.

Appendix 2. Differentiated summary table (by presence) for vegetation units 1.1 to 4.2. Only species with a presence class \geq III in at least one plant order are included.

Vegetation unit number		1.1	1.2	1.3	1.4	2.1	3.1	3.2	3.3	4.1	4.2
Number of plots		5	4	6	10	5	9	8	4	6	10
Species	Diagnostic value ¹	Presence class ¹ and mean species significance ¹									
<i>Rhizocarpon geographicum</i>	c	3 1.4	3 1.0	V 2.4	IV 2.4	2 +.0					
<i>Carex nigricans</i>		3 1.4	3 1.0			2 +.0					
<i>Polytrichum piliferum</i>	dd, cd	5 3.4	2 +.0	III 1.0	III 2.0	1 +.0	II +.0	IV 5.6	3 +.0	V 8.6	V 8.2
<i>Juncus drummondii</i>		3 1.1					III 2.3	III +.5	3 2.9	III 1.2	IV 2.0
<i>Luetkea pectinata</i>		3 3.1				1 +.0	II 3.0	II 1.0	2 +.0	II 1.1	III 2.0
<i>Antennaria alpina</i>	d	4 2.3								I 2.2	
<i>Sibbaldia procumbens</i>	d, cd	5 5.8					II +.0	II 1.0			
<i>Umbilicaria proboscidea</i>		2 1.2	3 1.4	IV 2.1	III 1.4						
<i>Penstemon davidsonii</i>	d, c		3 1.0	V 2.4		1 +.0					
<i>Polytrichum alpinum</i>	cd	1 1.1	3 1.4				V 5.3	II 1.0	3 1.4	IV 2.4	IV 6.7
<i>Luzula piperi</i>		1 +.0	3 1.4					IV 3.1		II 1.5	
<i>Carex preslii</i>		2 1.8	3 1.0	I +.0							
<i>Carex pyrenaica</i>			3 1.4	I +.0			I 1.1	II +.0			
<i>Carex spectabilis</i>		1 +.0	3 1.4	II 1.1					2 2.0	II +.5	II 3.0
<i>Heuchera micrantha</i>			3 1.0	II +.5	I +.0						
<i>Phacelia sericea</i>	d		3 1.4								
<i>Saxifraga bronchialis</i>			3 2.0	II 1.4		2 1.7					
<i>Silene aucalis</i>	d, c		5 4.1	I 1.0							
<i>Juniperus communis</i>	d, cd			V 7.9	III 3.1	2 5.9					
<i>Phyllodoce glanduliflora</i>		1 +.0		IV 3.7	III 2.3		I +.0	I +.0		I +.0	
<i>Festuca brachyphylla</i>				III 1.2	II +.5						
<i>Solorina crocea</i>	d			III 1.2							
<i>Stereocaulon alpinum</i>	d			III 1.2	I +.0		I +.0	I +.5			
<i>Thamnia vermicularis</i>				III 2.0	II 1.1						
<i>Cassiope mertensiana</i>				I 1.0	III 2.6	1 +.0	II +.5	I 1.5	3 +.0	I +.0	IV 4.2
<i>Phyllodoce empetriformis</i>		2 3.5			V 3.1		II 1.4	II 1.1	4 +.5	II 1.4	V 2.4
<i>Abies lasiocarpa</i>	d, cd				V 6.8						
<i>Brachythecium reflexum</i>	d				III 1.4						
<i>Dicranum fuscescens</i>	d				IV 2.1						
<i>Pseudoleskea baileyi</i>	d				III 1.8						
<i>Racomitrium canescens</i>		1 +.0		II 2.0	III 2.2					I 2.2	
<i>Rhytidopsis robusta</i>	d				IV 3.6						
<i>Paxistima myrsinites</i>	d					3 2.6					
<i>Penstemon procerus</i>				II +.5		3 1.1					
<i>Phlox diffusa</i>	d					4 5.0					
<i>Saxifraga occidentalis</i>	d					3 1.5					
<i>Selaginella wallacei</i>	d					3 +.5					
<i>Tortella tortuosa</i>	d					3 4.4					
<i>Marsupella brevissima</i>	cd						IV 6.3	IV 4.1	5 6.8	I +.0	II 3.1
<i>Saxifraga tolmiei</i>	c						II 1.5	IV 3.1	5 4.6	I +.0	II 1.1
<i>Kiaeria falcata</i>							II 4.5	III 1.1			I +.0
<i>Cephalozia bicuspidata</i>									3 +.0		III 1.0
<i>Kiaeria blyttii</i>					II +.5				3 2.4		III 4.1
<i>Anthelia juratzkana</i>	d								3 +.0		I +.0
<i>Calypogeia azurea</i>	d								3 2.0		I +.5
<i>Luzula</i> spp.	d					1 +.0			4 2.9		I +.0

