PLANT ASSOCIATIONS IN THE SUBALPINE MOUNTAIN HEMLOCK ZONE IN SOUTHERN BRITISH COLUMBIA

by

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B.S.F., The University of British Columbia, 1958
M.F., Yale University, 1959

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

in the Department

of

BIOLOGY AND BOTANY

We accept this thesis as conforming to the
required standard

THE UNIVERSITY OF BRITISH COLUMBIA

January, 1964

Department of **Biology and Botany**

The University of British Columbia,
Vancouver 8, Canada.

Date **January, 1964**

The University of British Columbia

FACULTY OF GRADUATE STUDIES

PROGRAMME OF THE

FINAL ORAL EXAMINATION

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

of

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B.S.F., The University of British Columbia, 1958

M.F., Yale University, 1959

IN ROOM 2211, BIOLOGICAL SCIENCES BUILDING,

FRIDAY, JANUARY 24, 1964, AT 2:30 P.M.

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ABSTRACT

The vegetation of the Subalpine Mountain Hemlock Zone was studied on 130 sample plots with analytic and synthetic methods of the Zürich-Montpellier school of phytosociology. This thesis describes 14 plant associations, predominantly of vascular plants, from two altitudinal subzones of the Subalpine Zone.

Published radiosonde temperature data, in combination with thermograph data from Mount Seymour, were used to characterize the climate of the zone. In winter, which is the season of maximum precipitation, the freezing isotherm most frequently occurs at altitudes near the lower limit of mountain hemlock. A climatic result is the sharp increase in snow accumulation and duration near the lower limit of this species; an ecological result is the relatively sharp boundary between the Subalpine Mountain Hemlock Zone and the Coastal Western Hemlock Zone.

Thus, the lower limit of the zone is indicated by the presence of mountain hemlock as a component of the forests and the upper limit is marked by the altitudinal "tree limit" of mountain hemlock. The zonal limits were placed at 3000 and 5000 feet in the Seymour - Grouse - Hollyburn - Cathedral Mountain area near the Strait of Georgia, and at 3700 and 5500 feet in the Paul Ridge - Diamond Head portion of Garibaldi Park. The lowest 600 to 800 feet of the zone are covered with continuous forest of mountain hemlock, amabilis fir, yellow cedar and western hemlock. This continuous forest is designated as the lower subzone.

The upper boundaries of the zone, in contrast to the lower, are irregular as a result of topographic influences on snow duration. Snow accumulation increases with altitude so that near the tree limit mountain hemlock can grow only on prominences or ridges where snow duration is less.

Most early stages of vegetation appear to develop towards the Phyllodoce - Cassiope association in the upper subzone. At altitudes of approximately 5000 feet and over (Alpine Zone), this association occupies mesic habitats where the relief is flat or convex and without seepage. In contrast, this same association occupies concave topographic positions, with temporary seepage, in the Subalpine Zone. Snow duration is approximately the same on this association in both bioclimatic zones. However, because of its occurrence on two distinct topographies it is chionophobous in the Alpine Zone but moderately chionophilous in the Subalpine Zone, when considered in relation to adjacent associations.

The Vaccinium membranaceum - Rhododendron association is the most successionally advanced in the upper subzone. Near its lower limit, this association occupies mesic habitats but at its upper limit in the Alpine Zone it becomes a 'topographic climax' restricted to warmer exposures or to ridges between areas of Phyllodoce and Cassiope.

In the lower subzone, the Vaccinium alaskaense association is successionally most advanced. Even if a distinct climatic "climax" association is recognized for the lower subzone, there are no tree species limited specifically to this altitudinal level. Both subzones are unified by the same tree species into one Subalpine Zone. Within this altitudinal belt most zonal features of the vegetation are related to the intensity, quantity and duration of snow.

GRADUATE STUDIES

Field of Study: Botany

Forest Autecology	V.J. Krajina
Forest Synecology	V.J. Krajina
Plant Physiology	D.J. Wort
Advanced Forest Pathology	J.E. Bier

Other Studies:

Geomorphology	Wm.H. Mathews
Soil - Plant Relationships	J. Basaraba
Forestry Tree Seed	G.S. Allen

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V. J. Krajina

ACKNOWLEDGEMENT

I wish to thank the National Research Council, Ottawa, for financing this study, and the British Columbia Department of Recreation and Conservation for the use of provincial parks facilities.

Dr. V. J. Krajina provided the initial stimulation for my interest in this project, and gave valuable advice from inception of the study to completion of the thesis. I am indebted to my Graduate Committee which provided further guidance, and to Dr. T. M. C. Taylor for the use of study facilities in the Department of Biology and Botany, at the University of British Columbia. Dr. W. B. Schofield and Dr. V. J. Krajina helped with the identification of bryophytes, and lichens were identified with assistance from Dr. M. Hale of the Smithsonian Institution, Washington, D. C.

Lastly, I am grateful to my fellow-students, R. C. Brooke and A. C. Archer for co-operation in field work, to L. Orloci for helpful discussions on the problems of ecological classification, and to my wife for her many hours of help. Assistance and encouragement given me by officials of the Canada Department of Forestry, Fredericton, New Brunswick, is also acknowledged.

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CHAPTER I

INTRODUCTION

British Columbia is predominantly a forested, mountainous province. The mountain forests, because of their low productivity, have not attracted the same attention as the valley and lowland forests. It is natural that this should be, as the forests of greatest commercial value occur in the lower elevations and the main transportation routes and settlements are found in the valleys.

When our thoughts and activities are so necessarily controlled by the economic, social and political activities in the settled areas of the province, it is easy to overlook the significance of less accessible and less productive areas. However, if the province's forest distribution is considered by area, regardless of commercial value, an entirely different picture emerges.

The area of British Columbia may be divided into five main components: commercial forest cover, 53 per cent of the total area; "rock and barrens", including snow-fields, glaciers and alpine tundra, 22 per-cent; non-productive tree cover (subalpine), 16 per cent; open range and forests in which cattle grazing is possible, 8 per cent; and less than one per cent in agricultural and urban use (B. C. Forest Service 1957, Haig-Brown 1961).

On a more local scale, forest land occupies 42.3 per cent of the Coast area, with non-forest land and fresh water accounting for the remaining 57.7 per cent (B. C. Forest Service 1957). In comparison, Whitford and Craig (1918) estimated 61 per cent of the southern mainland coast area to be above the merchantable timber line (10,000 board feet per acre). The large area of less productive forest land on the upper slopes of the southern Coast Mountains is the subject of the ecological study described here. Tree cover on this area is not entirely unmerchantable as most of the yellow cedar production comes from relatively high altitudes.

The main purpose of this thesis is to describe the plant associations and the zonal climatic controls in the southern portion of the region described by Rowe (1959) as the Coastal Subalpine Section (SA.3) and by Krajina (1959) as the Subalpine Mountain Hemlock Zone. This objective presumes the need for classification of natural areas.

Despite its early existence as a scientific tool, classification is still evolving. New discoveries often require changes in systems of classification and, as with organic evolution, improvements and increased diversity are the result. One should expect that the need for classification, and the intricacies of classification, should increase as man's knowledge broadens.

However, classification has not assumed the same importance in all fields of intellectual endeavor. A plant physiologist knows the species with which he works and is theoretically able to apply his analytical results to that species in its natural occurrence. At the other extreme is the field of soil science in which techniques of analysis are well developed but where synthesis is only beginning (Kubiëna 1960). In comparison, attempts to classify nature ecologically have been numerous and date back to the last century. Yet soil science and ecology have a startling similarity today in their relatively undeveloped synthetic treatment of analytical data. It should not need emphasis that information from field and laboratory studies is usually not applicable to all soil types, nor to all habitats. It is for this reason that Kubiëna (1960) asserted that the only way to rationalize research in a natural science is on the basis of broad, exhaustive systematics. Advances in experimental technique are negated if they are not accompanied by corresponding advances in application to specific habitats in nature. One of the most challenging problems today in ecology, as in soil science, is to ensure that the gap between the analytic and the synthetic (systematic) aspects of these sciences is not widened.

The synthesis of ecological findings requires an increased understanding of natural areas and increased uses of classification of these areas. This philosophy provided the motivation for the present study, and the following thesis is meant to complement the ecological information previously acquired through similar studies in other parts of British Columbia (Krajina and Spilsbury 1953, Krajina 1953, Arlidge 1955, Brayshaw 1955, McMinn 1957, Mueller-Dombois 1959, Lesko 1961, Orloci 1961, Eis 1962a, Archer 1963). These studies, when considered collectively, provide a classification that may serve as a basis for forest management and planning, for advisory work, and for experimental research. It is important to realize, though, that a classification, whatever its basis, is an artificial structure. It is a convenient tool used to express current ideas about the relationships of organisms, or parts of nature, to one another. As ideas change, or as new facts accumulate, classification systems may be revised, and conclusions based on such classification will need to be accordingly flexible.

Detailed reviews of the development of ecological classification have been presented by several authors, and it is unnecessary to present here a compilation of easily accessible references. It is important only to draw attention to some of the more comprehensive and recent reviews for the interested reader: Whittaker 1953, Poore 1955 and 1956, Becking 1957, Churchill and Hanson 1958, Hustich 1960, Krajina 1960, Whittaker 1962, and Poore 1962.

In British Columbia, ecological classification has a brief history. The province was first divided on a large regional basis, mainly for mensurational purposes by Whitford and Craig (1918). In 1937, Halliday presented subdivisions of a similarly large scale as part of his forest classification for Canada. His regions were formed on the basis of climatic criteria and they have recently been revised by Rowe (1959). A more detailed, but still very broad, division of the province into 12 bioclimatic zones was made by Krajina (1959).

The works of Ilvessalo (1929), Kujala (1945), and Spilsbury and Smith (1947) are commonly cited as the earliest detailed phytosociological studies in this province (Bell 1959, Orloci 1961).

During the last decade, ecosystematic studies which developed from a fusion of phytosociological and environmental classification have been carried out by researchers (cited on page 2) under the direction of Krajina, and by others in the provincial Forest Service (Illingworth and Arlidge 1960).

More recently, the Federal Department of Forestry has initiated research to test physiographic site mapping in coastal forest types (Lacate 1962). In this method, plants are not considered until the physiographic units are established. Published soils maps and reports have also provided useful environmental information for many parts of

British Columbia, but none is yet available for subalpine areas.

The approach in the present study was primarily phytosociological and followed the analytic and synthetic methods of the Zürich - Montpellier School (Braun-Blanquet 1932, Becking 1957). It was recognized, however, that environmental characteristics are equally as useful as floristic structure for the classification of plant associations. For this reason, modifications of the original Braun-Blanquet methods were made in accordance with recommendations by Krajina (1960).

The study was carried out in the Department of Biology and Botany, University of British Columbia, under the direction of Dr. V. J. Krajina and in co-operation with R. C. Brooke. A separate dissertation will discuss the microclimatic and edaphic characteristics in relation to vegetation (Brooke 1964), whereas this thesis concentrates upon phytocoenotic characterization with a stress upon some zonal features, especially macroclimate. However, both theses have a single ecosystematic theory as their foundation and they should be considered as a unit.

The most important features of the subalpine environment are discussed in Chapter III. In Chapter IV, the plant associations are described in terms of their present composition, and in Chapter VI they are related to one another dynamically where there is evidence of successional trends. These three chapters are the most important, since they represent the main findings of this study.

CHAPTER II

METHODS

Procedures in the field and the methods of arranging data are, to a large extent, controlled by the purposes of a particular investigation. Because an ecological study usually involves several related disciplines, it cannot have a single theory around which methods of study can be built. It is necessary, therefore, to briefly outline the field procedures and the methods of handling and presenting data.

A. Field Procedures

The methods used in this study do not differ markedly from those of Krajina (1933), Brayshaw (1955), McMinn (1957), Mueller-Dombois (1959) and Orloci (1961). This deliberate standardization of methods serves an important purpose by allowing direct comparisons to be made between floristic descriptions from different bioclimatic zones. Even if there is a choice of several available theories to serve as a basis for ecological classification, none of them will explain everything. The main object is to collect basic ecological information of sufficient accuracy to form an ecosystematic classification and to allow comparisons for multiple-use land planning.

The vegetation was studied by means of sample plots which, on forested areas, were one chain by two chains (1/5 acre) in size. The plots were located in places where the vegetation was uniform over such an area. For non-forested associations, plots 1/2 chain by 1/2 chain (1/40 acre) were sufficiently large. It was not only convenient to use these smaller plots, but also necessary in some cases where the associations were severely limited in area by the topography or the environmental gradients, as for example, around late snow-patches or along stream margins. At least one corner of every sample plot was marked by a wooden or steel post and an aluminum tag bearing a record of the plot number, its dimensions and its orientation. Subsequent visits to these cornerposts showed many of them leaning or knocked down, especially where snow-creep was pronounced.

The four corners of each plot were joined by string to facilitate the tally of trees. The diameters, at breast height, of all living trees over three inches, were measured with a steel tape. Since none of the sample plots was heavily forested, it was practicable to measure the heights of nearly all the trees with an Abney level. In some cases, heights were estimated by comparison with adjacent measured trees.

All of the forested sample plots were in uneven-aged old growth stands of mountain hemlock (Tsuga mertensiana (Bong.) Carr.), amabilis fir (Abies amabilis (Dougl.) Forbes), and yellow cedar (Chamaecyparis nootkatensis (D. Don) Spach). Therefore, stand age, as such, could not be determined, but ages were taken over the range of diameters for each species present on a plot. From six to twelve ages were obtained for each plot by increment borings at breast height.

Floristic analyses were carried out on homogeneous stands by listing all the vascular plants, bryophytes and lichens on each plot. An area was ocularly judged as homogeneous if the constituent species appeared uniformly distributed throughout the plot. Species were listed for each of the following arbitrary strata:

A_1 - dominant and co-dominant trees

A_2 - intermediate trees

A_3 - suppressed trees over 30 feet in height

B_1 - saplings and shrubs between 6 and 30 feet in height

B_2 - shrubs between 6 inches and 6 feet in height

C - herbaceous plants (all) and small woody plants under 6 inches in height (Note that by this definition subalpine species such as Phyllodoce empetriformis, Cassiope mertensiana and Vaccinium deliciosum occur in the C layer.)

D_h - humicolous bryophytes and lichens

The bryophytes and lichens on decayed wood, on rock and on tree trunks were also listed. Tree or shrub species which occurred in more than one stratum were listed and floristically evaluated for each.

Species significance, sociability and vigour were evaluated according to the scales shown in the legend preceding the appended Synthesis Tables. Plants of uncertain identity were collected for later identification, and were subsequently deposited in the University of

British Columbia Herbarium. Microscopic examinations of the bryophytes and lichens often revealed species that were not listed in the field notes. In such cases, the extra species were added for the appropriate sample plot to the preliminary synthesis tables, and, as suggested by Dahl (1956), their floristic ratings were estimated on the basis of the occurrence in other plots of the same association.

Detailed microclimatic measurements and edaphic descriptions of the associations are provided by Brooke (1964). Only hygrothermograph data and snow depth measurements from temporary climatic stations at 4000 feet (BP 124) and at 3200 feet (BP 15) are discussed here. Relative turgidity measurements on the needles of mountain hemlock and amabilis fir were also taken from these two stations to test if there were differences in the internal water balance of needles on altitudinally and ecologically distinct habitats.

Finally, it must be emphasized that methods of floristic analysis, as described above, are not statistical methods as the term is otherwise applied in biology. This point was also stressed by Dahl (1956). Statistical methods could be more appropriately applied if every association had the same chance of occurrence in a zone. Then a random sample would touch all habitats about equally. Since this ideal does not exist, stratification is necessary before statistical analyses can be carried out. In this particular study, stratification was made on the basis of floristic features. This need not imply that the plant association is the basic unit for ecological studies, but it is a useful unit for stratification because it provides information for studies of habitats and niches.

Boundaries between associations are rarely distinct, but transitions do not justify the annihilation of the units involved. For preliminary studies, it is best to avoid transitions. If they are included in association tables, they will reduce the difference between the units because, by definition, they represent conditions that are interpolative. It is better to describe the distinct and extreme units and to let the transitions be mathematically interpolated later. By this method, it is not possible to describe all variations of vegetation in an area, but any random point will fall into a described vegetation unit or will be readily assigned to an intermediate position between two units (McVean and Ratcliffe 1962).

In summary, the methods used for this study must be recognized primarily as standardized descriptions of vegetation which permit comparisons between different associations both intrazonally and interzonally.

B. Synthesis and Presentation of Floristic Data

The following paragraphs outline the philosophy which influenced the organization and descriptions of plant associations in Chapter IV. McVean and Ratcliffe (1962) pointed out that vegetation units can be arranged in at least three ways: systematically, or according to a hierarchical classification of the units distinguished; physiognomically, or according to the life-form of the dominant species; and ecologically, or according to the main habitat types and altitudinal zonation.

The first alternative, a systematic or hierarchical classification, was inappropriate for the present study, because it can only be used in later studies which will incorporate the associations described here into higher community units in combination with associations from other bioclimatic zones.

The second method is well suited for the Subalpine Zone since there are great physiognomic differences between the lower forested associations and the upper heath-like and herbaceous associations. This is in contrast to the associations of the Coastal Western Hemlock Zone most of which are forested and physiognomically more uniform. However, a physiognomic classification by itself provides only limited information. Studies which yield more detailed information about the habitat should utilize such ecological information in the classification scheme, as in the present study. Physiognomic differences were considered only in the comparisons of life-form spectra in each association (Chapter V), and by the grouping into forested and unforested categories in the classification of Chapter IV.

The remaining alternative of ecological organization was used effectively by Orloci (1961), in combination with floristic structure, for the forest types in the Coastal Western Hemlock Zone. Descriptions from the Subalpine Zone will be of more value if they can be directly compared with descriptions from lower elevations. Therefore, the organization of Chapter IV closely resembles that used by Orloci (1961).

The major categories in Chapter IV are two altitudinal subzones, and within each subzone there are habitats ranging from dry or moderately dry to wet. In the upper subzone, relationships to length of snow cover and physiognomy (forest, krummholz, small shrub, herb and bryophyte) form the basis for organization. Thus, floristic structure is the primary base for classification, but it is organized in altitudinal, habitat and physiognomic groups. The combination of several criteria for classification reduces the number of units in any one group. Such organization, in combination with descriptions of the associations, should enable the reader to identify the vegetation units of the Subalpine Zone without the aid of a key.

Presence, dominance and fidelity are the main criteria for describing and differentiating the associations. Those species which were present in over 80 per cent of the sample plots in a synthesis table are listed as constants. Each constant species whose average cover degree exceeded 10 per cent of the plot area is listed as a constant dominant. Fidelity was determined as outlined by Becking (1957), and the characteristic species for each association are listed as follows (Braun-Blanquet 1932):

Fidelity 5 - Exclusive species, which are completely or almost completely confined to one community.
Fidelity 4 - Selective species, which are found most frequently in a certain community.
Fidelity 3 - Preferential species, present in several communities more or less abundantly but predominantly or with better vitality in one certain community.

The choice of exclusive, selective and preferential species was based only on tabular data from plots in the restricted area of this study. Therefore, a species may be listed as exclusive to a certain association in the Coastal Subalpine Zone even though it is known to occur in other associations of the Coastal Western Hemlock Zone or the Alpine Zone. This possibility was recognized by Braun-Blanquet (1932) when he pointed out that fidelity always refers to the relation of a species to a certain community (within a particular region or zone). Of secondary importance are the social relations which this species has in all parts of its range. It is possible for one particular species to be exclusive in different regions to two or more distinct and different communities.

The average characteristic species (Fidelity classes 3, 4, and 5) and constant species, taken together, are the characteristic combination of species as used in the Zürich - Montpellier methods of synthesis. The use of dominance as a criterion is recommended for vegetation units containing few species (Poore 1955, Dahl 1956). Association characteristic species are not plentiful in the Subalpine Zone because the number of species in the associations is small compared to European study areas where the Zürich - Montpellier methods were developed. For this reason criteria such as dominance, environmental features of the habitat, or life-forms should also be used.

As pointed out by Krajina (1960), the ideal concept for ecosystem classification is the biogeocoenosis that is composed of an ecotope and a biocoenosis. The ecotope is divided into a climatope and an edaphotope. The biocoenosis is divided into a phytocoenosis, a zoocoenosis and a microbocoenosis (Sukachev, quoted from Krajina 1960). Most emphasis in this thesis is placed on the phytocoenosis (association), but other factors of the biogeocoenosis are considered, especially for sub-units of the associations.

Differential species, which may be non-characteristic, are used to distinguish closely related vegetation units (Braun-Blanquet 1932, Krajina 1933, McVean and Ratcliffe 1962). Thus, several subassociations are recognized in Chapter IV by the presence or absence of species, or by differences in the dominance and vigor of certain species. Subassociations reflect edaphic or microclimatic differences (Drees 1953), as in the hygric Cladothamnus subassociation versus the lithic Cladothamnus subassociation, whereas variants reflect macroclimatic differences. Only one variant is recognized in Chapter IV, where the subalpine Oplopanax stands are treated as a climatic variant of the Oplopanax - Adiantum forest type described by Orloci (1962) for lower elevations in the Coastal Western Hemlock Zone.

Common descriptive names of the vegetation units depicting a dominant species and environmental features are used throughout the text. Names based on the rules by Drees (1953) are also provided because they facilitate the systematic grouping of vegetational units into higher categories through standardization of phytosociological nomenclature in different bioclimatic zones. For associations, the suffix -etum was added to the stem of the genus-name of a dominant species. If two generic names were used, the first had an -eto ending, and in necessary cases the name of the species in the genitive case was also added. Subassociation names were formed by adding the ending -etosum to the generic stem, and variant names used an -osum suffix. Although descriptive prefixes and adjective names are not standardized, the terms nano-, hygric and lithic were used.

C. Synthesis and Presentation of Mensurational Data

The tree diameter tally was grouped by species into four-inch diameter classes for stand table presentation (Figure 25). Height-diameter curves were not constructed as a step in volume determination because actual height measurements were available for nearly all individual trees. This was possible because of the relatively small number of trees on most sample plots, and it allowed the determination of volume on an individual tree basis. Gross volume per tree was determined from the Coast Mature Hemlock Tables for both species of hemlock, from the Coast Mature Cedar Tables for yellow cedar, and from the Coast Balsam Tables for amabilis fir (Forestry Handbook for British Columbia 1959).

It was impossible to obtain reliable site indices for trees of the Subalpine Zone because only old growth stands were available and no site index curves exist for subalpine species. Furthermore, height growth is usually so slow in the Subalpine Zone (Figure 20) that the conventional expression of height at 100 years is inappropriate. Despite these weaknesses, average site index at 100 years was determined where possible to permit comparisons of growth rate with lower elevations. A large scale reproduction of the height-age curves published for coastal species at lower elevations (Forestry Handbook for British Columbia 1959, p. 371) served this purpose, but the site indices obtained are not reliable (Table XII).

For old-growth stands which are slow growing because of a rigorous environment, average height of the tallest tree regardless of age is a useful indicator of site productivity. Table XII shows, for each of the four major species, height of the tallest tree averaged for the number of plots in each association. These values, when considered together with the gross volumes and the approximate site indices, give a good indication of the potentialities of each species in the various associations.

The synthesis tables (Appendix III) provide per acre values for number of trees, basal area, and gross volume for each species on every sample plot. These data, excluding basal area, are summarized for five associations and two subassociations by histograms which readily allow a visual comparison of the number of trees per acre and gross volume in cubic feet per acre for each species in each diameter class (Figure 25).

CHAPTER III

THE SUBALPINE MOUNTAIN HEMLOCK ZONE

This chapter defines the study area geographically and altitudinally. The topography, geology and climate are described, and the chapter concludes with a discussion of the most important zonal features of the vegetation.

A. Definition of the Subalpine Mountain Hemlock Zone

It is well known that climatic and vegetational differences result from increases in altitude in mountainous country. Altitudinal zonation is so obvious that terms such as subalpine, alpine and timberline form part of our regular vocabulary. Increased usage of these terms has, however, lead to indefinite meanings, and for this thesis some definitions are necessary.

For the area of his study in Norway, Dahl (1956) drew the upper limit of the subalpine belt "at the timber-line or forest-limit". This definition, while good in principle, is inadequate because it contains within it poorly defined terms. For example, Hustich (1949) defined the timberline as the limit of timber-sized forests. This definition is of economic importance but is misleading as a biological boundary. If it were applied to south coastal British Columbia, timberline would be near the upper limit of western hemlock since the distribution of this species closely approximates the upper limit of merchantable forests today. Another definition of timberline, and the more usual one, was given by Dansereau (1957) as the highest elevation at which trees grow. However, it is questionable if coniferous species can be classed as trees near their northern limit or near their altitudinal limit (as for example, krummholz). Where would the timberline be placed in such areas? The designation of three biological boundaries, forest limit, tree limit and species limit (Dansereau 1957, Berner 1959) partly solves the problem.

These three limits, when applied to a particular species, make general terms such as montane, subalpine or alpine more meaningful by providing a biological basis for the zonal delineation. For the study area described here, the altitudinal distribution of mountain hemlock in tree form indicates coastal subalpine conditions, and the region may be justifiably called the Subalpine Mountain Hemlock Zone, as previously designated by Krajina (1959). The lower limit of the zone is represented by the lower limit of mountain hemlock as a dominant component of the forests, and the upper edge of the zone is placed at the altitudinal tree-limit of mountain hemlock. Thus, the vegetation is predominantly arborescent, but the trees are often dispersed and smaller than they are at lower elevations (Dansereau 1957). The upper limit of trees is discontinuous and there may be, because of locally unfavourable conditions, considerable areas within the subalpine belt not covered by forests or trees.

The definition above is not meant to imply that the Subalpine Zone represents the absolute upper limit of mountain hemlock as a species. The altitudinal species limit occurs higher up in the Alpine Zone (Archer 1963). The species does not attain the stature of a tree above the Subalpine Zone, however.

The term, forest limit, is useful for subzonal designation because forests are not of uniform continuity from the lower to the upper limits of the zone. In Garibaldi Park, Brink (1959) recognized a "lower subalpine forest" from 3500 to 5000 feet, and noted that the forest was more open above 5000 feet. This upper limit of continuity in the tree cover, or forest limit, coincides with the altitudinal division of the Subalpine Zone into two subzones in this thesis.

The following distributional, environmental and floristic features allow a comparison of the original zonal definition (Krajina 1959) with that presented later in this chapter for the specific area of this study. As defined by Krajina (1959), the zone extends along the coastal mountain ranges between altitudes of 3000 and 5500 feet in the south of British Columbia and between 1000 and 2000 feet in the north of the province. Total precipitation varies from 75 to 170 inches per year, with 14.0 to 15.5 inches in the wettest month and 1.3 to 3.3 inches in the driest month. In the southern part of the zone, 30 to 40 per cent of the precipitation occurs in winter or autumn with only 10 to 15 percent in the spring or summer. In the northern portion, 30 to 35 per cent falls in the autumn and 10 to 15 per cent in the summer. Snowfall varies from 170 to 800 inches per year, and it makes up 20 to 70 per cent of the total precipitation. Krajina (1959) placed the Subalpine Mountain Hemlock Zone in Köppen's Dfc category, and the zonal soil was called a coastal subalpine podzol. The Tsuga mertensiana - Abies amabilis - Vaccinium alaskaense - Vaccinium membranaceum - Rubus pedatus association was listed as the climatic climax plant community.

B. Related Studies

Of the 90 forest sections described for the forest regions of Canada (Rowe 1959), the briefest description is given for the Coastal Subalpine Section (SA.3). This brevity does not mean that the section is areally or economically unimportant, because there are other forest sections of smaller size or others of equally low forest productivity which are described in greater detail. Rather, it reflects the paucity of published information on the major tree species and cover types of this section.

In the brief literature review which follows, little attention is given to subalpine studies in mountains other than those in coastal British Columbia and in the Pacific Northwest region of the United States. Braun-Blanquet (1932), Daubenmire (1943), and McVean and Ratcliffe (1962) have all stressed that phytosociological studies on different mountain systems are not directly comparable because of individuality in the environmental conditions of any particular mountain system.

For the Olympic Mountains, the history of botanical and ecological investigations was reviewed by Jones (1936). He presented a similar history for Mount Rainier in 1938. A very recent review of subalpine work in the Pacific Northwest is that by Franklin (1962).

The earliest mountain studies in Coastal British Columbia were mainly botanical explorations. The first plant collections from higher altitudes were made in 1912 on Grouse Mountain, Hollyburn Ridge and from near Mount Garibaldi (Davidson 1913 to 1915). Other reports from subalpine areas were made by Henry (1915), Hardy (1927) and Perry (1928). Further north, McAvoy (1929, 1931) described alpine and subalpine conditions for the Bella Coola region. Additional references to the Garibaldi area were made by Davidson in 1931, and Taylor (1936, 1937)

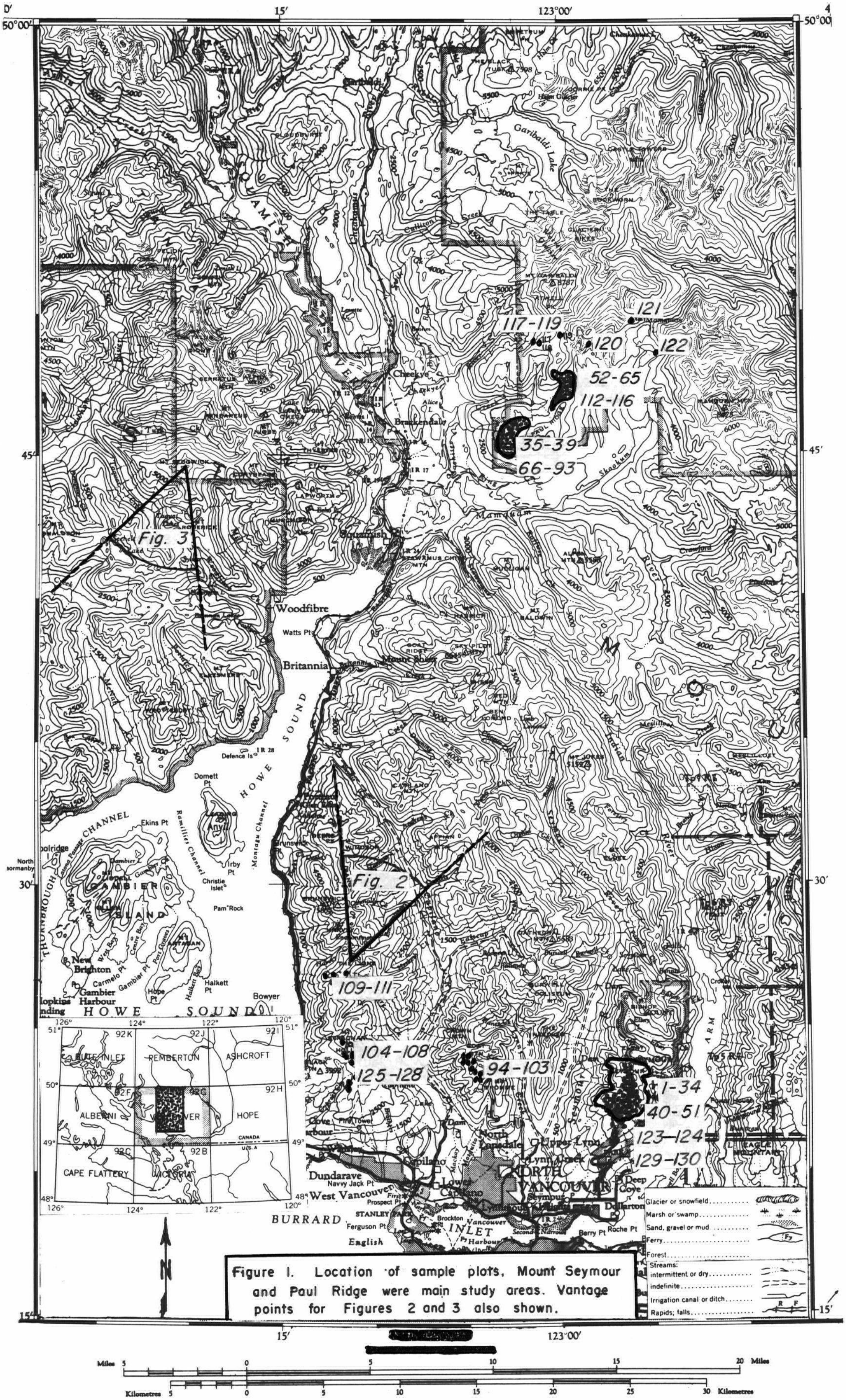

Figure 1. Location of sample plots, Mount Seymour and Paul Ridge were main study areas. Vantage points for Figures 2 and 3 also shown.

[redacted]

described former forest areas in Garibaldi Park which had been re-covered by a glacier.

The recent study by Schmidt (1957) provided valuable information on the silvical characteristics of amabilis fir, a common species in the Coastal Subalpine Zone. Brink's report (1959) described successional changes near the Black Tusk, just north of the present study area. Further reference is made to his study in later sections. At present, Brink, MacKay and Mathews of the University of British Columbia (unpublished) are studying alpine and subalpine vegetation in relation to frost, snow and solifluction in Coastal British Columbia.

C. The Study Area

1. Location and Extent

The study area is shown by the distribution of 130 sample plots in Figure 1. The plots were located as follows:

Mount Seymour	Plots 1-34, 40-51, 123, 124, 129, and 130.
Hollyburn Ridge	Plots 104-107, 125-128.
Grouse Mountain	Plots 94-103.
Mount Strachan	Plot 108.
The Lions	Plots 109-111
Paul Ridge (Round Mountain) and Diamond Head area, Garibaldi Park	Plots 35-39, 52-93, and 112-122.

Whitford and Craig (1918) classified this area as part of the Coast Forest. It occurs in Section SA.3, the Coastal Subalpine Section, of Rowe's (1959) classification, and it forms part of the Pacific Subalpine Forest referred to by Heusser (1960).

In the 450-square-mile study area, the altitudinal limits of the Subalpine Zone cannot be precisely defined, except locally. Near Burrard Inlet, the lower edge of the zone, as defined by the lower limit of mountain hemlock, closely follows the 3000 feet contour. In the triangular physiographic unit bounded by Burrard Inlet on the south, Howe Sound on the west, Stawamus River and Indian River on the northeast, and Indian Arm on the east, very few peaks have areas above the tree limit (except for Cathedral Mountain, 5683 feet, and Sky Pilot Mountain, 6645 feet). Therefore, the area of the Subalpine Zone should be closely approximated by the total acreage above the 3000 foot contour. The above physiographic unit, which includes the Seymour - Grouse - Hollyburn study area, has a total area of approximately 234,000 acres, 87,000 acres of which are above 3000 feet in altitude (determined from planimeter readings on Map sheet 92G, National Topographic Series, 1:250,000). Thus, approximately 37 per cent of this south coastal area may be classed as subalpine (Figure 4).

On Paul Ridge, northeast of Squamish, the lowest mountain hemlock is at 3800 feet and western hemlock is common to 4000 feet. There is thus an upward shift of the Subalpine Zone by almost 1000 feet in this part of the study area. Upper and lower altitudinal limits of individual associations are also about 1000 feet higher on Paul Ridge than they are on the mountains near Burrard Inlet (Figure 28).

The following table summarizes the zonal and subzonal altitudinal limits for this study:

	Seymour, Grouse, Crown Hollyburn and Cathedral Mountains	Paul Ridge (Garibaldi Park)
Subalpine zone:	3000 - 5000 feet	3700 - 5500 feet
Lower subzone:	3000 - 3600 feet	3700 - 4500 feet
Upper subzone:	3600 - 5000 feet	4500 - 5500 feet
Alpine zone:	over 5000 feet (only on Cathedral Mountain)	over 5500 feet

With such variation in the altitudinal limits of the zone over a 30-mile distance, comparisons with the altitudinal delineations of this zone in other study areas must be made with caution. In the Black Tusk area, just 15 miles north of Paul Ridge, the limits set by Brink (1959) correspond quite

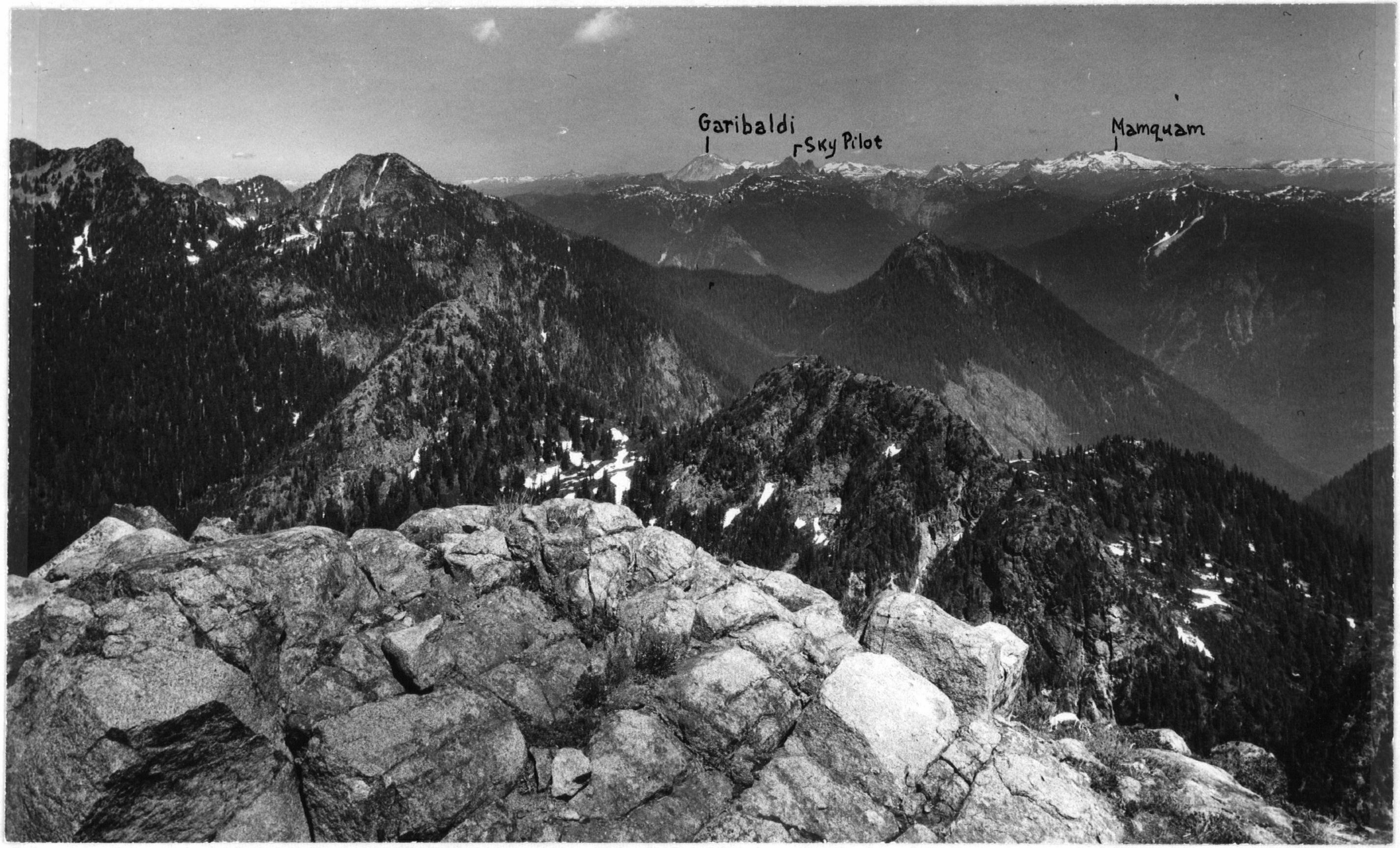

Figure 2. General view of the Coastal Subalpine Zone, from 5400 feet on the west Lion. Photograph courtesy of Surveys and Mapping Branch, Province of British Columbia.

to follow page 17

Figure 3. View from 6300 feet on Mount Sedgwick shows late snow in the Coastal Subalpine Zone, July 10, 1952. See Figure 1 for vantage point of photograph. Courtesy of Surveys and Mapping Branch, Province of British Columbia.

to follow page 17

closely. He considered the "lower subalpine forest" to occur from 3500 feet to 5000 feet. Above the 5000-foot contour, the character of the subalpine forest changed markedly but trees 50 feet high were common to 6300 feet. Similar comparisons can be made from studies in other coastal mountain ranges. The Hudsonian Zone of the Olympic Peninsula is similar to the Coastal Subalpine Zone in British Columbia in vegetational and climatic characteristics. Altitudinal limits of 3500 feet and 5000 feet were given for the Hudsonian Zone by Jones (1936), and for a similar classification on Mount Rainier (Jones 1938) the limits were placed at 4500 to 6000 feet. Many other examples exist in the literature (see especially Heusser 1960, pages 50-75). In the abstracts presented by Franklin (1962), there are 25 direct references to the altitudinal range of mountain hemlock. On the basis of his information, the Coastal Subalpine (Mountain Hemlock) Zone occurs from 6900 to 9400 feet in the Stanislaus and Lake Tahoe Forest Reserves, California (Sudworth 1900), and from 1200 to 2400 feet in the forests of southeastern Alaska (Hoffman 1912). This general depression of the zone, from south to north, has many local irregularities due to topographic and climatic differences.

2. Topography and Geology

The topography of the Coastal Subalpine Zone is best described by the photographs in Figures 2 and 3. The vantage point for Figure 2 is at an altitude of approximately 5400 feet on the most westerly of The Lions. The view is towards the northeast, and subalpine forest covers most of the visible area with the exception of the mid and lower slopes adjacent to Capilano Valley on the right. The latter are part of the Coastal Western Hemlock Zone (Orloci 1961). On the far horizon, the peaks of Mount Garibaldi, Sky Pilot Mountain and Mamquam Mountain represent the Alpine Zone (Archer 1963).

LEGEND TO ACCOMPANY MAP (FIGURE 4)

Geological subdivisions are shown only for those areas where sample plots were located (References: Armstrong 1954, Roddick and Armstrong 1956, Mathews 1958).

In the Diamond Head - Paul Ridge study area:

Quaternary
Garibaldi Group
G2 - Late glacial and early postglacial
G1 - Older
d - Dacite
b - Andesite and basalt

Pre-Upper Cretaceous
Older intrusions
Oq - Cloudburst quartz diorites (foliated and unfoliated quartz diorite, minor diorite, etc.)
Mv - Metavolcanic and metasedimentary rocks (greenstone, slaty argillite, breccia, minor conglomerate, limestone, green schist)

In the Seymour - Grouse - Hollyburn - Lions study area:

Triassic (?) and/or later
Gambier Group
3 - Tuff, breccia, agglomerate, andesite, slate, argillite, arkose, quartzite, greywacke, conglomerate, minor dacite, trachyte, and basalt

Triassic (?) and/or later
Bowen Island Group
2b - Banded hornblende-feldspar gneiss, hornblende-biotite-feldspar gneiss, hornblende biotite-quartz schist, dioritic gneiss, granitoid gneiss, hybrid diorite and granitic rock

Plutonic rocks formed at more than one period in the geological history of the map-area (not an age sequence)
Hb_{III} - Plutonic rocks in which hornblende forms 50 to 90 per cent and biotite 10 to 50 per cent of mafic mineral content. Quartz diorite
$H_{II,III,M}$ - Plutonic rocks in which hornblende forms 90 per cent or more and biotite 10 per cent or less of mafic mineral content. II, granodiorite; III, quartz diorite; M. migmatite

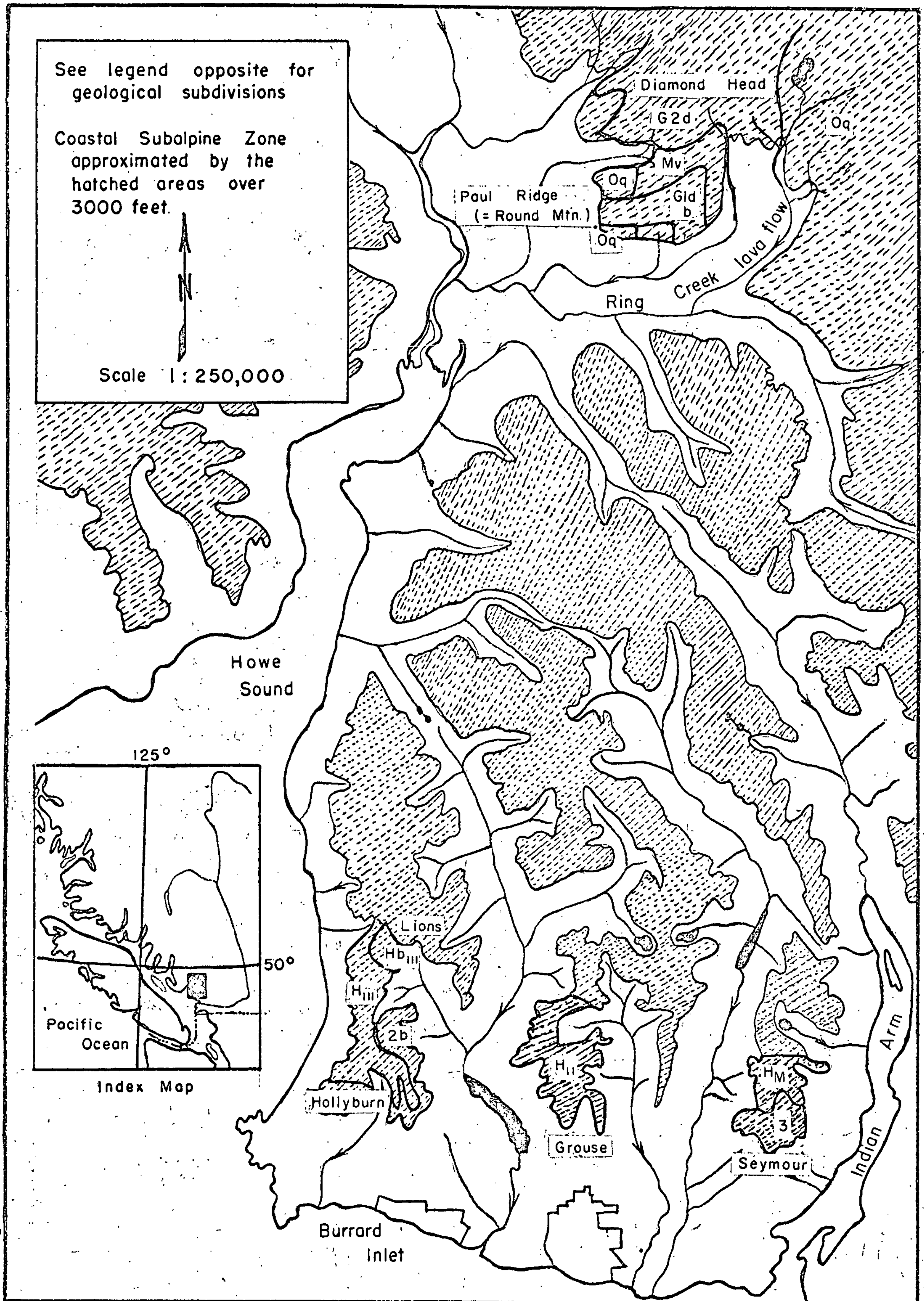

Figure 4. Approximate distribution of the Coastal Subalpine (Mountain Hemlock) Zone near Vancouver British Columbia.

The most important geological references for the area are: Heusser (1960) for the Coast Mountains in general and particularly for glacial history; Armstrong (1954) and Roddick and Armstrong (1956) for the Seymour - Grouse - Hollyburn study area; and Mathews (1958) for the Paul Ridge - Diamond Head study area. Geological subdivisions for the study areas are shown on the distribution map for the Coastal Subalpine Zone (Figure 4). The most striking features are the occurrence of older intrusive rocks through most of the area and the localized presence of Quaternary volcanic parent materials in parts of Garibaldi Park. The legend accompanying Figure 4 lists the rocks which are prevalent in each geologic subdivision.

Parent material differences in different parts of the study area do not seem to be correlated with changes in the species composition of the subalpine vegetation, except that Cladothamnus pyrolaeflorus is absent from parent materials of the Garibaldi Group.

The study area was glaciated recently, in both the geologic and anthropomorphic scales of time. For example, near the Opal Cone in Garibaldi Park subalpine forest is present on slopes above the trim-line of a glacial tongue which has melted back from the valley only in the last few centuries (Mathews 1958). Naturally the most obvious signs of very recent glaciation are near the upper limits of the Subalpine Zone. Glacial striae on rock surfaces are surprisingly few in the mid and lower portions of the zone because of the rapid weathering of rock surfaces since glaciation. The frequency of freezing cycles is an important factor in the surface weathering and exfoliation of rocks, and the increase in the number of freezing cycles with increasing altitude (Table I) indicates the potentially greater rate of weathering of rock surfaces in mountain areas. This phenomenon would be particularly effective in October, April and May when some rock surfaces would be free of snow.

TABLE I

Number of freezing cycles at Vancouver Airport (16 feet) and at 3200 feet and 4000 feet on Mount Seymour, Aug. 1, 1960 to July 31, 1961*

	Vancouver Airport 16 ft.	Mount Seymour B P 15 3200 ft.	Mount Seymour B P 124 4000 ft.
Aug.	-	-	-
Sept.	-	-	-
Oct.	-	1	7
Nov.	1	3	8
Dec.	12	5	10
Jan.	10	6	8
Feb.	-	6	4
March	1	5	7
Apr.	-	10	10
May	-	1	2
June	-	-	-
July	-	-	-
Year	24	37	56

* A freezing cycle was arbitrarily counted whenever the temperature dropped to 31° F or lower and then rose to 33° F or higher.

Parent materials, soil-forming processes, soil types, soil moisture and soil temperature relationships are described for the Subalpine Zone by Brooke (1964). Attention is drawn here only to the most important zonal features.

The high proportion of rock outcrop, particularly in the upper portions of the zone, is demonstrated well in Figure 2. On the ridges, the products of weathering are removed as quickly as they are produced and the soil is consequently very shallow. Slopes and depressions are generally covered with a thin mantle of glacial drift. Alluvial soils are absent from the Subalpine Zone except for small marginal deposits along mountain streams. Wet organic soils are also of very limited occurrence because the relief is too steep for bog development.

Skeletal disintegration is the most important weathering process in rock outcrop areas, and podzolization is the most common soil-forming process. In the subalpine podzols, the elluviated (A_e) layer is not readily visible, however, because of continuous darkening from acidic organic accumulations.

A high proportion of organic matter is typical for nearly all soils in the Subalpine Zone. The snow cover results in soil temperatures that are far below the optimal for bacterial activity and even below their minimal temperatures for much of the year. This leads to the development of a mor, in which decomposition is primarily due to fungi. The development of very acid conditions is partly due to fungal activity (Lutz and Chandler 1957). With decomposition limited to that by fungi, and with a very short season for such activities, the amount of unincorporated organic matter increases. As an example, on August 20, 1962, leaves of Vaccinium deliciosum from the previous autumn were still undecomposed in well-aerated litter at an altitude of 4800 feet. In contrast, decomposition by micro-organisms would probably have completely destroyed similar litter by June in warmer bioclimatic zones. These accumulations can result in very high percentages of organic matter in subalpine soils, especially where mineral soils are of limited depth. Freezing cycles, which take place before there is a snow cover, accelerate the mixing of moist organic matter by heaving, expansion and other physical disturbances in the uppermost horizons.

3. Climate

Increased altitude results in a general decrease in air temperature (despite increased insolation), larger differences in temperature between day and night, and greater precipitation. These three influences, in combination with a winter maximum in precipitation, give the Coast Mountains unusual accumulations of snow. The significance of this snow has been insufficiently emphasized in world classification of climate (Köppen 1954) and vegetation (Rübel 1936).