Vegetation unit number		1.1	1.2	1.3	1.4	2.1	3.1	3.2	3.3	4.1	4.2
Number of plots		5	4	6	10	5	9	8	4	6	10
Species	Diagnostic value ¹	Presence class ¹ and mean species significance ¹									
<i>Oligotrichum hercynicum</i>	d						II 6.1		4 2.4		
<i>Pohlia drummondii</i>									3 1.4		I 3.4
<i>Tsuga mertensiana</i>	d				I 3.2				4 1.2		I +.0
<i>Vahlodea atropurpurea</i>	d	1 +.0		II +.5		1 +.0	I +.0	I +.0	2 +.0	II +.5	IV 3.5

¹ Diagnostic values, species presence and significance classes as defined in [Table 2](#).

Appendix 3. Differentiated summary table (by presence) for vegetation units 5.1 to 7.2. Only species with a presence class \geq III in at least one plant order are included.

Vegetation unit number	5.1	5.2	5.3	5.4	5.5	5.6	6.1	6.2	6.3	7.1	7.2
Number of plots	10	12	12	7	5	7	8	12	1	13	10
Species	Diagnostic value ¹	Presence class ¹ and mean species significance ¹									
<i>Phyllodoce empetrifomis</i>		IV 5.7	V 8.4	V 6.7	V 5.9	4 6.6	III 2.5	II 1.2	I +.0		I +.0
<i>Vahlodea atropurpurea</i>		III 1.4	IV 1.2	III +.0	V 1.0	5 4.2	II 1.2	II +.0	II +.5	5 +.0	II +.0
<i>Cassiope mertensiana</i>		IV 6.0	V 7.5	IV 5.3	V 5.9	4 6.4	II +.0	I +.5	I +.0		I +.0
<i>Carex spectabilis</i>		IV 2.4	I +.0	I +.0	I +.0			V 8.2	V 4.0	5 7.4	III 2.8
<i>Racomitrium canescens</i>		III 2.7	II 1.1		II 2.1	1 3.3	I +.5	I +.0	III 1.2		I +.0
<i>Erigeron peregrinus</i>		III 1.1		I +.0	II +.0		II 1.0	II +.0	I +.0		I +.0
<i>Antennaria alpina</i>	d	III 2.5							I 1.4		
<i>Luetkea pectinata</i>		II 1.4	V 4.3	V 5.3	V 3.4	5 6.2	V 7.3	II 2.4	IV 3.3		III 1.4
<i>Barbilophozia floerkei</i>			V 5.1	III 4.3	V 4.5	4 5.1					I +.0
<i>Cladonia bellidiflora</i>			III 1.7	IV 2.2	III 2.0	3 1.8					
<i>Dicranum fuscescens</i>	c		IV 5.5	III 5.7	V 4.2	4 4.2			I +.0		I 1.0
<i>Tsuga mertensiana</i>			III 3.1	III 3.2	V 8.2	5 7.1					I +.0
<i>Vaccinium deliciosum</i>	dd	I +.0	V 3.7	V 7.5	V 4.7	5 3.9					II +.0
<i>Vaccinium membranaceum</i>		I +.5	III 2.5	III 3.0	III 2.7	4 1.1	II 1.7				I +.0