Summaries of climatic data from permanently established weather stations are usually presented in ecological descriptions. In this section, little attention is given to this practice because: (1) climatic records are unavailable for most mountain areas in British Columbia; (2) long-term measurements taken at lower elevations are not applicable to higher areas.

In this thesis, climatic data are discussed from only two temporary stations, one in the lower subzone at 3200 feet on Mount Seymour, and the other in the upper subzone at 4000 feet (see Map, Figure 23). The 12-month period from August 1, 1960 to July 31, 1961 was chosen to represent snowfall, temperature and humidity conditions at these two locations. Most attention is given to the development of a method which uses published radiosonde data to indicate the frequency of freezing temperatures at various altitudes.

a. Precipitation

Landsberg (1958) pointed out that early workers believed precipitation to increase uniformly to the tops of mountains, at least up to 10,000 feet. The increase in total annual precipitation up the slope of the mountain north of Burrard Inlet is clearly shown by the figures below (data from The Climate of British Columbia, Report for 1960):

Station	Altitude, feet	Total Prec., inches
North Vancouver (Norgate)	15	68.75
North Vancouver (Hollyrood)	600	74.52
North Vancouver (North Lonsdale)	950	81.58
North Vancouver (Mosquito Creek)	1130	99.01
Mount Seymour	2700	103.66
Hollyburn Ridge	3120	106.66

The relationship between annual precipitation at the foot of a mountain (P_o) to that at an elevation, h, (measured in 100-foot units) was expressed empirically by Landsberg (1958) as follows:

$$P_h = P_o + 0.72\ h$$

If Norgate data are applied to this formula, Hollyburn Ridge should have a total annual precipitation of about 91 inches. The discrepancy with actual measurements indicates that there may be anomalies due to topographic configuration and, more importantly, that there is not a straight-line relationship with increasing altitude. Walker (1961) discussed the limitations of upward extrapolation from stations at relatively low levels (as in Spilsbury and Tisdale's work, 1944). Spreen (1947) described a statistical method of relating precipitation to the slope and other characteristics of the terrain. However, this method requires a well distributed network of stations that is not available in British Columbia.

The main findings of a study by Walker (1961) are outlined in the following paragraphs because they represent the best information available for the Coastal Subalpine Zone. Specific estimates of precipitation over mountains were obtained by calculating the orographic component of precipitation along actual cross sections. These sections were used as interpolative guides and precipitation data were calculated from synoptic analyses which showed the amount of precipitation contributed by air-flows from different directions.

Walker's studies on the mechanism of precipitation indicated that the greatest precipitation occurs at cloud base. Frontal cloud systems give the bulk of the cold season precipitation and cloud bases during the heaviest rains average 4000 feet in coastal regions. In summer, convective precipitation is more important than precipitation from frontal systems. Again, maximum precipitation is probably near the base of cumuliform clouds, and Walker generalized by placing the summer level of maximum precipitation near

6000 feet on the southern coast of British Columbia. On the northern British Columbia coast, where frontal activity is frequent even in summer, the altitude of maximum summer precipitation is nearer 4000 feet.

There is a similar south to north gradient in the winter level of maximum precipitation. Since much of this winter precipitation occurs as snow, the altitude of heavy snow accumulation will be lower towards the north. This north-south gradient correlates with the northward altitudinal depression of mountain hemlock (Sudworth 1900, Hoffman 1912). The Coastal Subalpine Zone, which is defined by the altitudinal distribution of this species, is therefore similarly correlated with changes in the altitudinal level of heavy snow accumulations.

Comparisons of the altitude at which maximum precipitation occurs on coastal and interior mountains also explain why timberline is lower on the coast. Walker (p. 93) took into consideration that most precipitation fell from frontal cloud systems and placed the level of maximum precipitation at 4000 feet on the Coast for the whole year, but at 6000 feet in the Interior of the province. On the Coast there is a winter maximum in the precipitation regime so that much of the annual precipitation at the altitude of maximum occurrence will be in the form of snow. The result is an accumulation of snow at lower altitudes on the Coast than could be possible in the Interior, and the upper limit of forests is depressed.

Over the Coast Mountains, total annual precipitation in excess of 160 inches was calculated by Walker (1961) for 1956. Measuring stations are so scarce that similar amounts have not been actually recorded in the mountains. Walker (p. 90) gave the following monthly measurements at 3000 feet on Hollyburn Ridge, for a yearly total of 114.2 inches:

	J	F	M	A	M	J	J	A	S	O	N	D
Total ppt. inches	10.2	8.9	11.3	6.6	4.2	7.3	4.9	3.2	8.6	13.4	20.2	15.4

The regime above shows the winter concentration of precipitation which is largely in the form of snow. At 3120 feet on Hollyburn Ridge, the 7-year average for annual winter snowfall is 302.8 inches (Climate of British Columbia 1960). Winter totals from the Cascade Mountains where vegetation is similar to that in the Coastal Subalpine Zone show similarly large accumulations of snow. Freeman and Martin (1954) listed average winter totals of 400 inches at 3000 feet on Snoqualmie Pass, and 492 inches at 4400 feet near Mount Baker, both in the State of Washington. The maximum average snowfall recorded in the United States (575 inches) is from Paradise Ranger Station (5550 feet) in Mount Rainier National Park (Landsberg 1958).

In the present study, snow depth was recorded on upright graduated poles at weekly intervals. These weekly values of snow depth would not be the same as cumulative daily totals as recorded in permanent climatic stations. In the winter of 1960-61, maximum recorded snow depth was 175 inches at an altitude of 4000 feet on Mount Seymour but only 56 inches at 3200 feet (Figure 6). As expected, there is also a difference in duration of snow cover between the two stations. At 3200 feet the first snow was recorded on November 12, 1960, and, except for some snow-free patches in the last half of December and late January, there was complete snow cover until April 29. The last patches of snow were gone by May 29, to give a total of 199 days of snow cover. At 4000 feet a trace of snow on October 8 disappeared and the first permanent snow of the season was on October 29, 1960. The last patches disappeared by June 19, 1961 making the duration 234 days. These two examples are considered representative for the lower and upper subzones of this bioclimatic zone.

Data were used from laboratory information in Geology 412 at the University of British Columbia to show the relationships between seasonal precipitation, snow accumulation and stream discharge. The precipitation curve (Figure 5) is based on 33 years of measurements at an altitude of 583 feet in

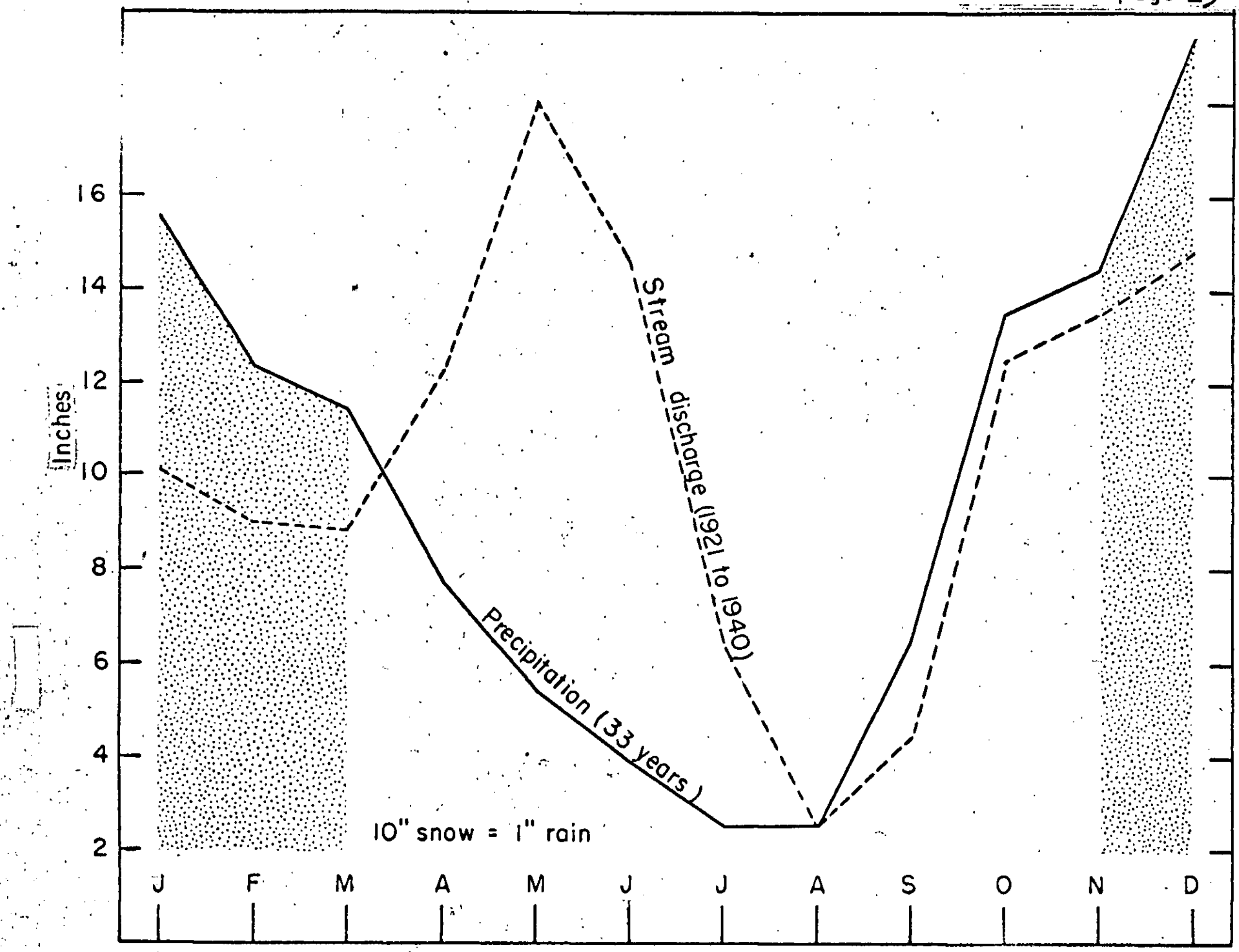

Figure 5. Monthly precipitation, including snow, at 583 ft. in Seymour Valley. Discharge is in equivalent inches for 47 sq.mile watershed. Stippling shows season of net increase in snow depth

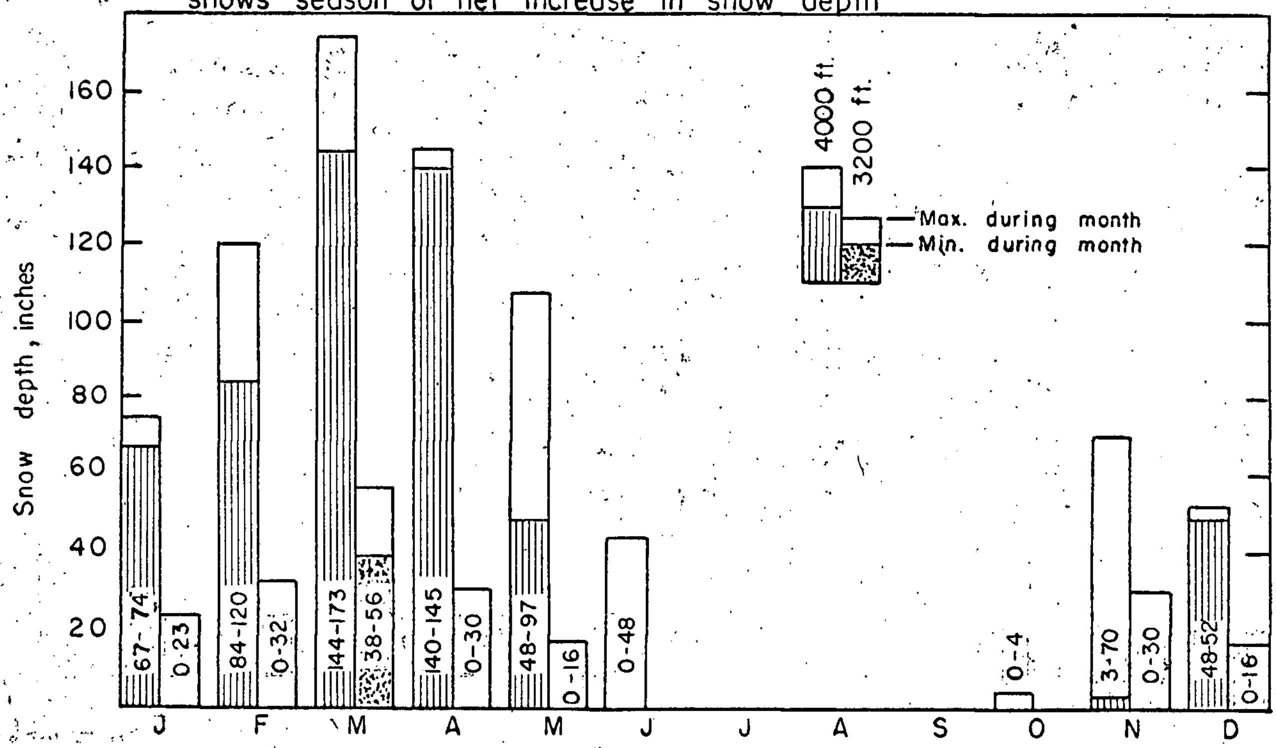

Figure 6. Monthly maximum and minimum snow depths for BP124 (4000 ft) and BP15 (3200 ft.) on Mount Seymour. 1960-61.

Seymour Valley. Average monthly stream discharge (cubic feet per second) for the Seymour River was theoretically converted to a uniform distribution over the entire area of the drainage basin by the formula:

$$\text{Equivalent depth in inches} = \frac{\text{Cu. ft./sec.} \times 60 \times 60 \times 24 \times 30 \times 12}{5280 \times 5280 \times \text{area in sq. mi.}}$$

For this particular watershed, months throughout a year may be placed in three categories: (1) months when there is a net increase in snow depth - November to March inclusive; (2) months when there is a net decrease in snow depth - April, May and June; and (3) months when little or no snow remains - July to October inclusive. These three periods are closely correlated with the monthly changes in stream discharge (Figures 5 and 6).

During the wettest months of the year most of the precipitation occurs as snow, and during the months when there is a net increase in snow there is an excess of precipitation over runoff because most of the snow is stored in the drainage basin (Figure 5). At the time of spring runoff, stream discharge in equivalent inches far exceeds precipitation. The excess of discharge over precipitation in July results from the melting of late snow-patches in the Subalpine Zone, even though the two stations represented in Figure 6 show no snow remaining in July, 1961.

The final feature of importance is the similarity in slope of the precipitation and discharge curves when snow is not involved as a storage factor. The normal increase in precipitation from August onwards is followed by a proportionate increase in stream discharge, until freezing temperatures and snow again hinder runoff. The secondary December peak in discharge is a result of heavy rains in the levels of the watershed which are below snow-line at that time of year.

The relationships described above indicate the necessity for knowledge of subalpine climatic and ecological conditions if water production and runoff control are to be considered in land management.

b. Humidity and Temperature

Stevenson screens were placed near ground level with the sensitive portion of the hygrothermographs 25 centimeters above the soil surface. During winter, the screens were mounted on trees so that they could be readily moved up or down with fluctuating snow levels. The station near 3200 feet (BP 15) was in a shaded mesic Vaccinium alaskaense association of the lower subzone. The station at 4000 feet (BP 124) was more exposed and was located in a lithic Cladothamnus association.

There are three distinct diurnal patterns of relative humidity throughout the year in the Subalpine Zone (Figures 7 to 10 inclusive). The first is the typical winter trace as shown by the first four days in Figure 7 and the entire week in Figure 8. During this season relative humidity may remain above 90 per cent for days at a time especially if cloud base is below the altitude of the measuring station. Eis (1962b) observed similar traces in lower elevations of the Western Hemlock Zone. Relative humidity in the Stevenson screen was often between 90 and 95 per cent even when it was raining. It rose to 100 per cent only in time of heavy dew or fog.

The second diurnal pattern of relative humidity occurs during clear summer weather. It is characterized by a very marked difference between day and night, as shown in the top trace of Figure 9. The daily range of relative humidity is greatest on the more exposed station at 4000 feet.

The third pattern is characterized by continuously low humidities and is associated with temperature inversions during the winter. The trace in Figure 10 shows humidities which are unknown at lower altitudes. Vancouver reported relative humidities of 100 per cent when they were as low as 10 per

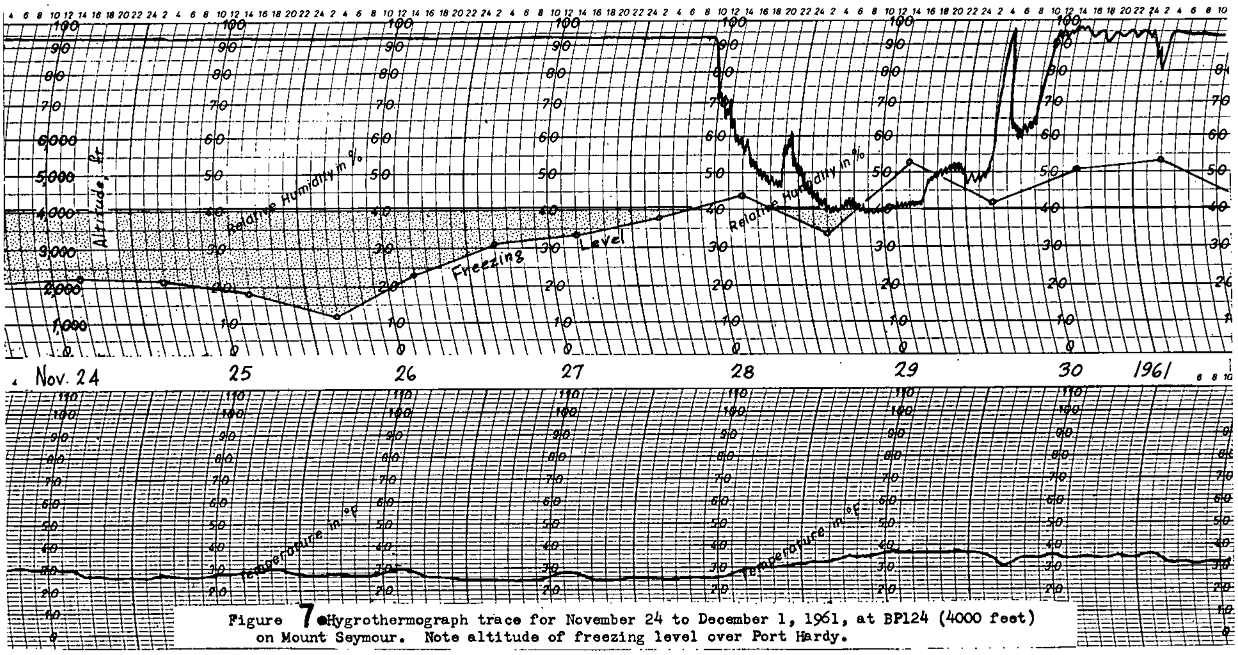

Figure 7. Hygrothermograph trace for November 24 to December 1, 1961, at BP124 (4000 feet) on Mount Seymour. Note altitude of freezing level over Port Hardy.

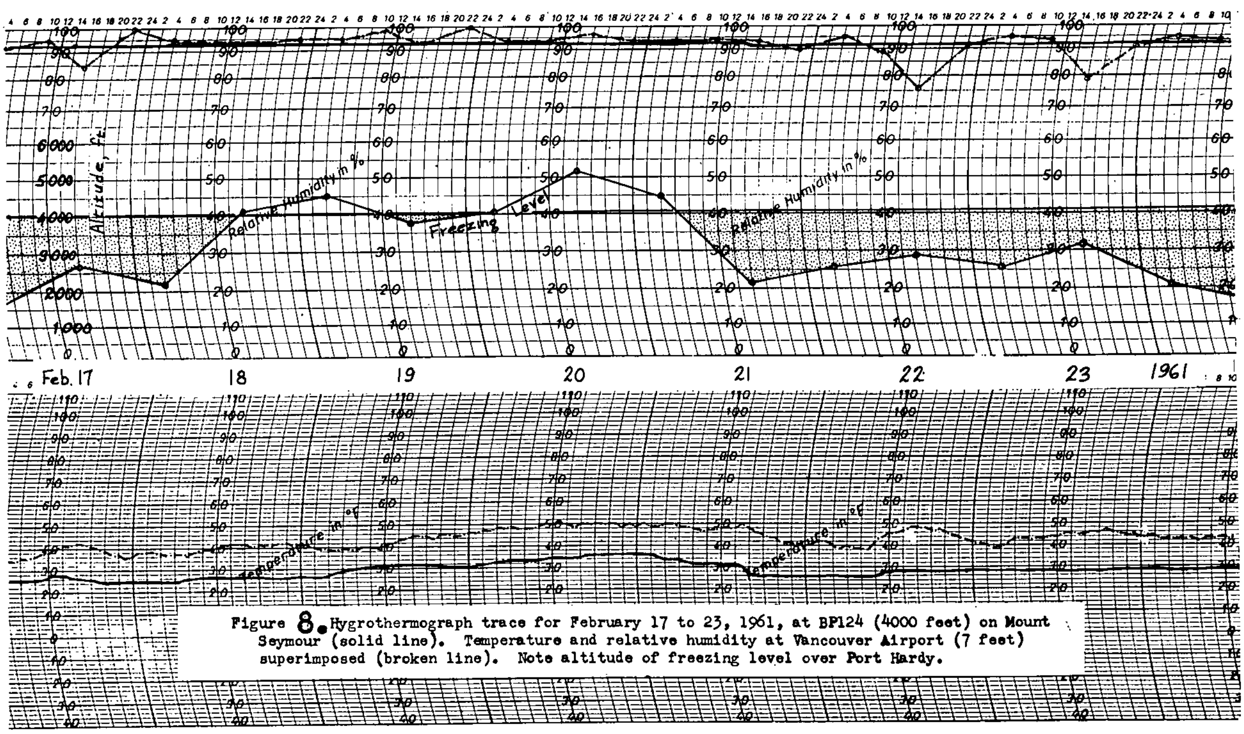

Figure 8. Hygrothermograph trace for February 17 to 23, 1961, at BP124 (4000 feet) on Mount Seymour (solid line). Temperature and relative humidity at Vancouver Airport (7 feet) superimposed (broken line). Note altitude of freezing level over Port Hardy.

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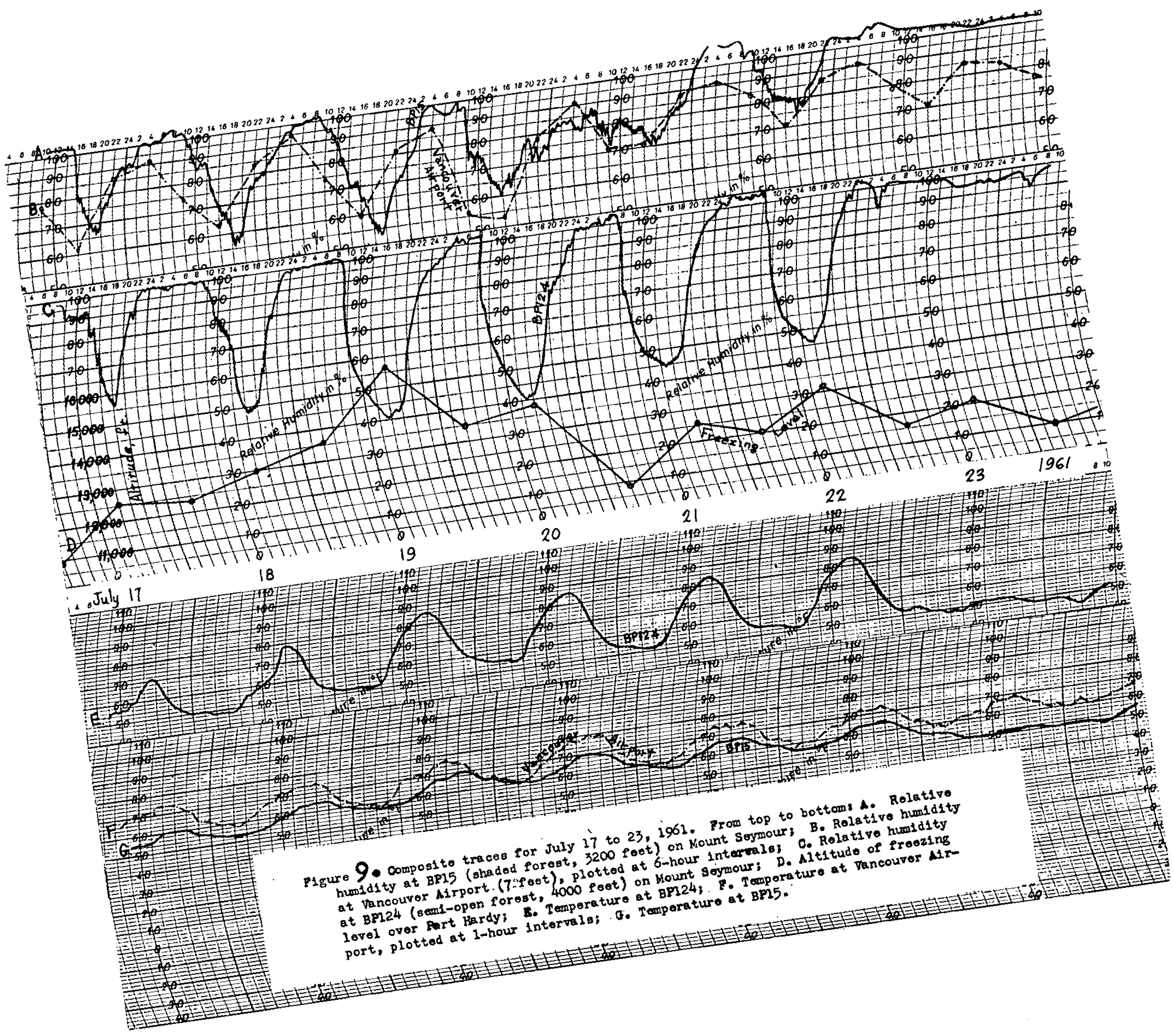

Figure 9. Composite traces for July 17 to 23, 1961. From top to bottom: A. Relative humidity at BP15 (shaded forest, 3200 feet) on Mount Seymour; B. Relative humidity at Vancouver Airport (7 feet), plotted at 6-hour intervals; C. Relative humidity at BP124 (semi-open forest, 4000 feet) on Mount Seymour; D. Altitude of freezing level over Port Hardy; E. Temperature at BP124; F. Temperature at Vancouver Airport, plotted at 1-hour intervals; G. Temperature at BP15.