<i>Kiaeria falcata</i>			III 4.5		III 2.7	3 4.2			II +.0		I +.0
<i>Racomitrium heterostichum</i>		I +.0	IV 3.7	II 2.2	III 4.8	3 3.8	II +.0				
<i>Leproloma membranaceum</i>			III 3.0	II 1.1	IV 2.0	1 1.1					
<i>Lycopodium sitchense</i>		II 1.8	IV 3.6	I 1.5	IV 3.2	2 2.5	I +.5				
<i>Carex nigricans</i>	c	I +.5	III 1.2	II 1.0	I +.0	2 2.6	III 2.3	II 1.0	II 1.1	5 1.2	IV 4.7
<i>Bryum</i> spp.			III 2.0	I 1.2							I 4.5
<i>Gaultheria humifusa</i>			III 1.0		II +.0	1 +.0					
<i>Marsupella brevissima</i>	d	I 1.1	III 3.2		I +.0						I 1.1
<i>Rhytiadopsis robusta</i>			II 2.5	IV 3.7	III 1.7	3 2.5					
<i>Cetraria islandica</i>	d	I +.5		III 1.8	I +.5	1 1.7					I +.0
<i>Rubus pedatus</i>	d			III 1.8	I +.0						I +.0
<i>Hieracium gracile</i>		I +.0	II +.5	I +.0	III +.5	1 +.0	IV 1.1	I +.0	IV 1.4		I +.0
<i>Chamaecyparis nootkatensis</i>			II 2.0	II 2.2	III 1.8	1 1.1					II 1.4
<i>Cladonia squamosa</i>	d			I +.0	IV 1.1						
<i>Kiaeria blyttii</i>	dd	I +.5		II 2.6	III 5.0	1 2.5					I +.0
<i>Sorbus sitchensis</i>			II +.0	II +.0	III 1.4	1 1.1					I +.0
<i>Stereocaulon tomentosum</i>			II 1.1		III 1.1	1 1.7					
<i>Abies amabilis</i>			II +.0	II +.0	II +.0	3 1.0					I +.0
<i>Hippuris montana</i>	d, cd		II 1.1			5 5.1					II 1.2
<i>Lophozia wenzelii</i>	d			I +.0		3 1.1					I +.0
<i>Lupinus arcticus</i>	dd, cd	II 2.0	I 2.9	I 4.1			III 2.0	IV 3.4	V 6.9		I +.0
<i>Arnica latifolia</i>		II 1.2					III 3.1	II +.0	III 2.0		II 3.2
<i>Valeriana sitchensis</i>		I 2.1					III 1.2		II 1.7		III 1.5
<i>Luzula piperi</i>			I +.0				III 1.7	I +.5	II 1.2		I +.0
<i>Juncus drummondii</i>	d, c		I +.0	I +.0	I +.0				III 1.4		III +.5
<i>Anaphalis margaritacea</i>	d								IV 5.9		V 1.2
<i>Epilobium anagallidifolium</i>	c						II +.0				I +.0
<i>Cardamine oligosperma</i>	d, c							I +.0	II +.5	5 1.2	IV 4.4
<i>Oxyria digyna</i>	d, cd									5 +.0	III 2.2
<i>Petasites frigidus</i>	d, c									5 8.5	I +.0
<i>Pohlia</i> spp.	d, c									5 3.3	II 2.4
<i>Senecio triangularis</i>	d, c									5 2.9	I 2.0
										5 1.2	II 2.1