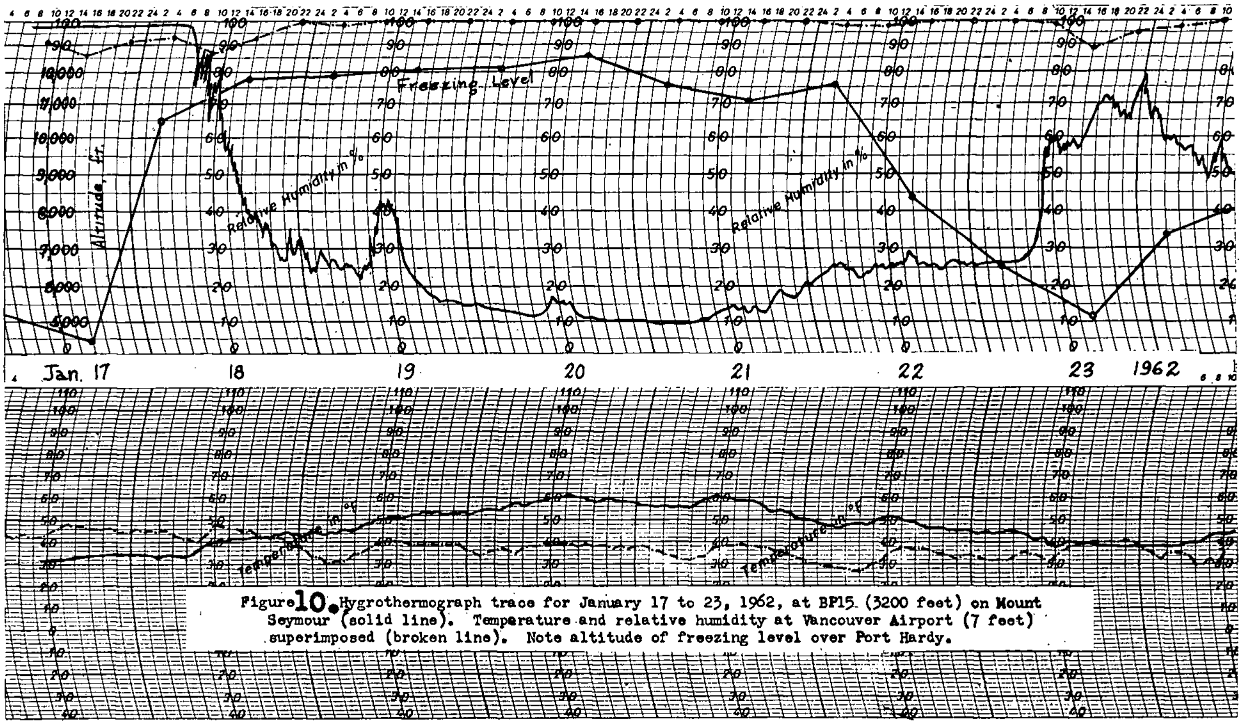

Figure 10. Hygrothermograph trace for January 17 to 23, 1962, at BP15 (3200 feet) on Mount Seymour (solid line). Temperature and relative humidity at Vancouver Airport (7 feet) superimposed (broken line). Note altitude of freezing level over Port Hardy.

cent at 3200 feet on Mount Seymour. From the evening of January 18 until January 23 it was foggy at Vancouver Airport, but continuously clear at higher altitudes on the mountains. Turner (1953) described similar periods of low humidity for south coastal British Columbia. They occur mainly when warm, dry tropical air overrides several hundred feet of cooler maritime air.

The great diurnal variations of relative humidity, particularly in the summer months, make average values relatively meaningless. To characterize humidity conditions at the two subalpine stations, a frequency distribution for 10 per cent humidity-classes was used (Figure 11). The original hygrothermograph sheets from a 12-month period were sampled by two-hour intervals. The humidity shown at every two-hour intersection along the trace was tallied in the appropriate 10 per cent class. By this method, 2504 readings were tallied for station BP 124 and 2687 for station BP 15 over the one-year period. The results were plotted on logarithmic paper so that the small frequency of low humidities could be shown. Figure 11 indicates the relative occurrence of the humidity features discussed in the preceding paragraphs. For example, humidities between 90 and 100 per cent occur more than 50 per cent of the time, and humidities less than 20 per cent occur approximately one per cent of the time. As expected, the shaded station showed a smaller frequency of humidities in the lower classes than the exposed station (BP 124).

During the periods of uniformly high relative humidity, temperatures do not vary more than three or four degrees daily and these uniform temperatures are common during much of the winter (Figures 7 and 8).

In clear summer weather, the diurnal variation of temperature is much greater on the relatively exposed station at 4000 feet (BP 124) than at sea level (Figure 9). Diurnal variation is much less in the shaded station at 3200 feet and it is a few degrees cooler than the sea level station at all times of the day. On a cloudy summer day (July 23, Figure 9) the great

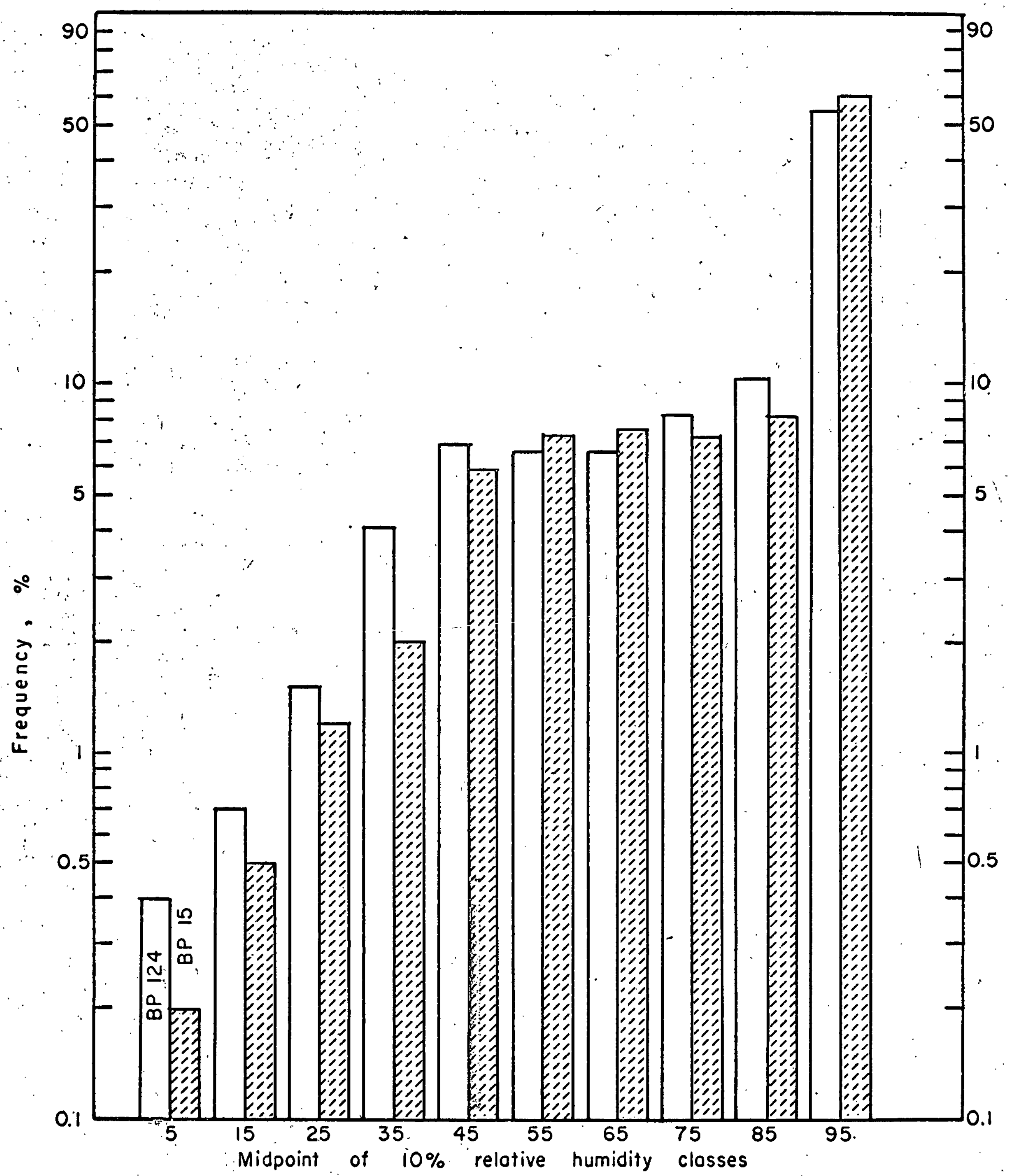

Figure 11. Frequency distribution of relative humidity by 10% classes for BP 124 (4000 ft.) and BP 15 (3200 ft.) on Mount Seymour. Aug. 1, 1960 to July 31, 1961.

differences in diurnal range between the shaded and unshaded subalpine stations are eliminated, and both of them are 10 to 15 degrees cooler than the station near sea level. The altitudinal gradient in temperature is best revealed during cloudy weather in winter; temperatures at 4000 feet are usually 15 degrees lower than those near sea level at this time of year (Figure 8).

During an inversion from January 18 to 23, 1962, temperatures at 3200 feet on the mountain were as much as 26 degrees warmer than those at Vancouver Airport (Figure 10). The freezing level at this time was over 11,000 feet which is a common summer position (compare to freezing levels for July 21 to 23, Figure 9). Such conditions are not common, but one or two invasions of warm, dry tropical air may be expected every winter. If the warm air mass remains over the mountains for several consecutive days, snow levels may be greatly reduced. The decrease in snow depth during December 1960 (Figure 6) resulted from a prolonged temperature inversion. There can also be inversions when there are outbreaks of continental Arctic air from the east. However, these are of shorter duration because of heating from below by water surfaces.

In all months, the mean temperatures are lower for mountain stations than for Vancouver Airport (Table II). The mean monthly temperature for January was less than the mean temperature for February at Vancouver Airport. In contrast, the January mean was considerably higher than the February mean at the mountain stations. This reflects the importance of temperature inversions during January. On the two mountain stations, the mean monthly minimum temperature was always lower at the relatively exposed station (4000 feet). The mean monthly maximum was higher at the 4000 feet station from June to October inclusive but the mean monthly temperature is higher at the upper station only during July, August and September.

Schmidt (1960) stressed that conventional methods of compiling meteorological data are of little use in relating climate to growth of trees, nor do

TABLE II

Summary of mean monthly, maximum and minimum temperatures for Vancouver Airport and for 3200 ft. and 4000 ft. on Mount Seymour. Aug. 1, 1960 to July 31, 1961

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Vancouver Airport (16 ft.):												
Mean monthly max.	68.5	63.1	56.7	48.3	44.3	45.5	47.9	51.6	54.3	61.5	70.4	73.9
Mean monthly min.	55.4	49.6	47.1	38.5	34.3	36.1	39.3	40.1	43.1	48.4	54.2	57.8
Mean monthly temp.	61.4	56.5	51.8	43.4	39.2	40.8	43.5	45.0	48.7	55.0	62.3	66.1
Mount Seymour (3200 ft.) BP15:												
Mean monthly max.	54.3	54.4	45.9	35.1	36.7	39.9	33.4	34.0	36.7	46.2	58.6	62.1
Mean monthly min.	47.2	46.9	40.2	31.4	31.3	33.7	29.0	28.9	31.7	39.0	48.6	53.1
Mean monthly temp.	50.7	50.1	43.0	33.2	34.0	36.8	31.2	31.4	34.2	42.3	53.6	57.6
Mount Seymour (4000 ft.) BP124:												
Mean monthly max.	59.8	62.6	47.6	34.6	36.3	39.0	31.3	32.2	35.3	44.6	61.5	72.4
Mean monthly min.	43.5	40.5	37.0	28.2	29.0	31.8	27.3	27.0	29.5	36.9	44.0	48.4
Mean monthly temp.	51.5	51.5	42.3	31.4	32.4	35.4	29.3	29.6	32.4	40.7	52.7	60.4

they provide a means of describing and classifying altitudinal climatic gradients. He recommended the use of accumulated temperatures on an hour-degree basis in relation to various threshold values.

Summaries of accumulated temperatures are presented in Table III to allow comparisons with other bioclimatic zones (Krajina 1959). Day-degrees above 43° F. were calculated from the difference between the daily mean temperature and 43° F., when the former was more than the threshold value. The annual number of day-degrees over 43° F. was 1486 at the shaded station (3200 feet), 1642 at the more exposed station (4000 feet), and 3264 at Vancouver Airport (16 feet). These compare with 1500-3000 for the Coastal Western Hemlock Zone and 2500-3500 for the Coastal Douglas-fir Zone (Krajina 1963). In this same table, the number of days with a mean temperature over 32° F. and the accumulated day-degrees over 32° F. are also shown. With 32° F. as the threshold value, the shaded station at 3200 feet was slightly warmer than the higher station, whereas the opposite was true when 43° F. was used as a threshold value.

Hour-degrees as recommended by Schmidt (1960) may be measured by a planimeter on thermograph sheets, or by taking direct hourly readings from the trace and relating it to the threshold value. The latter method was used here but readings were taken only every two hours as recommended by Landsberg (1958, p. 149). Because of its direct relationship to snow accumulation, 32° F. was chosen as the threshold value. The results are presented in Table IV as hour-degrees over 32° F. for each month. The monthly values would not be directly comparable because the months vary in length and correction factors to obtain a standard month were applied. The magnitude of temperature decrease with increased altitude is shown by the station at 4000 feet which has less than half the hour-degrees over 32° F. recorded for Vancouver Airport. By this method, the 4000-foot station is cooler than that

TABLE III

Summary of day-degrees over 43°F. and over 32°F. for Vancouver Airport and for 3200 ft. and 4000 ft. on Mount Seymour. Aug. 1, 1960 to July 31, 1961

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Year
Vancouver Airport (16 ft.):													
No. days with mean temp. over 43°F.	31	30	31	15	8	12	15	23	27	31	30	31	284
Day-degrees over 43°F.	487	401	268	42	20	44	46	119	168	380	581	708	3264
No. days with mean temp. over 32°F.	31	30	31	30	30	31	28	31	30	31	30	31	364
Day-degrees over 32°F.	828	731	609	400	180	351	321	429	496	721	911	1049	7026
Mount Seymour (3200 ft.) BP15:													
No. days with mean temp. over 43°F.	28	29	16	2	2	5	0	0	0	14	27	31	154
Day-degrees over 43°F.	249	231	85	6	2	38	0	0	0	97	324	454	1486
No. days with mean temp. over 32°F.	31	30	31	20	22	23	11	16	23	30	30	31	298
Day-degrees over 32°F.	587	560	342	70	96	170	30	50	88	330	650	794	3767
Mount Seymour (4000 ft.) BP124:													
No. days with mean temp. over 43°F.	22	26	14	2	2	4	0	0	0	10	26	31	137
Day-degrees over 43°F.	292	265	94	11	4	37	0	0	0	80	317	540	1642
No. days with mean temp. over 32°F.	31	30	31	13	15	19	4	14	17	29	30	31	264
Day-degrees over 32°F.	609	587	312	51	65	144	13	30	60	274	637	880	3642

TABLE IV

Summary of hour-degrees over 32°F. for Vancouver Airport and for 3200 ft. and 4000 ft. on Mount Seymour. Aug. 1, 1960 to July 31, 1961

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Year
Vancouver Airport (16 ft.):													
Hour-degrees over 32°F.	21874	17631	14734	8250	5527	6773	5979	9679	11757	16966	21750	25088	166,008
* Corrected to std. month	21458	17878	14454	8366	5422	6644	6493	9495	11922	16644	22055	24611	
% of hrs. in month 32° or more	100	100	100	100	90.6	93.4	100	98.9	100	100	100	100	
Mount Seymour (3200 ft.) BP15:													
Hour-degrees over 32°F.	13744	13008	7840	1650	2146	4092	860	1476	2236	7836	15502	18679	89,069
* Corrected to std. month	13483	13190	7691	1673	2105	4014	934	1448	2267	7687	15719	18324	
% of hrs. in month 32° or more	100	100	99.7	64.4	70.2	75.0	35.1	53.2	73.1	98.1	100	100	
Mount Seymour (4000 ft.) BP124:													
Hour-degrees over 32°F.	13554	12298	5918	1186	2116	3702	388	814	1424	6470	14222	19352	81,444
* Corrected to std. month	13296	12470	5806	1203	2076	3632	421	798	1444	6347	14421	18984	
% of hrs. in month 32° or more	100	100	96.0	39.4	48.6	58.1	21.7	39.8	58.1	94.4	100	100	

* Standard month taken as 365/12 = 30.417 days. Correction factor for 28-day month = 30.417/28 = 1.086; for 30-day month = 1.014; for 31-day month = 0.981

at 3200 feet during every month except July, whereas in other methods of calculating accumulated temperature (Table III) this relationship was not always revealed so clearly. There is little doubt that the expression of data by accumulated hour-degrees is more accurate, although more time consuming.

When accumulated hour-degrees are related to snow accumulation at various altitudes, a lag in early spring warming is noted at the two subalpine stations (Figure 12). Particularly in March and April, the high albedo of snow surface prevents it from absorbing much heat. These relationships result in a marked reduction of the growing season at higher altitude.

Ecologists have used temperature data in many different ways in attempts to correlate it with plant life. Daubenmire (1938) and Kramer and Kozlowski (1960) criticized methods of correlating temperature summations with biotic features because it requires the assumption that each degree of temperature has the same significance. A further weakness is that interacting phases of climate tend to make isotherms impractical as guides to the distribution of vegetation (Kramer and Kozlowski 1960).

Degrees along a temperature scale may ordinarily be considered as a continuum as far as their direct influence on plant life is concerned. However, the physical changes which occur at the freezing point of water disrupt the temperature continuum at this point. This is especially significant in areas of high precipitation where freezing temperatures of a certain frequency will cause snow accumulations that greatly shorten the growing season for plants. For this reason, the remainder of this section is devoted to a determination of the frequency of freezing temperatures at various altitudes in the zone.

c. Freezing Levels

The hypothesis that radiosonde freezing level data could be used

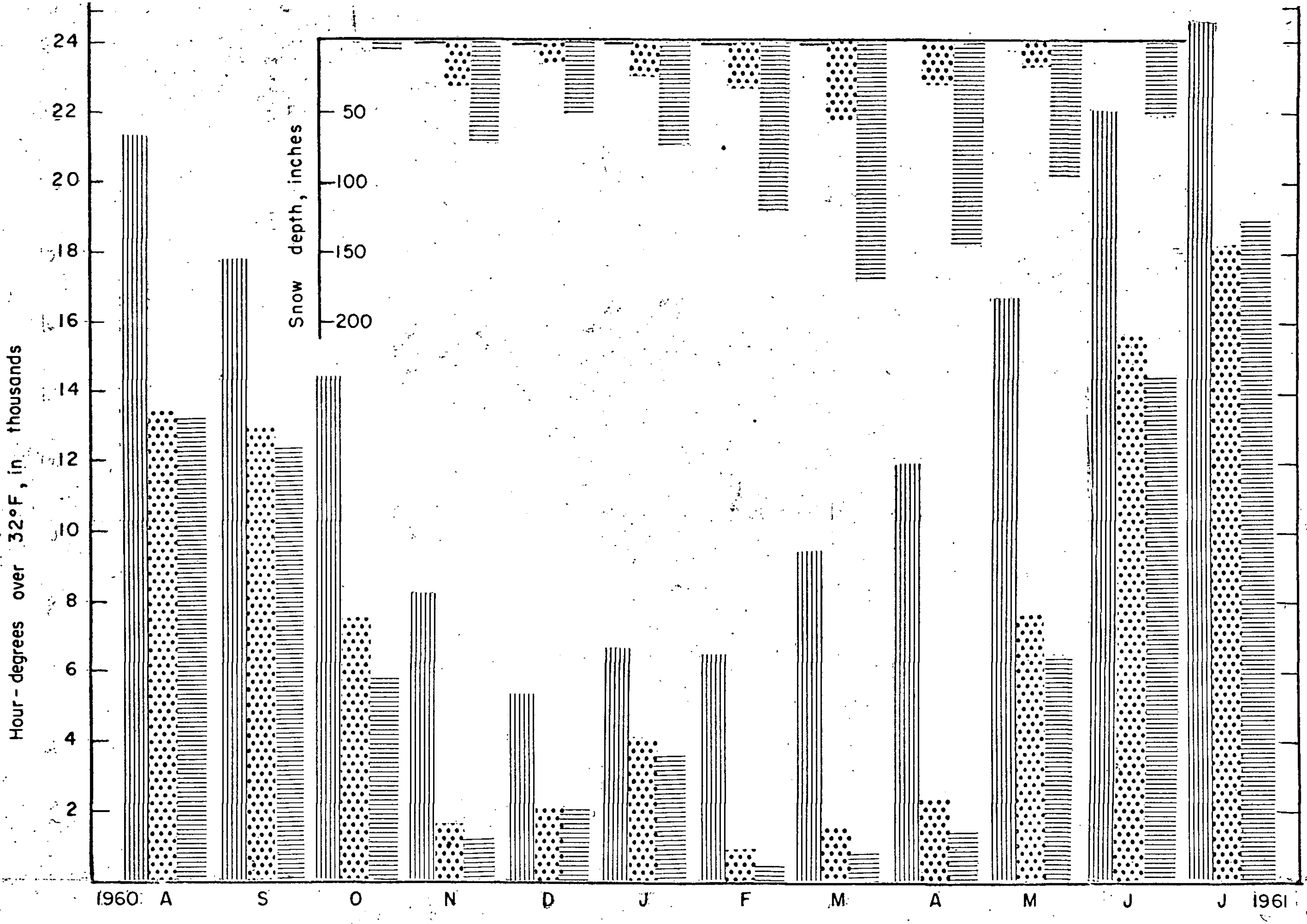

Figure 12. Relationship of accumulated temperature to snow depth for altitudes of 7 ft. (Vancouver airport - vertical bars), 3200 ft. (BP15 - dots), and 4000 ft. (BP124 - horizontal bars)

to follow page 34

to determine the frequency of freezing temperatures on a mountain slope was tested in several ways.

The nearest station from which readings were available was Port Hardy (Latitude 50°14' N, Longitude 127°22' W) 225 miles northwest of the study area. Daily readings at 4 p.m. (00:00 Greenwich Mean Time) and 4 a.m. (12:00 Greenwich Mean Time), obtained from a balloon ascent which records the altitude at which a freezing temperature is first encountered, are published as geopotential kilometers above sea level in the Monthly Bulletin Canadian Radiosonde Data.

Radiosonde readings were converted to altitude in feet and the values were plotted on the hygrothermograph sheets for the days shown in Figures 7 to 10 inclusive. Figures 7 and 8 are stippled when the freezing level was at 4000 feet or less on the basis of radiosonde readings. This stippling represents the time when the temperature should also be 32° F. or less at the same altitude (4000 feet) on a mountain slope if temperature measurement by atmospheric radiosonde methods are comparable with those obtained from a thermograph at a ground station.

From November 24 to 28, 1961, when the freezing level was below 4000 feet at Port Hardy (stippled area, Figure 7) temperatures were also below freezing at 4000 feet on Mount Seymour. When the level rose above 4000 feet over Port Hardy, a corresponding rise above freezing was shown at the 4000-foot mountain station. Even small fluctuations in the freezing level over Port Hardy coincide with changes in the thermograph trace on Mount Seymour, 225 miles away (see Figure 7, 4 a.m., November 30, 1961). Further relationships can be observed by study of the graphs in Figures 7 and 8, and even closer correlations could be expected if radiosonde data were available more frequently than every 12 hours. For comparison, the freezing levels for one week in the summer are shown in Figure 9, and the great change in freezing level during a winter temperature inversion is shown in Figure 10.

The selected examples (Figures 7 to 10) do not necessarily prove that the radiosonde readings can be used to characterize freezing levels on a mountain slope. For example, a weather front between Port Hardy and the local study area could disrupt freezing levels. Therefore, it was necessary to test the relationship over a period of time.

The monthly frequencies of temperature 32° F. or over at altitudes of 3200 feet and 4000 feet over Port Hardy, based only on radiosonde data, show a remarkable similarity to the same information for the same 12-month period based on thermograph data from stations at 3200 feet and 4000 feet on Mount Seymour (Figures 13a and 13b).

To test the relationship further, a Chi-square test of the frequency of freezing temperatures at 4000 feet or less over Port Hardy and at 4000 feet on Mount Seymour was carried out for the season when freezing levels could be expected to intersect the mountain-side (Table V). At the .05 level of probability, there is no significant difference in the frequency of freezing temperatures at 4 p.m. when the radiosonde and thermograph methods are compared. At 4 a.m. there is a significant difference because the daily minimum at the ground station occurs in the early morning as a result of nocturnal cooling. But this lack of agreement for the early morning readings is a result of the morning heat balance near the ground and is not necessarily dependent upon the atmospheric freezing level, nor does it reflect a fault of the proposed use of atmospheric radiosonde data. Both a.m. and p.m. radiosonde readings could be used, and the only weakness would be an underestimate of the frequency of freezing temperatures at ground level in the early morning.

The evidence above indicates that over a period of time the freezing isotherm will intersect a mountain-side at an altitude similar to that measured

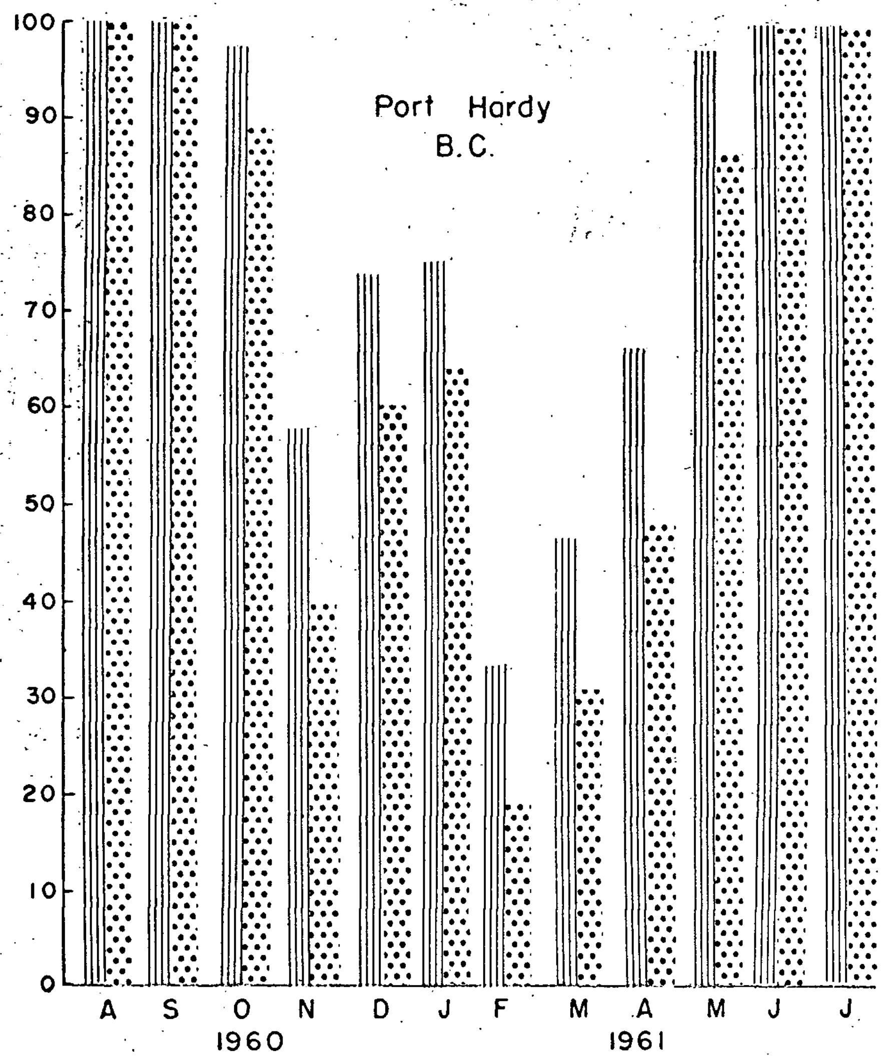

Figure 13a. Frequency of temperatures 32°F or over for 3200 ft. and 4000 ft. over Port Hardy, based on 679 radiosonde readings for each altitude.

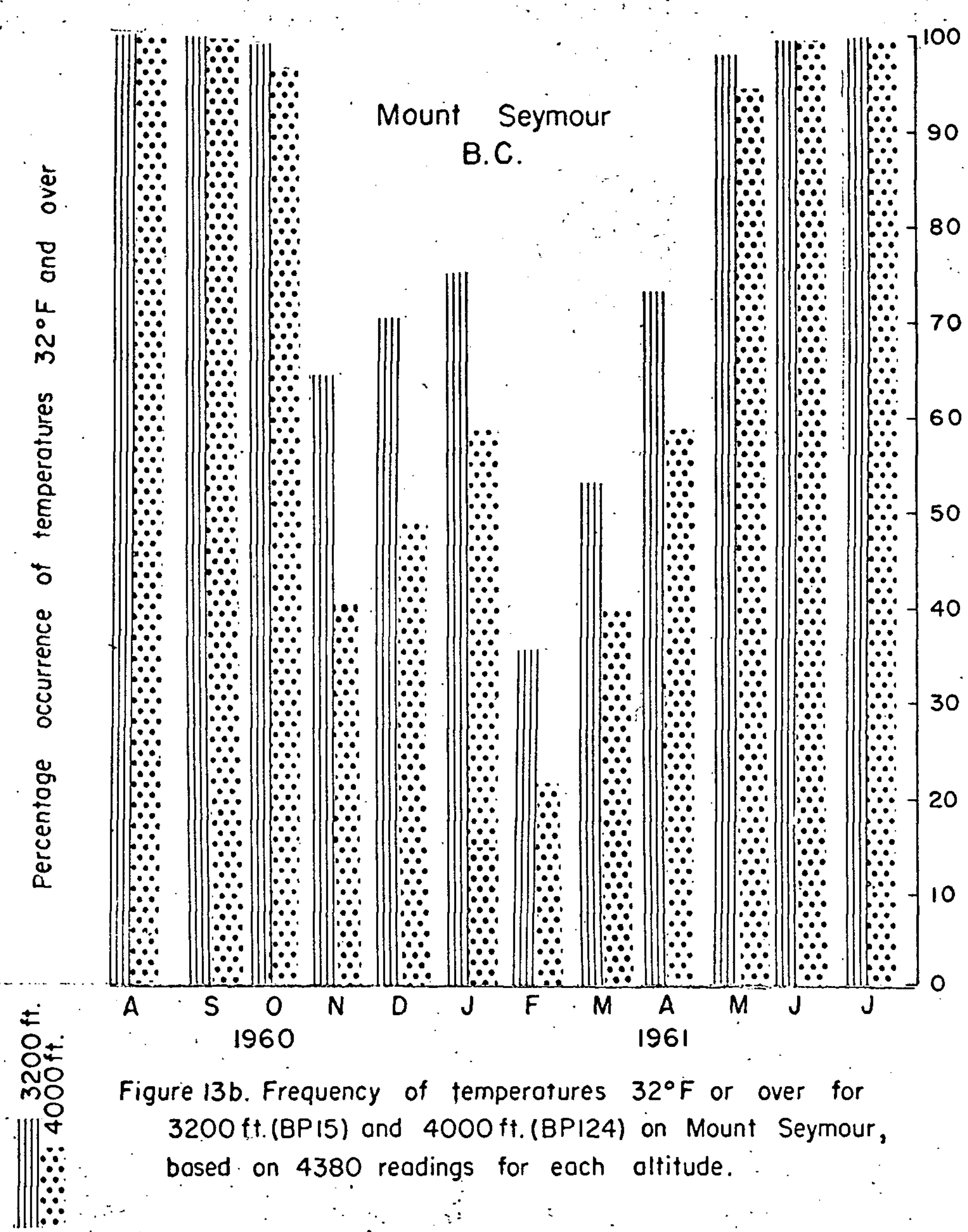

Figure 13b. Frequency of temperatures 32°F or over for 3200 ft. (BP15) and 4000 ft. (BP124) on Mount Seymour, based on 4380 readings for each altitude.

to follow page 36

TABLE V

Frequencies of freezing temperatures (4 a.m. and 4 p.m.) at an altitude of 4000 feet over Port Hardy and for the same altitude on Mount Seymour. Sept. 1, 1960 to May 31, 1961

4000 feet over Port Hardy			4000 feet on Mount Seymour		
	4 p.m.	4 a.m.		4 p.m.	4 a.m.
Freezing level 4000 feet or less	89	98	Temp. 31.5°F. or less at 4000 feet	99	123
Freezing level over 4000 feet	184	175	Temp. 31.5°F. or over at 4000 feet	174	150
Total	273	273		273	273

Tests of significance: ($P_{.05}$ for 1 d.f. = 3.84)

at 4 p.m. 0.81 = no significant difference
at 4 a.m. 4.75 = significant difference

some distance away. This will apply especially for relatively cold air masses, which are more affected by obstructing mountain ranges than are warm air masses; stable cold air may be slowed or even stopped in its movement by intercepting high mountains (Davis 1959, p. 138). Periodic discrepancies can be expected because it is known that during flight over mountains in cloudy weather, icing may occur at lower levels than in the same air mass over level country (World Met. Organ. 1960), and the presence of a weather front between the radiosonde station and the mountain in question could influence the altitude of the freezing level. Furthermore, evapotranspiration and other vegetational influences could affect the freezing isotherm. The forest cover on the 3200-foot station, in contrast to the openness at the 4000-foot station, would have some influence on the frequency of freezing temperatures (Figure 13b), but apparently none of these influences was important enough in the comparisons between Port Hardy and Mount Seymour to disrupt the close relationships

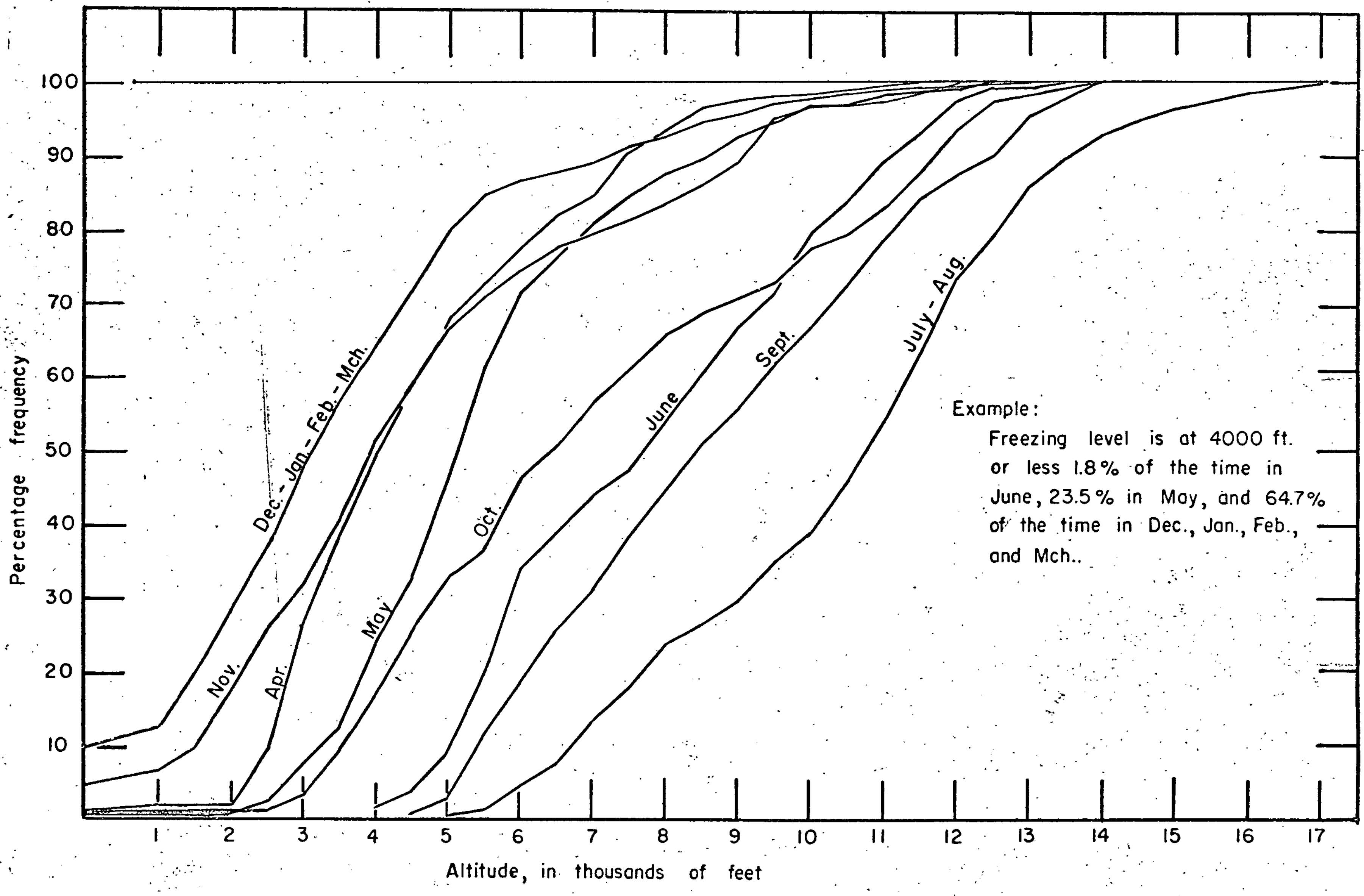

Figure 14. Cumulative percentage frequency showing occurrence of freezing level at various altitudes. Data from Port Hardy, B.C., Jan.1, 1959 to May 31, 1962.

to follow page 37

shown above. Therefore, it should be possible to determine from radiosonde data the frequency of freezing temperature for any period of the year for any altitude on a mountain-side.

Accordingly, a cumulative percentage frequency (ogive) curve was constructed for altitudes up to 17,000 feet (Figure 14). These curves are based on approximately 2400 published radiosonde readings from January 1, 1959 to May 31, 1962. In cases where the temperature was below freezing throughout the sounding, freezing level was tallied at the surface. In cases when there was a temperature inversion, the freezing level was not tallied at the ground level but at the altitude where a freezing temperature was again recorded. The results were plotted by months, but where two or more months showed a similar frequency distribution they were grouped. The curves are similar to those published by the U. S. Navy (1956) and have a number of useful applications. They allow determination of the frequency of occurrence of the 32° F. isotherm above or below any given altitude. There are two ways to read the graph: if freezing level is equal to or less than 3000 feet in 32 per cent of the observations during November, then obviously it is above 3000 feet during 68 per cent of the observations.

There is a great altitudinal lowering of the freezing isotherm from November to May inclusive (Figure 14). The curves also rise more sharply during these months, particularly within the altitudinal limits of the lower subzone. This means that a small increase in altitude in the lower half of the Subalpine Zone will be associated with a relatively large increase in the frequency of freezing temperatures during the winter months (Figure 15a).

To construct the histograms in Figure 15, an altitudinal range which would include all mountains in the study area was selected (0 to 11,000 feet). From a large-scale reproduction of Figure 14, the frequency of freezing temperatures for each month were tallied for every 500-foot altitudinal class.

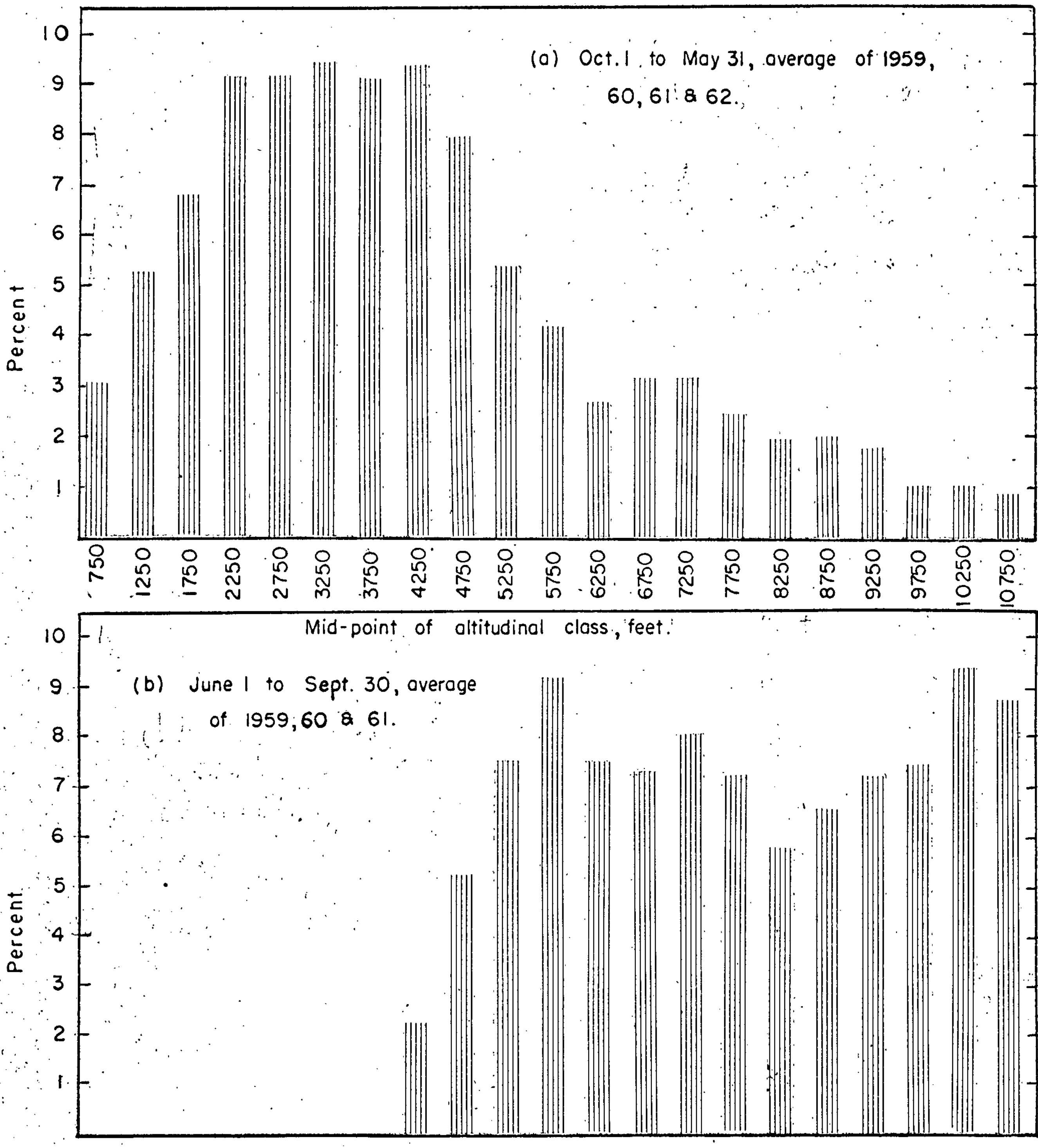

Figure 15. Percentage increase in the frequency of freezing temperatures for each additional 500 ft. rise in altitude from 500 to 11,000 ft. above m.s.l., for (a) "winter" and (b) "summer". Data from Port Hardy, B.C.

Months during which snowfall normally occurs in the Subalpine Zone were grouped as "**winter**" months (October to May inclusive) and the remainder were grouped as "summer" months. Freezing temperatures which were recorded at zero altitude in Figure 14 were excluded in the computation for Figure 15 because they were mainly ground frosts and were not directly related to an altitudinal analysis of freezing levels. Therefore, the 500 to 1000 ft. altitudinal class is the first one shown in Figure 15. The bars are plotted at the mid-points of the classes, and each bar shows the percentage increase in the frequency of freezing temperatures that could be expected for each additional 500-foot rise up a mountain-side. The bars are additive to 100 per cent, but this does not mean that the freezing level is below 11,000 feet 100 per cent of the time (Figure 14 shows that it is not). Percentages refer only to the particular altitudinal range that was chosen. The summer values are presented only for comparison and are of little importance since the freezing level is usually above the Subalpine Zone during these months.

The 32° F. isotherm most frequently occurs between 2250 and 4250 feet in the period from October 1 to May 31 (Figure 15a), and in many individual months the modal occurrence of the freezing level was observed to be in the 3250-foot altitudinal class. The concentration of winter freezing levels in this altitudinal range coincides with the sharp increase in snow accumulation at this level on the mountains of the study area. At 3000 feet approximately 33 per cent of the observations from October 1 to May 31 indicate temperatures at or below freezing (summation of the first five bars in Figure 15). This is sufficient to maintain a snow cover that greatly shortens the growing season. The rapid increase in the frequency of freezing temperatures up to the 4250-foot class accounts for the 117-inch difference in maximum snow depth between the 3200 and 4000-foot stations (Figure 6). This is the main climatic difference of the two floristically distinct subzones of the Subalpine Zone.

D. The Vegetation

In this section, the floristic features which identify the Subalpine Mountain Hemlock Zone and which distinguish within it two altitudinal

TABLE VI

Vegetational characteristics of the Subalpine Zone

Character species for entire zone	Differentiating species for lower subzone	Differentiating species for upper subzone
ON MESIC HABITATS	ON MESIC HABITATS	ON MESIC HABITATS
Abies amabilis (low vigour)	*Tsuga heterophylla*	*Vaccinium deliciosum*
Tsuga mertensiana	*Menziesia ferruginea*	*Cassiope mertensiana*
Vaccinium membranaceum	*Vaccinium alaskaense*	*Phyllodoce empetriformis*
Rhododendron albiflorum	*Vaccinium ovalifolium*	*Gaultheria humifusa*
Sorbus occidentalis	*Pyrola secunda*	*Luetkea pectinata*
Rubus pedatus	*Cornus canadensis*	*Saxifraga tolmiei*
Rhytidiopsis robusta	*Clintonia uniflora*	*Deschampsia atropurpurea*
Kiaeria blyttii	*Listera caurina*	*Hieracium gracile*
Orthocaulis floerkii	*Listera cordata*	
	Streptopus streptopoides	ON WET EDAPHIC HABITATS
ON WET EDAPHIC HABITATS	*Hypnum circinale*	*Salix commutata*
Abies amabilis (high vigour)	*Rhytidiadelphus loreus*	*Carex nigricans*
Chamaecyparis nootkatensis	*Lophocolea heterophylla*	*Carex spectabilis*
Valeriana sitchensis		*Caltha leptosepala*
Veratrum eschscholtzii	ON WET EDAPHIC HABITATS	*Erigeron peregrinus*
	Rubus spectabilis	*Hippuris montana*
ON DRY EDAPHIC HABITATS	*Athyrium filix-femina*	*Juncus drummondii*
Cladothamnus pyrolaeflorus	*Blechnum spicant*	*Leptarrhena pyrolifolia*
Lescuraea baileyi	*Lysichitum americanum*	*Parnassia fimbriata*
Pilophoron hallii	*Streptopus amplexifolius*	*Tofieldia glutinosa*
	Streptopus roseus	*Juncus mertensianus*
	Tiarella trifoliata	*Andreaea nivalis*
	Tiarella unifoliata	*Gymnomitrium varians*
	Mnium spinulosum	*Polytrichum norvegicum*
	Scapania bolanderi	
	Plagiothecium undulatum	ON DRY EDAPHIC HABITATS
		Saxifraga ferruginea
	ON DRY EDAPHIC HABITATS	*Luzula wahlenbergii*
	Goodyera oblongifolia	*Lycopodium sitchense*
		Cetraria islandica
		Cetraria stenophylla
		Crocynia membranacea
		Andreaea rupestris
		Grimmia alpestris
		Oligotrichum hercynicum
		Umbilicaria torrefacta

subzones are discussed. There is also an enumeration of species which occur sporadically within the zone, and finally some of the more important zonal influences on the vegetation are presented. The latter section deals with vegetation patterns, height growth of trees and relations of tree height to diameter with increasing altitude, the influence of snow on basal crook in tree stems, and relative turgidity measurements of amabilis fir and mountain hemlock needles from trees in the upper and lower subzones.

1. Zonal and Subzonal Floristic Features

The low forest productivity and the relative inaccessibility have helped to keep the vegetation undisturbed. There are no anthropogenous communities in the zone and few introduced species.

The zonal character species are shown for mesic, wet and dry habitats in the first column of Table VI. In addition, there is a tabulation of differentiating species for the lower and upper subzones. Many of the differentiating species for the lower subzone occur also in the Coastal Western Hemlock Zone at lower altitudes. But when they occur in combination with the zonal subalpine species of column one in Table VI, they can be used for differentiation of lower subalpine conditions.

Mountain hemlock is the most common large trees in the zone (Table VII). Of all trees measured on 71 forested sample plots, 46.7 per cent of the trees larger than the 10-inch diameter class were mountain hemlock, 38.4 per cent were amabilis fir and only 14.9 per cent were yellow cedar. Conversely, amabilis fir was the most abundant tree in the 10-inch class or less, followed by mountain hemlock and yellow cedar. Almost 70 per cent of the amabilis fir on the sample plots were in the 10-inch class or less, 67.0 per cent of the cedar, and 53.3 per cent of the mountain hemlock (Table VII).

Silvical characteristics of mountain hemlock were summarized by

TABLE VII

Proportion of species, size distribution, and frequency of basal snow-crook on 71 forested plots in the Subalpine Zone.

	Amabilis fir		Yellow cedar		Mountain hemlock		Total
	No.	%	No.	%	No.	%	
Trees 10" class or less	1054	51.4	360	17.6	634	31.0	2048
% of total for species	69.7		67.0		53.3		
Trees over 10" class	457	38.4	177	14.9	556	46.7	1190
% of total for species	30.3		33.0		46.7		
Total	1511		537		1190		3238
Trees 10" class or less with snow-crook	222		133		255		610
% of total possible	21.1		36.9		40.2		
Trees over 10" class with snow-crook	18		3		53		74
% of total possible	3.9		1.7		9.5		

Dahms (1958) and the 1962 review by Franklin collects many additional references for the species. Heusser's (1960) range map for mountain hemlock is the best available. Schmidt (1957) discussed the silvics and distribution of amabilis fir in detail, Dimock (1958) reviewed the silvical characteristics of the species, and Haddock (1961) recently published new information on the distribution of amabilis fir. Silvical characteristics of yellow cedar were discussed by Sudworth (1908), Betts (1953) and Andersen (1959).

As the zonal species in the study area, mountain hemlock grows on a wide variety of habitats. It can regenerate in dense shade, on decayed wood, or on humus. When it occurs in seepage habitats at lower levels of the zone, it is often confined to humps created by irregularities in the topography or by accumulation of organic matter; the species thrives on emminences of its own making. In the upper portions of the Subalpine Zone, ridges are the most podzolized areas and mountain hemlock is the most successful tree species there. Even on relatively bare areas, such as morainal surfaces, it will germinate and grow successfully. It is also the first tree species to invade the Phyllodoce - Cassiope heaths (see Plate I, F and Plate II, C), as discussed by Brink (1959). The sparsely distributed trees on the upper slope in Figure 3 and in Plate I, C are all mountain hemlock. It is clearly the zonal species for the area.