Vegetation unit number		5.1	5.2	5.3	5.4	5.5	5.6	6.1	6.2	6.3	7.1	7.2
Number of plots		10	12	12	7	5	7	8	12	1	13	10
Species	Diagnostic value ¹	Presence class ¹ and mean species significance ¹										
<i>Leptarrhena pyrolifolia</i>	d, cd	I	I +.0								V 6.8	III 1.8
<i>Philonotis fontana</i>											IV 6.1	IV 5.4
<i>Caltha leptosepala</i>	d, c		I +.0								V 4.8	
<i>Drepanocladus aduncus</i>	d										III 5.3	
<i>Equisetum palustre</i>	d										IV 4.2	
<i>Mitella pentandra</i>	d										III 1.0	I +.0
<i>Parnassia fimbriata</i>	d										IV 4.2	
<i>Rhytiadelphus squarrosus</i>	d										III 5.4	
<i>Epilobium latifolium</i>	d						I +.0		II 1.7			IV 5.2
<i>Mimulus lewisii</i>	d										I +.0	IV 5.9
<i>Saxifraga nelsoniana</i>	d										I +.0	III 1.8

1 Diagnostic values, species presence and significance classes as defined in [Table 2](#).

Appendix 4. Differentiated summary table (by presence) for vegetation units 8.1 to 9.5. Only species with a presence class \geq III in at least one plant order are included.

Vegetation unit number		8.1	8.2	8.3	8.4	9.1	9.2	9.3	9.4	9.5
Number of plots		5	10	5	1	8	21	1	1	7
Species	Diagnostic value ¹	Presence class ¹ and mean species significance ¹								
<i>Valeriana sitchensis</i>		5 4.1	V 5.7	5 7.4	5 7.5		II 2.0	5 2.9		V 4.8
<i>Senecio triangularis</i>		3 +.5	IV 4.8				I +.0			III +.5
<i>Epilobium anagallidifolium</i>	d	3 +.0	I +.0				I +.0			
<i>Parnassia fimbriata</i>	d	4 1.0	I +.0							
<i>Ranunculus eschscholtzii</i>	d	3 +.0		1 +.0			I +.0			I +.0
<i>Salix commutata</i>	d	3 5.8								
<i>Veratrum viride</i>		2 3.8	V 4.8		5 4.6	II 1.4	II 3.0			III 3.1
<i>Heracleum maximum</i>		2 2.3	IV 4.6			III 3.7	II 4.0			III 2.4
<i>Sanguisorba canadensis</i>	d, c		III 3.0				I 1.1		5 1.4	I 1.2
<i>Luetkea pectinata</i>	d, c		I 1.2	3 3.4			I +.0	5 3.6		I +.5
<i>Carex nigricans</i>	d		I +.0	3 4.0						
<i>Carex spectabilis</i>	d, c	1 +.0	II 4.4	5 4.5						
<i>Lupinus arcticus</i>	d, c	2 +.0	I +.5	5 2.9						
<i>Pulsatilla occidentalis</i>	d			4 3.3						
<i>Athyrium filix-femina</i>			II 3.7		5 3.6	V 6.0	IV 5.4		5 1.4	IV 5.2
<i>Streptopus roseus</i>	c		I 2.0		5 4.6	IV 2.5	II 2.9			II 4.1
<i>Viola</i> spp.	c		I 1.4		5 1.4	IV 3.1	I +.0			
<i>Sorbus scopulina</i>			I +.5		5 3.3	I +.0	I +.0	5 1.4		II 1.1
<i>Abies amabilis</i>					5 1.4				5 1.4	
<i>Leptarrhena pyrolifolia</i>			I +.0		5 1.4				5 1.4	II 2.0
<i>Gymnocarpium dryopteris</i>	d, c		II 2.6		5 4.6	II +.5	I 3.2			III 2.1
<i>Mitella pentandra</i>	d, c	2 4.8	II 3.3		5 1.4					III +.5
<i>Streptopus amplexifolius</i>	d, c		I 1.5		5 3.6	II 1.1	I 1.4			III 2.6
<i>Tiarella trifoliata</i>	d, c		I +.0		5 1.4	I +.0	I 1.2			III 1.8
<i>Elliottia pyroliflorus</i>	d, cd				5 7.7		I +.0			I 1.2
<i>Rhizoplaca glaucophana</i>	d, c				5 3.6	I 1.2	I 2.5			
<i>Rubus pedatus</i>	d, c				5 3.6	I +.5				
<i>Sphagnum</i> spp.	d, cd				5 8.5					I 1.2
<i>Vaccinium ovalifolium</i>	d, c				5 4.6	I 1.2				
<i>Rubus spectabilis</i>	c		I 4.0			IV 4.4	III 4.8		5 1.4	II 1.0
<i>Sambucus racemosa</i>						IV 3.0	IV 4.0			III 3.1
<i>Oplopanax horridus</i>						IV 5.0	III 3.3			I 3.1
<i>Salix sitchensis</i>			I 4.8			III 2.7	I 3.1	5 1.4	5 2.0	III 5.0
<i>Galium triflorum</i>			II 1.2			III 2.4	II 1.2			III 2.1
<i>Acer glabrum</i>	d					IV 5.7	I 3.4			
<i>Calamagrostis canadensis</i>	d		I 3.1			V 5.4	I 1.5			
<i>Dryopteris expansa</i>	d					II 5.8	I 1.4			
<i>Pteridium aquilinum</i>	d					II 3.2	I 3.4			
<i>Rubus parviflorus</i>	d, cd					II 1.7	II 4.4			
<i>Alnus viridis</i>			I 1.1			II 2.4	IV 8.1	5 9.5	5 9.9	V 9.5
<i>Arundus dioicus</i>			I 3.1				III 4.0			I +.5
<i>Epilobium angustifolium</i>		2 5.2	II 2.5				III 3.6			
<i>Viola glabella</i>			II 2.5				III 3.2			II 2.0
<i>Epilobium</i> spp.	d, c		II 1.0				I +.5	5 1.4		III 1.2
<i>Vahlodea atropurpurea</i>	d, c		I 3.1	1 +.0			I 1.5	5 2.9		III 2.0
<i>Arnica latifolia</i>	d, c	2 1.0	II +.0	2 1.2				5 1.4		I 3.0