Amabilis fir and yellow cedar, which are both typical Pacific Coast elements (Porsild 1958), are strongly controlled by edaphic conditions. The most productive forest stands are on warm southwest slopes near the lower limits of the zone, and amabilis fir contributes the greatest volume on such stands (see Figure 25A - the typical subassociation of the Streptopus association, and Plate I, A). Amabilis fir is abundant in all layers because it is the most shade tolerant tree on the coast of British Columbia, and its best development is in seepage habitats where it even grows in depressions. When raw humus is thick, amabilis fir regeneration is far less successful than mountain hemlock.

Yellow cedar has a distributional range similar to mountain hemlock except that it is very uncommon in the Interior of British Columbia. However, on a local scale the two species have little in common; where mountain hemlock grows well, yellow cedar does not, and vice-versa. Yellow cedar has some features which adapt it well to subalpine climate conditions. For example, the drooping and vertically-disposed branchlets prevent great accumulations of snow in the crowns of this species. Nevertheless, it is at a disadvantage because it does not grow well on the very acid raw humus which covers so much of this zone. Its best development is on seepage slopes, often in combination with large amabilis fir (see Figure 25B, the degraded subassociation of the Streptopus association). The oldest tree found in this study was a recently-felled yellow cedar at 3500 feet on Mount Seymour. A count of rings on its stump showed that it was at least 800 years old, an indication that yellow cedar is highly resistant to decay. In the upper subzone, yellow cedar occurs as a gnarled shrub around isolated clumps of mountain hemlock (Plate I, D) or marginal to seepage and moor areas (Plate II, A).

A common feature of subalpine vegetation is the substitution of different species in a genus that is common in lower bioclimatic zones: as examples, Tsuga heterophylla is replaced by Tsuga mertensiana in the Subalpine Zone; Sorbus sitchensis by Sorbus occidentalis; and Vaccinium parvifolium by Vaccinium alaskaense.

2. Sporadic Species in the Zone

Western hemlock (Tsuga heterophylla) is common up to 3200 feet on Mount Seymour and up to 4000 feet on Paul Ridge. It is the most common low-elevation tree species in the zone. Tolerance to podzolization and raw humus allows its growth in subalpine areas in contrast to Douglas-fir (Pseudotsuga menziesii) or western red-cedar (Thuja plicata). The latter species is restricted to moist edaphic habitats at lower altitudes, and in comparable subalpine habitats it is replaced by yellow cedar. Western red-cedar shows little frost resistance so its occurrence in the study area was limited to the lower Lysichitum sites at 2900 feet on Hollyburn Ridge. Taxus brevifolia, another sporadic species in the Subalpine Zone, occurred with western red-cedar on the same site.

Western white pine (Pinus monticola) is very sporadic in the zone and the largest tree was found in a moist Lysichitum association. Stunted individuals of white pine occur on exposed rock outcrops but the species is rapidly being reduced in abundance, mostly through the action of white pine blister rust. Dead trees of the species are common. On Hollyburn Ridge at 3200 feet, 14 dead standing white pines were counted on a 1/2-acre portion of a Cladothamnus ridge.

Lodgepole pine (Pinus contorta) occurs on exposed rock outcrops near The Lions and has been reported on the top of Crown Mountain (Krajina, personal communication), but it is otherwise very rare in the zone. Whitebark pine (Pinus albicaulis) was seen at Garibaldi Lake, north of the study area. Alpine fir (Abies lasiocarpa) occurs at the tree-line near Diamond Head and in the Eenostuck Meadows. These locations extend the range of alpine fir to the west slopes of the Coast Mountains where it had not previously been mapped by Alexander (1958). The only other sporadic tree species in the zone is Sitka spruce (Picea sitchensis) on the subalpine Oplopanax association at 3760 feet above sea level (Paul Ridge). This is an important extension of its recorded altitudinal range since Ruth (1958) stated that it was not recorded above 2500 feet in southern British Columbia. As expected, many of the low elevation species which reach their upper limit in the Subalpine Zone occur there in much reduced vigor (see site indices for western hemlock in Table XII, Chapter VI).

Lonicera utahensis, which is a common shrub at lower elevations in the Interior of British Columbia, occurs at 3700 feet on Paul Ridge, and Letharia vulpina, a lichen commonly associated with the Interior Douglas-fir Zone (Brayshaw 1955), was found on dead branches of yellow cedar at 4600 feet on the same mountain. Other interior species which were collected in the Coastal Subalpine Zone are Saxifraga lyallii and Habenaria dilatata. The most important Arctic-Alpine elements (Porsild 1958) sporadically present are: Empetrum nigrum, Vaccinium uliginosum, Epilobium latifolium, and Oxyria digyna. Cladonia pacifica, which Ahti (1961) described as a lowland species, was collected far above its normal altitudinal range at 4390 feet near The Lions.

3. Zonal Influences on the Vegetation

a. Patterns in the Vegetation

Two levels of vegetational zonation must be recognized. Bioclimatic

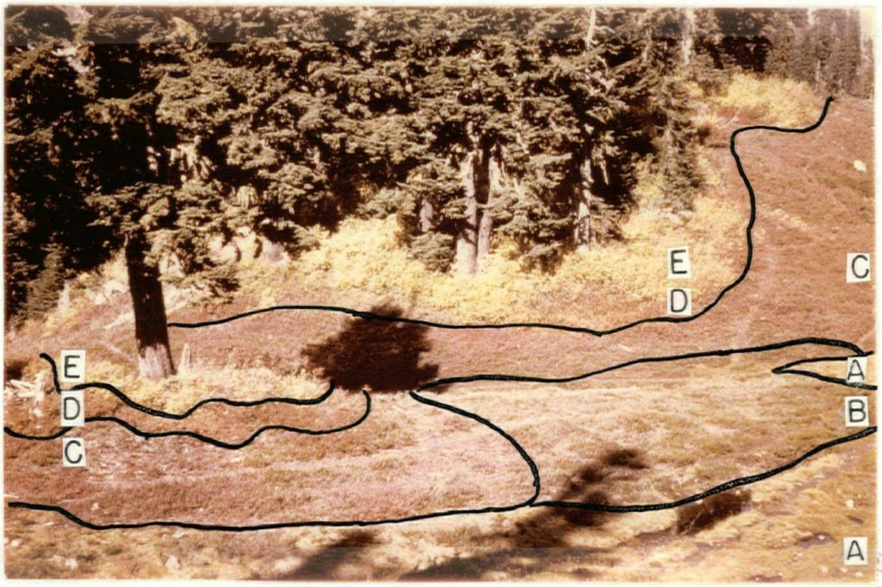

Figure 16. Biotic zonation associated with decreasing snow duration from A to E. The dominant species in each band are: A, Carex nigricans; B, Phyllodoce empetriformis and Cassiope mertensiana; C, Vaccinium deliciosum; D, Vaccinium membranaceum; E, Rhododendron albiflorum and Tsuga mertensiana.

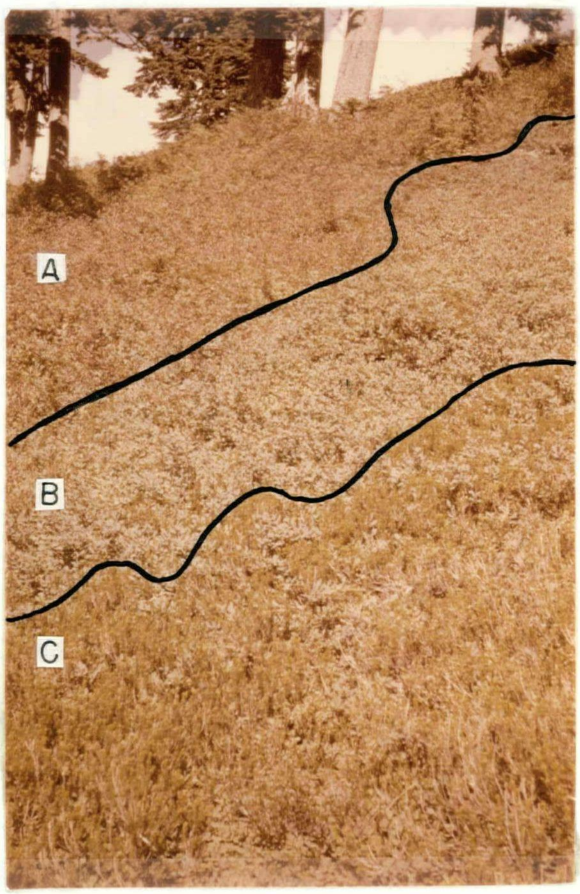

Figure 17. Closer view of zonation parallel to a clump of Tsuga mertensiana. A, Vaccinium membranaceum; B, Vaccinium deliciosum; C, Phyllodoce empetriformis and Cassiope mertensiana.

Figure 18. Small-scale vegetation patterns controlled by duration of snow. Phyllodoce empetriformis and Cassiope mertensiana occur beneath these late snow-banks. 4400 feet, July 13, 1961.

zonation has already been discussed; it is the basis for the recognition of a distinct Coastal Subalpine Zone. However, within the zone, vegetation patterns are influenced by environmental gradients to give small scale biotic zonation, as shown in Figures 16 and 17. Irregular topography allows uneven accumulation of snow and in Figure 16 the snow remains longest in the depression at the right. The sequence of decreasing snow duration from the depression to the edge of the trees on the slope results in biotic zonation. Each zone has distinct dominant species and the boundaries are sharp. Figure 17 is a closer view of this zonation parallel to a group of trees. Proof that these small-scale vegetation patterns are closely correlated with the duration of snow is given in Figures 18 and 19. Note how closely the dark green patches of Phyllodoce empetriformis and Cassiope mertensiana match the last patches of snow in Figure 18. The aspect of a slope may cause similar differences in vegetation through differences in snow duration. In Figure 19, snow had disappeared from the warmer southeast slope of a ravine by July 13. A distinct association of dwarf mountain hemlock was established on this slope. On the

Figure 19. Dwarf mountain hemlock established on warm southeast slope of ravine where growing season is longer. One to three feet of snow remain over the Phyllodoce - Cassiope area on northwest slope, July 13, 1961, 4300 feet.

opposite northwest slope, where one to three feet of snow remained, an association of Phyllodoce and Cassiope was present. On certain aspects, the steepness of the slope may also influence snow duration and vegetation. The well developed Phyllodoce - Cassiope association shown in Plate II, D was on a 14 degree southeast slope, but not far below where the slope steepened to 36 degrees clumps of mountain hemlock surrounded by Vaccinium membranaceum were developed. The steeper slope was more at right angles to the sun's rays and the increased insolation would lengthen the growing season sufficiently to allow the establishment of mountain hemlock. The more heavily forested slope in the center of Plate III, A (Appendix IV) shows a similar phenomenon. Snow measurements showed that this southwest slope was free of snow a month before the surrounding Phyllodoce - Cassiope areas where trees are much more sparse. These examples clearly indicate the influences of topography, slope and aspect.

The distinguishable vegetation units shown in Figures 16 and 17 do not occur only as narrow bands along sharp environmental gradients. In places where changes in snow duration are more gradual, the units may cover larger areas. It was in such areas that sample plots were located for floristic analyses. The zones shown in the photographs above were too narrow for sampling by plot but their relative position along an obvious gradient of snow duration provided useful information which would have been less detectable where the associations cover broader areas.

A characteristic of the upper subalpine region is the isolated clumps of trees. Shaw (1909) recorded similar features in the Selkirk Mountains, where the groups were mostly confined to spots where, from local contours, the snow had not accumulated so deeply. This is a possible explanation for the origin of such clumps. At present, many clumps are on ground no higher than the surrounding heath-like areas, but initially the trees must have established on higher points of morainal material which were the first to be free of snow. Subsequent smoothing of morainal surfaces by organic accumulations or by erosion could mask the small prominences on which the trees originally developed. Mountain hemlock is known to be a successful pioneer species on glacial moraines (Lutz 1930), and once it grew to a height greater than the winter snow level it could hasten the melting snow around the clump. Evergreen trees reflect only 7 per cent of the radiant energy which falls on them, whereas a fresh snow surface reflects from 80 to 90 per cent (Landsberg 1958, p. 122). A result is increased melting of snow near the isolated clump; this is in contrast to conditions under a closed forest canopy where shading delays snow melt. This influence on the ecoclimate is aided by interception of some snow by the tree's crown. When this snow melts and when it rains, the dripping also helps to melt the snow around the tree or clump of trees. The combination of these three factors creates openings as shown in Plate I, D. Thus the growing season may be one month longer in this band near the clump than it is just a few yards away in the heath-like area. As a result, zonation similar to that shown in Figure 17 occurs around every tree clump. The lengthening of the growing season near the tree clump also means that this is the only place where mountain hemlock has a chance to germinate; thus the clumps are self-perpetuating.

Wind is not a control of tree-line in this zone as it is in the Rockies (Daubenmire 1943). Mountain hemlock and alpine fir at their tree limit near Little Diamond Head in Garibaldi Park did not have asymmetric tops and they reached their greatest altitude on ridges where snow accumulation was less. Daubenmire (1943) and Shaw (1909) gave these as criteria of a snow-controlled upper limit. In contrast, where wind controls timberline the upper parts of the trees are asymmetrical and the highest occurrence is in the lee of obstructions or in sheltered valleys (Daubenmire 1943).

In sharp contrast to lower altitudes, the short subalpine growing season allows only two clearly marked seasonal aspects - a hibernal and an aestival. The seepage communities which have the highest number of herbaceous plants naturally have species with different antheses: for example, in the Lysichitum association Coptis asplenifolia flowers before any other species; and at higher elevations Caltha leptosepala and Leptarrhena pyrolifolia flower in late June but Parnassia fimbriata not until late August. However, the differences are insufficient to distinguish separate vernal and aestival aspects.

Along the margins of mountain streams or on slopes of abundant seepage certain species may transcend their usual altitudinal range (Table VIII). Alpine and subalpine species, such as Valeriana sitchensis, Parnassia fimbriata, and Senecio triangularis reach their lowest limits at 3000 feet on a very wet Lysichitum area and the low elevation species Thuja plicata, Taxus brevifolia and Maianthemum dilatatum reach their highest limits on the same area to give an unusual combination of species (Table VIII). These examples show that certain edaphic conditions can over-ride the influences of macroclimate and altitude. It is for similar reasons that large areas of "alpine meadows" extend

Table VIII Comparison of species in seepage communities by cover degree-abundance values and by characteristic cover degree. Plots are listed in order of increasing altitude from 700 feet in the Western Hemlock Zone to 4800 feet in the Subalpine Mountain Hemlock Zone. Values for plots E-95, E-58 and E-10 taken from Orloci,1961. See legend at bottom of next page.

		Vaccinium alaskaense - *Lysichitum* forest type													Leptarrhena - Caltha non-forest type of the Subalpine-Alpine transition Zone					
		West. Hemlock Zone				Subalpine Mountain Hemlock Zone													
Plot Number		E-95	E-58	E-10		BP-49	BP-126	BP-127	BP-128	BP-18	BP-41	BP-89		BP-88	BP-95	BP-79	BP-73	BP-70	
Locality ⊛		SC	H	SM		SM	H	H	H	SM	SM	RM		RM	G	RM	RM	RM	
Elevation (ft.) - hundreds		7	11	29		29	29	29	30	30	30	40		40	42	45	47	48	
Exposure		E	?	SE		SE	SW	SW	W	NW	SW	NW		SW	SE	SW	SW	NW	
Slope (degrees)		4	?	15		15	8	7	20	27	25	10		2	14	10	9	4	
Snow Cover (weeks),estimate		0	0	26		26	26	26	26	29	29	34		34	36	36	37	37	
% Cover, Layer A		75	50	30		80	75	60	80	45	55	30		-	-	-	-	-	
B		50	65	40		50	65	35	55	65	45	40		-	1	15	-	-	
C		95	55	80		60	65	65	65	65	75	70		90	95	98	85	85	
D		65	60	60		95	90	95	73	85	65	88		85	85	70	90	95	
LIST OF PLANTS ⊛⊛⊛	Sub-layer				Char. cov. deg.								Char cov deg						Char. cov. deg.
Layer A:																			
Picea sitchensis	1	+	+	+	-														
Alnus rubra	2		3		15														
" "	3		4																
Pinus monticola	1			+	-	+							-						
Thuja plicata	1	8	+		95				5 ⊛⊛				50						
" "	2	8	5						5										
" "	3	4	3						+										
Tsuga heterophylla	1		3		28		6	5	4	+			24						
" "	2	5	3	+		5	}2	+	+										
" "	3	5	5	+		7		+	5	1	1								
Abies amabilis	1				2		+				}4		19						
" "	2		3			+	}6		5	+									
" "	3	+	+	+		3		5	4		3								
Tsuga mertensiana	1			+	-	2	+	+	+	4	}4	}2	8						
" "	2					2	}2	+		+									
" "	3					2				4	4	4							
Chamaecyparis nootkatensis	1			+	-		6	5			}4	}5	30						
" "	2					4		5		1									
" "	3					5				+	3	5							
Layer B:																			
Gaultheria shallon	2	5	1		12														
Alnus rubra	1		3		5														
Oplopanax horridus	1	+	1		10														
" "	2	4	4																
Sambucus pubens	1		+		1														
" "	2		2																
Thuja plicata	1	4	1		7				1				-						
" "	2		3						1										
Taxus brevifolia	1	3			5				2				1						
" "	2								+										
Ribes bracteosum	1		+		-								-						
" "	2								+										
Rubus spectabilis	1	+	4		29								-						
" "	2		8	2		1			2	+	1								
Tsuga heterophylla	1	4	3	3	7	4	2	1	3	2	1		4						
" "	2			+		3	1	1	1	1	1								
Abies amabilis	1	3	+	+	5	2	4	5	4	3	4	3	13						
" "	2	4		2		4	3	3	2	3	2	1							
Vaccinium ovalifolium	2	2	+	4	4				1	1	2	3	1						
Vaccinium alaskaense	1				23				1				18						
" "	2	6	4	5		4	5	5	4	7	4	1							
Menziesia ferruginea	1								3				5						
" "	2					2	4	2	4	1	3	2							
Vaccinium membranaceum	2							+		1	2	2	-						
Cladothamnus pyrolaeflorus	1								+		+		2						
" "	2								1	+	3	-							
Sorbus occidentalis	1								+		+		-						
" "	2						+		1		2								
Tsuga mertensiana	1			+	-	4	1	2	4	2	4		5						
" "	2					2	+		1	2	2	2			+				-
Chamaecyparis nootkatensis	1			+	-	4	1	1	1	1	2	5	5			4			19
" "	2					1		1	1	+	1	5				3			
Rhododendron albiflorum	2											1	-			1			-
Salix commutata	2															1			-
Vaccinium deliciosum	2															1			-

Cont'd.

Table VIII Continued.	E-95	E-58	E-10	Char c.d.	BP-49	BP-126	BP-127	BP-128	BP-18	BP-41	BP-89	Char c.d.	BP-88	BP-95	BP-79	BP-73	BP-70	Char 6.d.
Layer C:																		
Lycopodium selago		1	+	-														
Circaea alpina		2		1														
Luzula parviflora		+		-														
Carex bolanderi	+	1	3	2														
Dryopteris austriaca	2	2	+	1														
Moneses uniflora			2	1														
Maianthemum dilatatum	5	2		13		+	1	1				-						
Viola glabella		1		-				4		2	3	5						
Linnaea borealis	+			-	3					+		2						
Galium triflorum		1		-				1				-						
Polystichum munitum							+					-						
Goodyera oblongifolia					+							-						
Rubus spectabilis						+		+		+		-						
Boykinia elata								+				-						
Athyrium filix-femina	2	1	1	1		+	2	2	+	4	3	3						
Tsuga mertensiana					+	2	2	1	1	1		-						
Listera cordata	+		1	-	+	+	+	+	+	+		-						
Tiarella unifoliata					+		1	3	+	2		1						
Tiarella trifoliata	4	2	3	5	1		1	3	1	+		1						
Gymnocarpium dryopteris		1	+	-		2		3	2	4	1	3						
Blechnum spicant	3	4	4	8	2	3	2	2	4	1		3						
Cornus canadensis	2		2	1	2	1	1	1	1	2		-						
Streptopus amplexifolius	+	+	2	-	1	+	+	1	3	1	2	1						
Rubus pedatus	2	+	4	4	4	4	4	2	4	3	1	7			+			-
Lysichitum americanum	9	7	7	65	6	5	7	7	6	7	5	38						
Streptopus roseus						1	2	2	3	3	2	2						
Streptopus streptopoides					2		1	2	1	2		-						
Coptis asplenifolia						4	4	3	2	2		5						
Carex laeviculmis					1		+	+	+	+	6	5						
Abies amabilis					2	2	2	1	1	1	2	-						
Veratrum eschscholtzii			2	1	2	1	1	1	3	4	3	3		+	5	+	+	6
Habenaria saccata	3			5			+	+	+	1	2	-	1					-
Clintonia uniflora			4	10	4	4	3	2	3	3	2	5						
Vaccinium sp.					3	1	1	1	1	2	1	1						
Menziesia ferruginea					+	1		+	+	2	+	-						
Chamaecyparis nootkatensis					+		1	1		1	2	-			1	+		-
Pyrola secunda			+	-	1			+				-						
Osmorhiza purpurea								+		1		-						
Trientalis arctica								1				-						
Lycopodium clavatum					+			+				-						
Nephrophyllidium crista-galli							2	2				1						
Epilobium alpinum			+	-						+	3	2		3	1	2	1	1
Melica smithii										+	+	-						
Saxifraga arguta								1			1	-						
Caltha leptosepala											5	25	6	5	4	6	5	25
Leptarrhena pyrolifolia										1	5	12	6	7	5	6	6	35
Juncus mertensianus											5	25	2	1		2		1
Habenaria dilatata											+	-	1					-
Equisetum palustre											5	25	5		7	3		27
Arnica latifolia										1		-			1		+	-
Senecio triangularis								1		1	3	1			4	3		7
Erigeron peregrinus										1	3	2	3	5	6	4	7	24
Carex spectabilis										+	1	-	4	3	4	+		6
Hippuris montana											1	-		1			2	-
Parnassia fimbriata								1		1	4	3	5	3	3	5		15
Mitella pentandra								1		+	1	-		1	1	1	1	-
Valeriana sitchensis								4		4	2	7	1	+	2	2		-
Agrostis aequivalvis										+	2	-	1	5		1		8
Petasites frigidus																3	+	2
Viola palustris													5		2			13
Tofieldia glutinosa													3		1			2
Carex nigricans													2	7	2	5	5	20
Calamagrostis canadensis													5					25
Veronica serpyllifolia														1		1		-
Deschampsia atropurpurea														2	1	+	1	-
Hordeum brachyantherum														3				5
Agrostis thurberiana															1		+	-
Salix commutata															4			10
Carex illota															2	+		-
Juncus drummondii																1	1	-

(✻) Legend: SC - Seymour Creek Valley; H - Hollyburn Mountain; SM - Seymour Mountain; RM - Round Mountain, Garibaldi Park; G - Grouse Mountain.

(✻✻) Tabular values refer to the cover degree-abundance symbols of the Domin/Krajina scale (+, 1, 2, ---- 10.)

(✻✻✻) Characteristic cover degree = total cover degree value divided by the number of plots on which species is present, expressed in percent.

well down into the Subalpine Zone, especially in moist edaphic habitats. For example, plot BP89 at 4000 feet (Table VIII), even though it is partially forested, is floristically closer to the Leptarrhena - Caltha leptosepala than to the Lysichitum associations of lower altitudes. This transitional plot is a good example to show that the Lysichitum habitat is occupied in the upper subzone of the Subalpine Zone by the Leptarrhena - Caltha association.

b. Altitudinal Influences on Trees

In this section there is a discussion of changes in height/diameter relationships with increasing altitude. An analysis of basal snow-crook in subalpine species is presented because of its possible applications to solifluction and snow-creep studies in the Subalpine Zone (Mathews and MacKay 1962). In the final part of the section, relative turgidity measurements which were taken on two altitudinally and ecologically distinct habitats are discussed.

Average maximum height of mountain hemlock is as great as 139 feet at the lower limit of the zone and as low as 71 feet near the upper tree limit (Table XII). In extreme cases height growth is only five feet in 100 years (Figure 20). For larger trees it was noted that the reduction of maximum height with increasing altitude was not accompanied by a proportionate reduction in maximum diameter at breast height. The result is a marked increase in taper of tree trunks. One way to express it is with an index that relates diameter and height (maxima) to one another.

Indices were calculated for the tallest mountain hemlock with an unbroken top on each of 44 sample plots on Hollyburn, Seymour and Grouse Mountains, with the following formula:

$$\text{Index} = \frac{D_{H\ max.}}{H_{max.} \times 12} \times 100$$

where, $D_{H\ max.}$ = d.b.h. of tallest tree, in inches

$H_{max.}$ = height of tallest tree, in feet

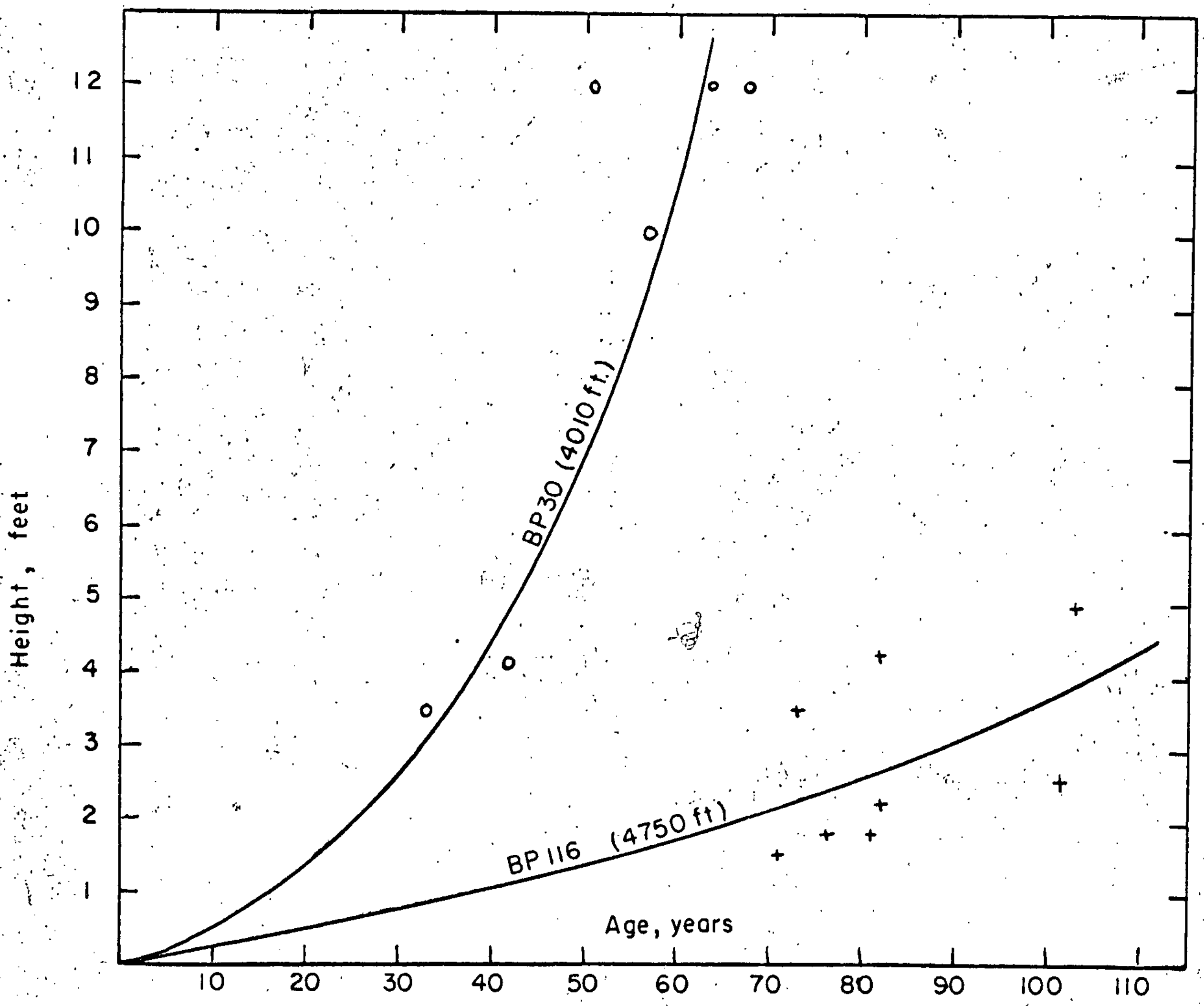

Figure 20. Height-age relationships for mountain hemlock on 2 "dwarf-hemlock" plots.

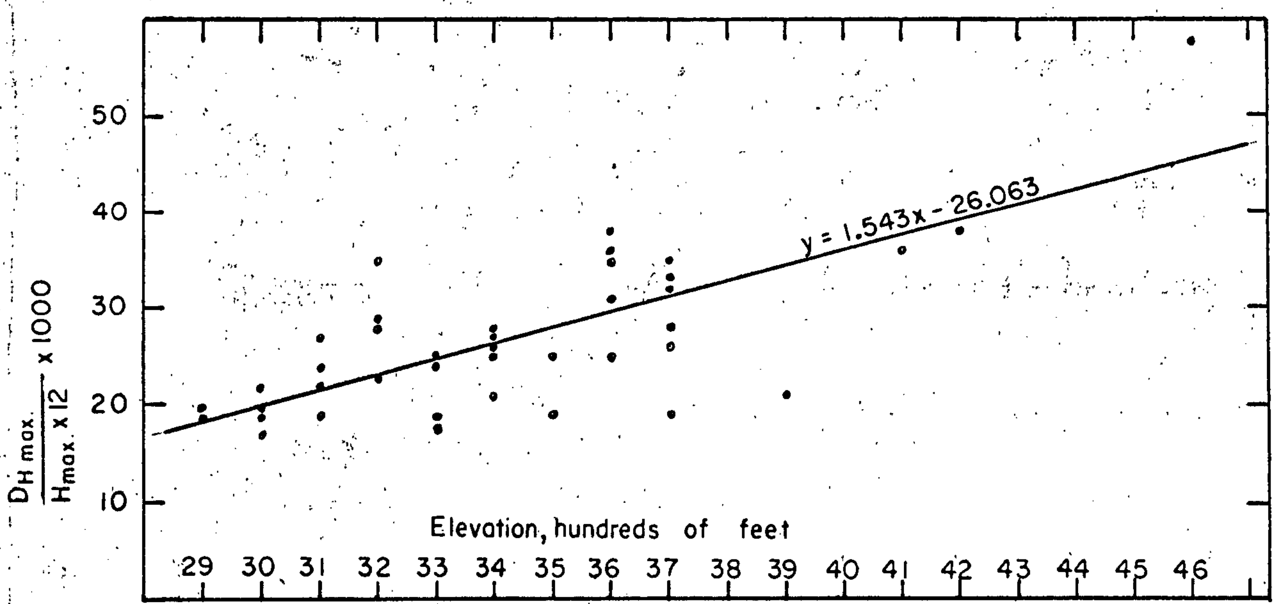

Figure 21. Change in diameter-height ratio (growth-form index) of mountain hemlock with increasing altitude. Based on 44 plots.

Mountain hemlock was chosen because it extended over the widest altitudinal range of the three subalpine species. It also showed the lowest percentage of wind-broken tops, even if it is the most common species in exposed habitats. To analyse the influence of altitude on the index, it was necessary to restrict the sample to the Seymour - Grouse - Hollyburn areas where the altitudinal range of mountain hemlock is similar. On Paul Ridge, the lower limit of mountain hemlock was nearly 1000 feet higher than in the Seymour area. Obviously samples from these two localities would need to be treated separately if elevation is being considered as an independent variable.

An increase in diameter-height index is shown for increasing altitude in Figure 21. The regression equation was calculated with elevation expressed in units of one hundred feet so that the index value on the y-axis has been increased by a factor of 10. The increased index value with increasing altitude is partially explained by characteristics of diameter growth in exposed trees. Baker (1950) stated that in exposed trees annual rings increase in thickness from the base of the crown downward, and in a study of wind sway Jacobs (1954) found that sway increased diameter growth of roots near the trunk and increased eccentric trunk development along the line of the main winds. Although winds are less frequent in coastal subalpine areas than in interior mountains (Daubenmire 1943), exposed trees at higher altitudes may have good diameter growth from the base of the crown downwards. Even near their upper limit, trees can have a large diameter at breast height far out of proportion to the total height of the tree. Studies of environmental and altitudinal influences on auxin balances within the trees would probably explain some of these relationships.

The weight and movement of snow on subalpine slopes greatly depresses the stems of shrubs and small trees. Plate III, B shows the force exerted on dwarf mountain hemlock by snow creep as late as July 7, 1962. These small trees can return to an upright position for only a short time each year. When they are tall enough to exceed the maximum winter snow depth, the upper trunk and crown will usually be upright, but a distinct basal snow crook remains as evidence of the great force of snow creep.

Basal snow crook has been mentioned only rarely in the literature, even if it is a common feature of subalpine trees. Sudworth (1918) recorded the phenomenon in mountain hemlock and Kienholz (1930) discussed anatomical features of wood from the base of "pistol-butted" trees.

When trees were measured in the present study, snow crook was recorded if it was noticeable. A summary of its occurrence on 71 forested sample plots is given in Table VII, page 42. For trees larger than the 10-inch diameter class, 9.5 per cent of the mountain hemlock had basal crook, 1.7 per cent of the yellow cedar, and 3.9 per cent of the amabilis fir. In the 10-inch class or less, 40.2 per cent of the mountain hemlock were affected, 36.9 per cent of the yellow cedar, and 21.1 per cent of the amabilis fir.

As Sudworth (1918) pointed out, subsequent growth fails to straighten entirely the bent stems, but the figures above show that the phenomenon is much less noticeable in older and larger trees. The frequency of snow crook is especially reduced for yellow cedar larger than the 10-inch diameter class. There are two probable reasons for this. First, the characteristic butt-swell at the base of large yellow cedar trees would obscure the earlier effects of snow crook, and secondly, most of the 177 trees measured in the larger diameter classes occurred in associations near the lower limit of the subalpine zone where the force of snow-creep would be less. Conversely, yellow cedar in the small diameter classes extends to higher elevations and a marked increase in the frequency of snow-crook is evident.

When the three subalpine species were compared, there was a very highly significant difference in the frequency of snow-crook. However, when only yellow cedar and mountain hemlock were compared there was no significant difference (Table IX). These relationships were examined further in an attempt to learn more about differences in species responses to great accumulations of snow. The Alwac III-E computer was used for a multiple regression analysis of seven independent variables on the percentage of trees exhibiting snow-crook. Details of the analyses are provided in Appendix II, but the main findings are summarized below.

The regression analyses were carried out with the standard S-7.1 programme which provided a stepwise reduction analysis. This gave an indication of the relative importance of each independent variable. Amabilis fir was treated separately since it showed the effects of snow-creep much less than the other two species. The independent variables in decreasing order of importance for amabilis fir were: steepness of slope, total basal area on plot, length of slope above, percentage cover by the tree layer (crown closure), snow duration, altitude and aspect. The coefficient of determination (100 R^2) for all variables was 53.9 per cent. Only the first two variables were significantly correlated with the percentage of trees showing snow crook; steepness of slope at the .01 level of probability, and total basal area at the .05 level.

For mountain hemlock and yellow cedar, decreasing order of importance for the same variables was: steepness of slope, elevation, length of slope above, aspect, percentage cover by the tree layer, snow duration, and basal area. In this case the coefficient of determination for all variables was only 42.3 per cent, and steepness of slope was the only variable significantly correlated with the percentage of snow crook (.01 level of probability).

The results indicate some weaknesses of such a multiple regression stepwise analysis. One fault in the above analysis is that some independent variables were inter-related (snow duration, aspect and elevation; or basal

TABLE IX

X^2-test of differences in frequency of basal snow-crook in three tree species for 10-inch class or less on 71 sample plots.

	Amabilis fir	Yellow cedar	Mountain hemlock	Total
Trees with crook	222	133	255	610
Trees without crook	832	227	379	1438
Total	1054	360	634	2048

$X^2 = 99.77$ = very highly significant.
(for 2 degrees of freedom, $X^2 = 5.99$ at the 5% level)

	Yellow cedar	Mountain hemlock	Total
Trees with crook	133	255	388
Trees without crook	227	379	606
Total	360	634	994

$X^2 = 1.04$ = not significant.
(for 1 degree of freedom, $X^2 = 3.84$ at the 5% level)

area and per cent coverage by the tree layer). When a regression is applied to such a complex of factors, the variance due to the complex is attributed to several factors, none of which can appear significant precisely because of the intercorrelations within the group of factors (Canada Department of Forestry 1961).

In addition, the relationships between many variables are non-linear. For example, the length of slope in the analysis above should probably not be forced into a linearly additive model. Snow creep and its influences on trees should be negligible at the crest of a ridge but would increase in importance on the shoulder of the ridge. However, a maximum rate will be reached somewhere on the slope beyond which increased length of slope above will have little or no effect. (W. H. Mathews, personal communication).

The non-linear relationships of some variables impose limitations upon such methods of analysis. The necessary precautions are well expressed below (Canada Department of Forestry 1961):

> "A multiple regression analysis is only a tool to be used as a guide in preliminary work on construction of more realistic models. At best, this procedure will yield the researcher a rough idea as to which variables are accounting for a significant proportion of the variance in the system. At worst, blind application of multiple regression analysis leads to erroneous conclusions. A significant regression coefficient may not mean that a factor is important; rather, the factor may be highly correlated with some factor which is important but is not included in the regression analysis."

These limitations account for the low coefficients of determination above (53.9 per cent for amabilis fir, and 42.3 per cent for mountain hemlock and yellow cedar). But even if some important factors were omitted from the regression analyses, steepness of slope is indicated as the most important control of snow-crook. However, it was noted in the field that snow-deformed stems were also common on the small trees which grew around groups of larger trees. These groups, mainly of mountain hemlock, often occurred on distinct prominences on plots that were otherwise of gentle slope. Data from such plots were not used in the regression analyses because it was impossible to quantitatively express steepness of the slope when the elevated clumps of trees made the topography irregular. Only sample plots of uniform slope were used in the analyses but this neglected the influence of snow cascading down from the crowns of larger trees onto the smaller trees around the group. Mountain hemlock and yellow cedar are the usual species around these elevated groups of mountain hemlock, whereas small amabilis fir trees often occur in the depression between the humps. Therefore, mountain hemlock and yellow cedar would be most subject to deformation by cascading snow from the larger tree crowns. Failure to include this as a variable in the regression analyses resulted in a lower coefficient of determination for these two species than for amabilis fir.

Persistence of lower branches can also influence the incidence of snow-crook. Dahms (1958) observed that natural pruning was poor in mountain hemlock, and in this study branches persisted almost to the ground in both mountain hemlock and yellow cedar. This would provide more surface area against which the forces of snow creep could act. Conversely, amabilis fir prunes itself better and should be less subject to deformation by the down-slope forces of snow. These species differences are reflected in the lowest incidence of snow-crook in amabilis fir for trees of the 10-inch diameter class or less (Table VII). The omission of lower branching habit as an independent variable could also account for some of the unexplained portion of variation in snow-crook for mountain hemlock and yellow cedar.

Altitude was not significantly correlated with the percentage of trees with basal snow-crook in either analysis because samples were taken from the Subalpine Zone only. If some samples had been taken from below the levels of heavy winter snow accumulation, altitude would have been more important as a variable. This would have been possible only with amabilis fir because it is the only species whose range extends downwards into a relatively snow-free bioclimatic region. Mountain hemlock and yellow cedar are restricted to an altitudinal range which is influenced by the forces of snow accumulation throughout. Even near the lower limit of these species there is enough snow to deform the stems of small trees so that increasing amounts of snow with increasing altitude do not result in a significant correlation with the occurrence of basal snow-crook. In conclusion, some of the variation of this particular phenomenon is related to silvical characteristics of the species involved, but unless more realistic regression models can be constructed, it is unwise to attempt to fit a multiple regression to such a complex natural phenomenon.

Influences of altitude and exposure were clearly shown by needle

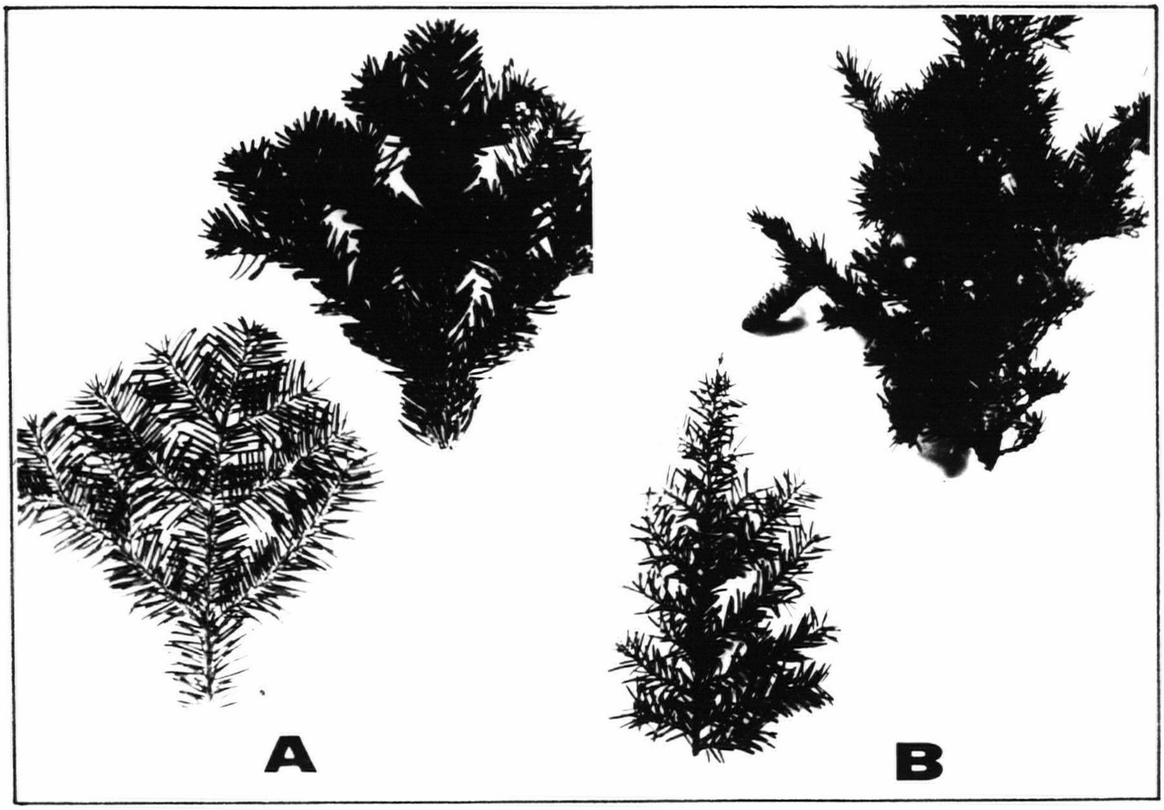

Figure 22. Terminal portions of lower branches from which needles were cut for relative turgidity measurements: A. Abies amabilis; B. Tsuga mertensiana. In both cases, the lower sample is from near BP15, and the upper from near BP 124.

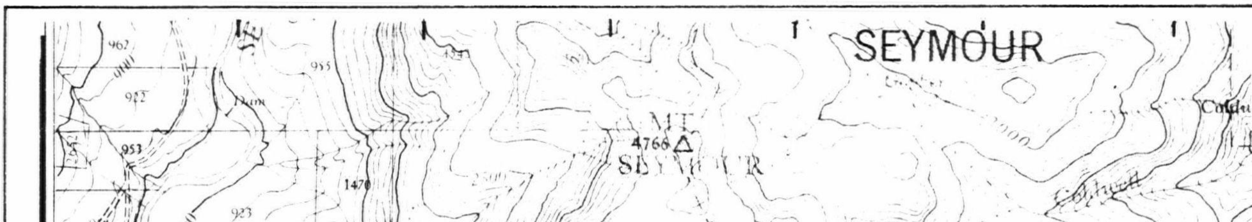

Figure 23. Location of BP15 and BP124 in Mount Seymour Park.

morphology of amabilis fir and mountain hemlock collected at different levels in the Subalpine Zone. The dense, stiff needles of open-grown trees are shown in the upper portion of Figure 22. They were collected from an altitude of 4000 feet in the upper subzone (see Figure 23). The lower portion of Figure 22 shows the more sparsely distributed needles on terminal branches collected from shaded subalpine forest of the lower subzone (near BP 15, 3200 feet).

Four 1/2-inch lengths of twig were sampled from each of the terminal portions of lower branches shown in Figure 22, and the measurements are summarized in Table X. The branches from more exposed trees in the upper subzone had approximately twice as many needles on a given length of twig in both species. Average length of needle was not markedly different in either species from the two altitudes, but average thickness was much greater on the needles from the higher altitude. This would be a result of the well-known difference between sun and shade foliage where there is a much thicker layer of palisade cells in foliage exposed to full sunlight. The resulting differences in length/thickness ratio are clearly shown for the four branch collections in Table X.

These morphological differences occurred on two localities which were altitudinally and environmentally distinct. Because of such distinct differences, these localities were good sampling points at which to test the sensitivity of a measure of the internal water balance. Kramer and Kozlowski (1960) stressed that all other phenomena or factors related to soil moisture are important chiefly because they affect the internal water relations of trees and thereby modify the physiological processes and conditions which affect growth. A measure of relative turgidity which describes the actual water content of plant tissues relative to what it would be if the tissues were fully hydrated was proposed by Weatherley (1950) and has been used for tree species in British Columbia by Bier (1959) and Baranyay (1961). Similar methods were used here with some modifications as discussed below.

TABLE X

Summary of length/thickness ratios in needles of <u>Tsuga mertensiana</u> and <u>Abies amabilis</u> from 4000 feet and 3200 feet on Mount Seymour (values in inches).*

	Tsuga mertensiana				Abies amabilis			
Sample No.	Needles on ½ in. twig	Av. Length	Av. Thick.	L/T Ratio	Needles on ½ in. twig	Av. Length	Av. Thick.	L/T Ratio
A. Exposed, open-grown trees, elevation 4000 ft.: (BP124)								
1	28	.532	.029	18.3	37	.632	.024	26.3
2	29	.541	.032	16.9	36	.765	.027	28.3
3	25	.510	.028	18.2	32	.841	.026	32.4
4	33	.523	.027	19.4	31	.808	.027	29.9
Average	28			18.2	34			29.2
B. Shaded trees beneath forest canopy, elevation 3200 ft.: (BP15)								
1	15	.623	.010	62.3	16	.850	.016	53.1
2	17	.538	.010	53.8	15	.697	.016	43.6
3	14	.561	.010	56.1	17	.791	.015	52.7
4	20	.582	.010	58.2	16	.756	.016	47.2
Average	16			57.6	16			49.2

*All needles on a standard 1/2-inch length of twig were measured as one sample. Leaf thickness was measured to the nearest one one-thousandth of an inch with a STARRETT Comparator. Leaf length was measured only to the nearest twentieth of an inch, but the average for each sample was carried to three decimal places to correspond with the thickness readings.

There were two objectives in the study of relative turgidity: (1) to compare the water content in two different tree species in different months on the same habitat; and (2) to compare the results from two distinct habitats which varied in altitude and in density of tree cover. Amabilis fir and mountain hemlock were sampled from an exposed lithic <u>Cladothamnus</u> association at 4000 feet (near BP 124) and from a shaded, mesic <u>Vaccinium alaskaense</u> association in the lower subzone at 3200 feet (near BP 15).

A terminal portion of branch (Figure 22) was cut from each species at each locality at approximately one-month intervals from February 23, 1962 to August 30, 1962. The branch tips were always collected in the early morning to reduce the effects of diurnal variation, and they were always cut at eye level from the north side of the same tree. They were placed in plastic bags and taken to the laboratory for weighing on a Mettler precision balance.

Three samples of 15 needles each were cut from every branch. Needles from 1961 were used for the entire six-month period of this study. These cut needles were weighed immediately for fresh weights and then placed in distilled water to bring them to saturation. During this period, the needles were held upright in a small vial by a folded piece of paper towel. The cut ends of the needles stood in the water at 10° C. and after 24 hours they were removed and surface dried on paper towels. A second weighing at this stage gave the saturated weight, and a final weighing after 4 hours of oven-drying at 90° C. gave the dry weight of the sample.

Relative turgidity was calculated for each sample from the formula:

$$\text{Relative turgidity} = \frac{\text{fresh weight} - \text{oven dry weight}}{\text{saturated weight} - \text{oven dry weight}} \times 100$$

The data are shown in Table XI and averages of the three replications are plotted in Figure 24. Moisture as a percentage of dry weights was calculated only for comparison. The great differences in tissue density (see Table X) are reflected in the bottom portion of Figure 24 where the thin needles from the low station have a consistently higher water/dry weight ratio than the thick needles from the exposed location. These great differences show the importance of a measure such as relative turgidity which eliminates variations due to varying tissue density.

With the methods described above, no consistent difference in relative turgidity was revealed for mountain hemlock on the different habitats, but at the upper station species differences were detectable by this method

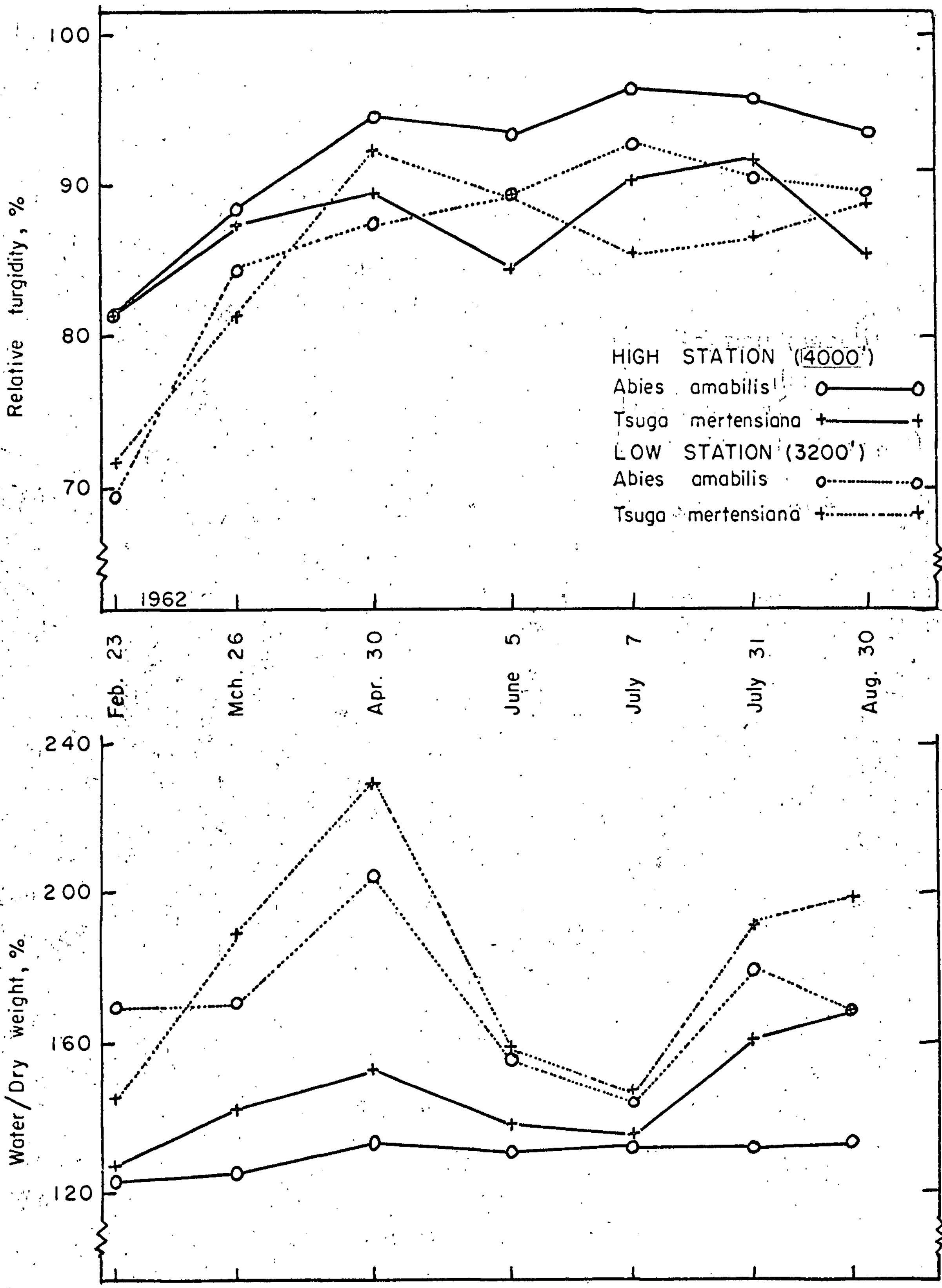

Figure 24. Seasonal changes of relative turgidity and water-dry weight ratio in Abies amabilis and Tsuga mertensiana from 2 localities on Mount Seymour.