Vegetation unit number		8.1	8.2	8.3	8.4	9.1	9.2	9.3	9.4	9.5
Number of plots		5	10	5	1	8	21	1	1	7
Species	Diagnostic value ¹	Presence class ¹ and mean species significance ¹								
<i>Cassiope mertensiana</i>	d, c						I +.0	5 2.9		
<i>Castilleja</i> spp.	d, c		I 1.7				I +.0	5 1.4		
<i>Cladonia bellidiflora</i>	d, c							5 1.4		
<i>Dicranum</i> spp.	d, cd							5 6.4		
<i>Epilobium latifolium</i>	d, c		I 1.1				I +.0	5 3.6		II 2.1
<i>Erigeron peregrinus</i>	d, c	2 +.0	I +.0					5 1.4		I +.0
<i>Hieracium triste</i>	d, c							5 1.4		
<i>Phyllodoce empetriformis</i>	d, cd		I +.0	I 1.1			I +.0	5 8.5		
<i>Polytrichum juniperum</i>	d, c							5 3.6		
<i>Racomitrium</i> spp.	d, c						I 1.5	5 4.6		I 2.0
<i>Stereocaulon</i> spp.	d, c							5 2.9		
<i>Tsuga mertensiana</i>	d, c					I +.0		5 1.4		I +.0
<i>Salix barclayi</i>	d, c								5 1.4	III 5.0
<i>Agrostis scabra</i>	d, cd								5 5.5	
<i>Alnus rubra</i>	d, c						I +.0		5 2.9	
<i>Anaphalis margaritacea</i>	d, c								5 1.4	
<i>Aster foliaceus</i>	d, c								5 1.4	
<i>Aster subspicatus</i>	d, c						I 2.1		5 2.9	
<i>Calamagrostis</i> spp.	d, c		I 1.7						5 3.6	
<i>Carex lenticularis</i>	d, c						II 3.2		5 4.6	I +.0
<i>Cornus sereica</i>	d, c					II 3.4	I +.0		5 1.4	
<i>Equisetum variegatum</i>	d, c		II 1.4						5 2.9	I 4.7
<i>Galium palustre</i>	d, c								5 2.9	
<i>Juncus ensifolius</i>	d, cd								5 1.4	
<i>Mimulus lewisii</i>	d, c						I +.0		5 7.5	
<i>Mimulus tilingii</i>	d, c								5 1.4	II +.0
<i>Phleum alpinum</i>	d, c	I +.0	I +.0	I +.0			I +.0		5 1.4	I +.0
<i>Picea sitchensis</i>	d, c						I +.0		5 1.4	I +.0
<i>Spiraea douglasii</i>	d, c					I +.0	I +.0		5 1.4	
<i>Thuja plicata</i>	d, c					I 1.2	I 1.0		5 1.4	
<i>Viburnum edule</i>	d, c					I 3.0	I +.5		5 2.0	
<i>Viola palustris</i>	d, c								5 1.4	
<i>Brachythecium</i> spp.		I +.0	II 4.5			II 1.5	II 3.0			III 4.4
<i>Tellima grandiflora</i>			I +.5			II +.5	II 1.2			III 1.5

¹ Diagnostic values, species presence and significance classes as defined in [Table 2](#).

Appendix 5. Differentiated summary table (by presence) for vegetation units 10.1 to 11.2. Only species with a presence class \geq III in at least one plant order are included.

Vegetation unit number		10.1	10.2	10.3	10.4	10.5	11.1	11.2
Number of plots		5	6	5	4	5	1	19
Species	Diagnostic value ¹	Presence class ¹ and mean species significance ¹						
<i>Eriophorum angustifolium</i>	d	4 7.8	V 2.1	5 6.8	5 6.5	4 6.1		
<i>Warnstorfia exannulata</i>	dd	4 6.7			2 +.0			
<i>Fauria crista-galli</i>	dd		III 3.4	5 3.1	4 6.1		5 1.2	
<i>Vaccinium caespitosum</i>	dd		III 3.1	4 1.0	3 +.5			
<i>Empetrum nigrum</i>	dd		IV 5.5		3 +.0			
<i>Erigeron</i> spp.			III +.5		3 +.5			
<i>Kalmia microphylla</i>	c		V 1.0		4 +.0			I +.0
<i>Vaccinium uliginosum</i>	dd		V 6.6		2 +.0		5 4.0	I +.0
<i>Cassiope mertensiana</i>	d		III 4.3					
<i>Cladonia mitis</i>	d		III 5.5					
<i>Cladonia rangiferina</i>	d		IV 5.7					
<i>Pleurozium schreberi</i>	d		IV 6.0					
<i>Tofieldia glutinosa</i>			I +.0	4 1.1	3 +.0	2 1.8		
<i>Sanguisorba officinalis</i>				3 3.1				IV 3.3
<i>Agrostis aequivalvis</i>			I +.0	3 +.0	2 +.0	2 1.2		
<i>Leptarrhena pyrolifolia</i>	d			3 +.0				
<i>Sphagnum</i> spp.	d, cd				3 6.3		5 9.9	
<i>Calliergonella cuspidata</i>	d					3 1.8		
<i>Carex aquatilis</i>	d					4 6.9		
<i>Drepanocladus aduncus</i>	d					4 5.1		
<i>Polytrichum commune</i>	d					3 3.2		
<i>Rhizomnium nudum</i>	d					3 2.1		
<i>Scapania uliginosa</i>	d					3 3.6		
<i>Sphagnum subnitens</i>	d					3 5.0		
<i>Vahlodea atropurpurea</i>	d					3 2.2		
<i>Veratrum viride</i>	d					3 +.5		
<i>Carex pluriflora</i>							5 6.0	V 7.4
<i>Erigeron peregrinus</i>	d, c	1 +.0	I +.0	2 +.0	2 +.0		5 2.0	
<i>Sphagnum fallax</i>	d							IV 6.4
<i>Sphagnum papillosum</i>	d							IV 3.3

¹ Diagnostic values, species presence and significance classes as defined in [Table 2](#).