TABLE XI

Relative turgidity and water/dry weight values for needles of Tsuga mertensiana and Abies amabilis from 4000 feet and 3200 feet on Mount Seymour (values in per cent).

Cladothamnus, lithic subassociation					Vaccinium alaskaense association			
Exposed Trees - 4000 ft. - BP124					Shaded Trees - 3200 ft. - BP15			
	Tsuga		Abies		Tsuga		Abies	
Date	R. T.	Water/DW	R. T.	Water/DW	R. T.	Water/DW	R. T.	Water/DW
Feb. 23	-	-	81.2	124.3	71.3	140.8	68.5	150.5
	--	-	80.9	121.4	70.4	142.7	68.9	177.6
	81.5	127.3	82.4	123.4	74.0	152.3	70.3	179.7
Avge.	81.5	127.3	81.5	123.0	71.9	145.6	69.2	169.3
Mch. 26	88.5	147.9	86.7	126.5	81.4	200.0	85.4	169.2
	88.0	142.0	91.3	125.4	78.8	189.8	84.8	172.1
	85.3	137.1	87.6	127.6	84.6	176.3	82.7	174.1
Avge.	87.3	142.4	88.5	126.5	81.6	188.7	84.3	171.8
Apr. 30	90.4	154.3	96.1	135.4	92.1	218.7	90.7	189.2
	87.9	147.0	94.1	131.4	92.6	240.4	85.6	217.1
	90.7	159.9	94.3	132.9	93.1	232.7	86.2	206.2
Avge.	89.7	153.7	94.8	133.2	92.6	230.6	87.6	204.2
June 5	88.7	131.5	94.2	139.9	86.6	156.7	89.7	148.1
	84.2	139.0	93.3	123.0	89.0	162.9	88.5	166.4
	81.0	143.6	92.1	128.3	92.6	158.9	89.9	150.7
Avge.	84.6	138.0	93.2	130.4	89.4	159.5	89.4	155.1
July 7	88.3	134.2	97.6	137.3	89.9	156.5	92.3	129.7
	90.4	137.3	97.1	130.4	87.3	142.3	93.4	153.1
	92.5	134.4	95.1	132.6	80.1	141.9	93.0	144.5
Avge.	90.4	135.3	96.6	133.4	85.7	146.9	92.9	142.4
July 31	92.9	165.3	95.5	141.4	87.6	229.0	89.9	183.6
	87.1	164.4	97.0	133.0	86.8	176.8	89.0	187.0
	95.9	155.2	94.7	126.6	85.6	171.2	92.9	168.7
Avge.	92.0	161.6	95.8	133.7	86.7	192.3	90.6	179.8
Aug. 30	81.2	153.1	93.0	138.6	88.4	-	93.6	155.9
	88.3	171.0	93.3	134.3	87.6	202.0	89.9	179.7
	86.0	178.5	94.4	133.7	90.8	194.1	85.6	168.7
Avge.	85.2	167.5	93.5	135.5	89.0	198.0	89.7	168.1

because amabilis fir showed a higher relative turgidity than mountain hemlock throughout the study period. The most meaningful results were obtained from a comparison of amabilis fir on the two habitats (Figure 24).

On the basis that a fully turgid plant is in the most satisfactory condition for growth and other physiological responses (Kramer and Kozlowski 1960), amabilis fir growing on the exposed site at 4000 feet is more vigorous than that in a more heavily forested site at a lower elevation (Figure 24). In the Coastal Subalpine Zone of British Columbia, precipitation is frequent enough so that even trees growing on shallow soils of sites without seepage can maintain a high relative turgidity. The results may have been different if samples had been taken from the top of mature dominant trees, because at the lower station shading of the low branches probably influenced their relative turgidity. Trees in the shaded forest stands at lower elevations are often suppressed and greater root competition may result in relative turgidity values lower than those shown in open-grown trees on supposedly drier sites. Another reason for the lower relative turgidity rates in amabilis fir on the shaded, mesic Vaccinium alaskaense association might be the reduction of absorptive surfaces by the great mortality of roots and rootlets in the acid subalpine raw humus. The high percentage of dead roots in subalpine humus was observed, but no actual measurements were made to determine if there were differences in growth and abundance of roots on different habitats. It is possible that roots are better developed on trees which occur on exposed rock outcrop areas where competition is less, and this could explain the more favourable water balance on such sites.

Unfortunately the measurements were not continued long enough to show distinct seasonal trends. A winter minimum was indicated in both species at both altitudes. Freezing of the soil is not severe beneath the snow cover in the Subalpine Zone but it may be sufficient to reduce the amount of water available to the roots in mid-winter. It is unlikely that a minimum would occur near the end of the growing season, as reported in other studies, because the late snow provides meltwater at least until the end of July, and precipitation during the remainder of the growing season is sufficient to maintain high relative turgidity on even the "driest" habitats in the Subalpine Zone.

Relative turgidity is a simple and reliable measurement that will reflect species and habitat differences. As a symptom which integrates various factors such as soil moisture, temperature, root vigour and crown closure, it is of practical use. A weakness is that even though it may provide a relative measure of tree vigour, it does not explain the cause of good or poor tree vigour.

CHAPTER IV

DESCRIPTION OF PLANT ASSOCIATIONS

The appended synthesis tables provide full details of the floristic analyses. Therefore, only the main floristic and environmental features of each vegetation unit are outlined in this chapter. Mensurational data and life-form spectra are presented separately in Chapter V, and estimated average coverage by each vegetation layer is shown in Table XIV, Appendix III. Figure 28 indicates the altitudinal distribution of associations described below.

A. Lower Subzone

All associations described for the lower subzone are forested, except for those which occur on moor habitats. The variations in predominant tree species and other floristic features are described for dry, mesic, moist, wet, and moor habitats below.

a. Dry Habitat

Rock outcrop habitats with very shallow soils occur in both the upper and lower subzones. Such areas are well drained and are usually topographically situated so that there is no opportunity for supplementary seepage water.

(1a) Cladothamnus association, lithic subassociation (Tsugeto - Cladothamnetum subassoc. lithicum)

Reference: Synthesis Table I

Characteristic combination of species

Constant dominants	Constants, not dominant
Tsuga mertensiana	Menziesia ferruginea
Cladothamnus pyrolaeflorus	Vaccinium ovalifolium

Constant dominants, cont'd.

Vaccinium membranaceum
Chamaecyparis nootkatensis
Vaccinium alaskaense
Abies amabilis
Dicranum fuscescens
Rhytidiopsis robusta

Selectives

Cladothamnus pyrolaeflorus

Constants, not dominant, cont'd.

Sorbus occidentalis
Rubus pedatus
Phyllodoce empetriformis
Orthocaulis floerkii
Cladonia bellidiflora

Preferents

Menziesia ferruginea
Sorbus occidentalis
Gaultheria humifusa
Lescuraea baileyi
Cladonia rangiferina
Pleurozium schreberi

The lithic subassociation of the Cladothamnus association is the subalpine equivalent of the Vaccinium - Gaultheria forest type described by Orloci (1961) and Lesko (1961) for the Coastal Western Hemlock Zone. The equivalence is both edaphic and microclimatic for, in both cases, these associations occur on ridges or on the upper portions of exposed convex slopes.

The most important environmental feature is the shallowness of the soil. Bare rock was estimated to cover between 10 and 15 per cent of the surface area, and only a thin mantle of organic soil covers the rock in the remaining portions. Most of the sparsely forested ridges in Figure 2 belong to the lithic subassociation of the Cladothamnus association.

The extreme exposure, the lack of seepage and the shallow soils result in an average gross volume of only 2,647 cubic feet per acre, 73 per cent of which is mountain hemlock. Trees were estimated to cover only 24 per cent of the total area and their tops are so often broken that the average height of the tallest amabilis fir is only 45 feet and of yellow cedar, 44 feet. Mountain hemlock crowns are more resistant to wind, snow and ice breakage and the tallest tree of this species averages 71 feet, on the basis of 12 sample plots.

The trees usually occur in clusters. Very few of them are without decay and most have broken or dead tops. In most cases, the groups of trees grow on emminences created by their own litter or on humps made by underlying boulders. Such prominences, which are the first spots to be clear of snow in the spring, are the most favourable places for tree species to regenerate. It is for this reason that on this association the best regeneration can be found under existing clumps of trees. The sparse tree cover allows a dense shrub layer to develop because shading is negligible. These shrubs also confine regeneration because they cover the area completely except immediately around the clusters of trees.

The shrub layer, with an estimated average cover of 75 per cent, is made up mostly of Cladothamnus pyrolaeflorus, Vaccinium membranaceum and saplings of the three major tree species.

Greater amounts of Phyllodoce empetriformis, Cassiope mertensiana, Vaccinium deliciosum, Luetkea pectinata, Carex nigricans, Lycopodium sitchense and Deschampsia atropurpurea differentiate the C layer of this subassociation from that which occurs on hygric habitats in the lower subzone.

Dicranum fuscescens, Rhytidiopsis robusta, Dicranum scoparium and Rhytidiadelphus loreus are the most important humicolous bryophytes. Cladonia gracilis, Cladonia pleurota and Crocynia membranacea on this subassociation distinguish the ground layer from the hygric counterpart. There are also greater quantities of Rhacomitrium heterostichum, Cladonia rangiferina and Cladonia squamosa on this drier subassociation.

The estimated average amount of rock outcrop is 12 per cent of the plot area. Whenever there is a thin humus cover over rock surfaces the same species of humicolous bryophytes occur. Pleurozium schreberi is another important species in such cases, particularly as a raw humus builder. On bare rock surfaces Diplophyllum taxifolium, D. obtusifolium, Rhacomitrium heterostichum and Pilophoron hallii are common.

Ptilidium pulcherrimum and Lescuraea baileyi are the main species on decayed wood, aside from the humicolous species that also develop there. An important floristic feature of this association is the abundant Lescuraea baileyi on twigs and stems of ericaceous shrubs near ground level. Cetraria stenophylla occurs on low-lying twigs in greater amounts than in the hygric subassociation.

Amabilis fir and mountain hemlock trunks support mainly Ptilidium pulcherrimum, Alectoria sarmentosa, Parmelia enteromorpha and Cetraria glauca. On yellow cedar, Lescuraea baileyi and Radula complanata predominate and near the base of the tree Rhytidiopsis robusta, Lobaria linata and Mnium spinulosum are more common.

The vegetational similarities of the Cladothamnus association on two different habitats in the Seymour - Grouse - Hollyburn area indicate that ecosystem differences do not always coincide with distinct vegetational differences.

Because Cladothamnus pyrolaeflorus is not present in the Paul Ridge - Diamond Head portion of Garibaldi Park, Synthesis Table I includes no sample plots from there. A special variant of the Cladothamnus association, characterized mainly by Vaccinium membranaceum, would occupy similar habitats in that part of the study area.

b. Mesic Habitat

This habitat is predominantly on glacial till substrate and lacks the exposed rock outcrops that are characteristic for the xeric habitat described above. Mesic habitats usually occur on the upper portions of gentle slopes and the influence of seepage during the driest part of the summer is negligible (Brooke 1964).

(2) Vaccinium alaskaense association (Abieteto - Tsugetum mertensianae)

Reference; Synthesis Table II

Characteristic combination of species:

Constant dominants	Constants, not dominant
Tsuga mertensiana	Vaccinium membranaceum
Abies amabilis	Rubus pedatus
Vaccinium alaskaense	
Rhytidiopsis robusta	

Exclusive, selective and preferential species, none.

Broad areas in the lower subzone, in which there is only temporary seepage during the early summer, are covered by this association. It is topographically and successionally similar to the Vaccinium alaskaense - Plagiothecium - Clintonia forest type of the Western Hemlock Zone (Orloci 1961). However, much greater snow accumulations in the Subalpine Zone make the two associations mensurationally and floristically distinct. The most obvious difference is that western hemlock is largely replaced by mountain hemlock in this association.

The tree layer has an estimated average coverage of 69 per cent. Average gross volume is 12,081 cubic feet, made up mostly of mountain hemlock (Table XII). Average height of the tallest tree is 109 feet for mountain hemlock, 98 feet for western hemlock, 87 feet for amabilis fir, and 78 feet for yellow cedar. An indication of the low productivity in the Subalpine Zone is shown by the average site index of only 65 feet for amabilis fir; on the mesic zonal forest type between altitudes of 700 and 2700 feet, the same species had an average site index of 97 feet (Orloci 1961). All diameter classes are well represented by the four tree species which is an indication that the habitat is representative of "climax" conditions (Figure 25). Invasion by other species is difficult under these circumstances, as shown by the absence of sporadic tree species in this association. Trees are largely confined to humps which rise three or four feet above general ground level, except for amabilis fir which may also occur on the lower ground between the prominences.

Estimated average coverage for the shrub (B) layer is 59 per cent. It is often locally sparse where the tree canopy is dense. Vaccinium alaskaense and Abies amabilis provide the largest degree of cover, but Tsuga mertensiana and Vaccinium membranaceum are also constant species in this layer.

The average coverage of the C layer is only eight per cent, mainly a result of the dense shading by the tree and shrub layers. Blechnum spicant and Streptopus streptopoides indicate the presence of some temporary seepage on this association even if these species are present with low sociability and vigour. Rubus pedatus and Clintonia uniflora are the most important non-woody species in this layer, but regeneration of Vaccinium and amabilis fir also provide small coverage.

Rhytidiopsis robusta, Dicranum scoparium, D. fuscescens and Rhytidiadelphus loreus are the main humicolous species. More moisture and shade on this mesic association allow Blepharostoma trichophyllum, Cephalozia media, Calypogeia neesiana, Lophocolea heterophylla and Lepidozia reptans to occur on 60 to 80 per cent of the plots. Amabilis fir germinants are constant and plentiful in the D layer.

Bryophytes and lichens on rock surfaces are not noticeably different from those on the Cladothamnus association. There is a greater amount of decayed wood on the Vaccinium alaskaense association and it contains a greater variety of bryophytes. Most of the mosses and liverworts from the humus spread to decaying logs, where they form a mixture with Bazzania ambigua, Lophozia porphyroleuca and Hypnum circinale.

Lescuraea baileyi occurs rarely on Vaccinium stems in this association, although Ptilidium pulcherrimum commonly does.

Bryophytes and lichens epiphytic on tree trunks include those of the

Cladothamnus association, with the following additions: Hypnum circinale, Parmeliopsis hyperopta, Sphaerophorus globosus and Cladonia squamosa.

c. Moist Habitat

This category includes areas with temporary or irregular seepage. Slopes that have shallow soils become mesic toward the end of the growing season and support the hygric (moist) subassociation of the Cladothamnus association. On moist habitats that have deeper soils the Streptopus association, with its luxuriant herbaceous layer, occurs. Although both of these vegetation units occur on moist habitats, individual tree size is far greater on the Streptopus association. It is not known if the poor tree growth on the Cladothamnus association is due to some factor other than the shallow soil.

(1b) Cladothamnus association, hygric subassociation (Tsugeto - Cladothamnetum subassoc. hygricum)

Reference: Synthesis Table I

Characteristic combination of species: as in lithic subassociation with differentiating features as described below.

This subassociation represents an ecosystematic variation of the Cladothamnus association. Floristic features of this subassociation on moist, but shallow, soils are not markedly different from those of the lithic counterpart.

The tree layer, predominantly of mountain hemlock, has an estimated average cover of only 43 per cent. Average gross volume is 5,466 cubic feet per acre, and the average height of the tallest tree is 84 feet for mountain hemlock, 76 feet for amabilis fir and 73 feet for yellow cedar. Site indices at 100 years are between 40 and 50 feet for all three species. Mountain hemlock has the greatest number of trees and the greatest gross volume of the three species in all diameter classes except the smallest (5-inch class), where amabilis fir is the predominant species.

The shrub layer on this subassociation is the most dense in the entire zone. The estimated 90 per cent coverage is of Cladothamnus pyrolaeflorus, Vaccinium alaskaense and V. membranaceum. Where there is occasional coniferous regeneration amongst the shrubs it appears to stagnate at approximately four or five inches in diameter and at 10 to 14 feet in height. This stagnation may be a result of the weight and movement of snow which depresses and deforms shrubs and small trees.

Phyllodoce empetriformis is a constant species in this subassociation but it is not abundant and is of poor vigour. Cassiope mertensiana and Vaccinium deliciosum are poorly represented when compared to the lithic subassociation.

Dicranum fuscescens, Rhytidiopsis robusta, Dicranum scoparium and Rhytidiadelphus loreus are the most common mosses on humus. Lichens occur very sparingly on this subassociation.

(3) Streptopus association (Abieteto - Streptopetum)

Reference: Synthesis Table III and Plate I, A.

Two subassociations are recognized and described below for this association.

(3a) Typical subassociation (subassoc. abietetoso - streptopetosum)

Characteristic combination of species:

Constant dominants

Abies amabilis
Tsuga mertensiana
Vaccinium alaskaense
Rubus pedatus
Rhytidiopsis robusta

Exclusives and selectives, none

Constants, not dominant

Menziesia ferruginea
Blechnum spicant
Streptopus roseus
Veratrum eschscholtzii

Preferents

Blechnum spicant
Streptopus roseus
Streptopus streptopoides
Plagiothecium denticulatum

This association is closely related to the orthic Blechnum forest type at lower elevations in the Coastal Western Hemlock Zone. The most obvious floristic difference is the low species significance, sociability and vigour of Blechnum spicant in the Subalpine Zone. The greater accumulations of humus and the shorter growing season in the Subalpine Zone probably hinder the occurrence of Blechnum, but the presence of its usual associates, such as Streptopus spp. and Tiarella spp. suggests edaphic similarities in the two associations of the two bioclimatic zones.

The typical subassociation usually occurs on middle portions of slopes and often there are steep rock faces exposed above. All precipitation runs off from the rock surfaces to ensure a plentiful supply of seepage below. The soil on this association is usually deeper than 70 cm., therefore seepage is not confined to the surface.

It was frequently noted that these habitats are free of snow in June when portions of the slope both above and below are still covered by two to three feet of snow. In many instances this is due to a relatively warmer west or southwest exposure. Furthermore, this association frequently occurs on slopes as steep as 30 degrees where occasional small snow-slides are possible. These factors combine to lessen snow accumulation, and the consequent increase in length of growing season allows greater decomposition of humus. The breakdown of humus is further enhanced by seepage water which laterally translocates nutrients required for the process of decomposition. The final result is excellent tree growth for such an altitude; at 3700 feet on Grouse Mountain a 20-year radial increment of three inches was noted for amabilis fir. The greatest heights and diameters recorded in this study were on this association (total height 170 feet and d.b.h. 64.5 inches for amabilis fir; 171 feet and 58.9 inches for mountain hemlock). The tallest yellow cedar (130 feet) also occurred here and the greatest diameter for the species (70.0 inches) was on a degraded subassociation of the Streptopus association.

The highest average volume in the zone, 17,951 cubic feet per acre, is on this association and 55 per cent of it is amabilis fir. Average height of the tallest tree is 142 feet for amabilis fir, 135 for mountain hemlock, 114 for yellow cedar and 102 for western hemlock. Amabilis fir is more numerous than other species in all diameter classes. Yellow cedar is rarely present in diameter classes less than 20 inches, and above this size it averages only one tree per acre in each diameter class. Both species of hemlock are represented in all diameter classes.

Constant dominant shrubs are not noticeably different from those on the mesic Vaccinium alaskaense association; Vaccinium alaskaense and Abies amabilis dominate the B layer in both cases. The sporadic occurrence of Oplopanax horridus indicates that there is at least temporary seepage on this habitat.

Rubus pedatus, Blechnum spicant, Streptopus roseus, Veratrum eschscholtzii, Clintonia uniflora and Tiarella spp. dominate the herbaceous layer. Lysichitum americanum occurs with low vigour and only on the wettest parts of the association.

There are no distinctive bryophytes on the humus; they are a combination of mesophytic species such as Dicranum fuscescens and Rhytidiopsis robusta and hydrophytic ones such as Mnium nudum and Plagiothecium undulatum.

Lignicolous species are mainly Hypnum circinale, Dicranum scoparium, Rhytidiadelphus loreus, Scapania bolanderi, Plagiothecium elegans, Tsuga heterophylla and patches of mixed liverworts. The latter are usually Cephalozia media, Blepharostoma trichophyllum, Lepidozia reptans and Lophocolea heterophylla.

Yellow cedar bark is partially covered with Heterocladium procurrens, Radula complanata, Plagiothecium elegans, Hypnum circinale and Lobaria linata. On a recent yellow cedar windfall Antitrichia curtipendula, Parmelia enteromorpha, Ptilidium pulcherrimum and Sphaerophorus globosus were noted on the upper sides of branches in the upper half of the tree crown.

Amabilis fir and both species of hemlock support species on their lower trunks distinct from those on yellow cedar. Parmelia enteromorpha, Sphaerophorus globosus, Parmeliopsis hyperopta, Alectoria sarmentosa, Ptilidium pulcherrimum, Hypnum circinale and Dicranum fuscescens are all common.

(3b) Degraded subassociation (subassoc. chamaecyparetosum)

Reference: Synthesis Table III

Characteristic combination of species: as in typical subassociation, with differentiating species as described below.

In the shrub layer Cladothamnus pyrolaeflorus and Rhododendron albiflorum distinguish this from the typical subassociation. The absence of Rubus spectabilis in the degraded subassociation is a further difference.

In the subordinate layers, Gymnocarpium dryopteris and Bryum sandbergii are absent from this subassociation, and species such as Streptopus streptopoides, Tiarella trifoliata, T. unifoliata and Athyrium filix-femina occur in less than 20 per cent of the plots. Conversely, Listera caurina and Plagiochila asplenioides have a higher presence rating than on the typical subassociation.

The degraded subassociation is further distinguishable by the following features of its tree layer: (1) amabilis fir is exceeded by mountain hemlock, both in number of trees and in gross volume, for most diameter classes; (2) western hemlock is only sporadically present, most often as large trees over 40 inches in diameter; and (3) yellow cedar is more numerous, but still absent from some of the smaller diameter classes. As the typical Streptopus association develops towards this degraded subassociation there is a poorer representation of the low altitude species, western hemlock and amabilis fir, and an increased number of yellow cedar and mountain hemlock (Figure 25).

Yellow cedar entirely dominates in the diameter classes over 37 inches. For this species there is an average of 12 trees per acre over 39 inches in diameter; it is not surprising that over 40 per cent of the gross volume on the subassociation is from yellow cedar alone. Average gross volume per acre is approximately 3000 cubic feet less than on the typical subassociation. Average height of the tallest tree is 24 feet less in the two species of hemlock, 25 feet less in amabilis fir, but 2 feet greater in yellow cedar on the degraded subassociation.

Another noticeable feature is the reduction in average coverage by the herbaceous layer to only 16 per cent. This indicates a marked development towards the mesic _Vaccinium alaskaense_ association where increased shade, greater depth to seepage, and more raw humus limit coverage of the C layer.

A distinct concentration of _Mnium spinulosum_, _Plagiochila asplenioides_ and _Barbilophozia lycopodiodes_ near the base of large yellow cedar trees are additional differentiating floristic features of this subassociation. On the two occasions when _Polystichum munitum_ was observed in the Subalpine Zone, it grew in close contact with yellow cedar. The bark of this tree may provide nutritional benefits to species growing at its base and, for _Polystichum_, the required moisture would be provided by the portion of intercepted precipitation which reaches the forest floor as stem-flow on these large trees.

d. Wet Habitat

This habitat is characterized by permanent seepage which is often near the surface. Where these seepage habitats occur adjacent to mountain streams, tree growth is good, as on the subalpine _Oplopanax_ association. In other cases, tree growth may be hindered by slow-moving water and poor aeration near the surface, as on the subalpine _Lysichitum_ association.

(4) Subalpine Oplopanax association (Thujeto - Oplopanacetum abietetosum amabilis)

Reference: Synthesis Table V and Plate I, b

The characteristic combination of species below is tentative because synthesis was based on only four sample plots. Presence classes could not be accurately assigned to the constituent species for such a small number of samples.

Constant dominants

Tsuga heterophylla
Abies amabilis
Oplopanax horridus
Vaccinium alaskaense
Athyrium filix-femina
Gymnocarpium dryopteris
Streptopus roseus
Rhytidiopsis robusta

Exclusives

Oplopanax horridus
Lonicera utahensis
Ribes bracteosum

Selectives

Picea sitchensis

Preferents

Thuja plicata
Vaccinium ovalifolium
Rubus spectabilis
Athyrium filix-femina
Gymnocarpium dryopteris
Tiarella unifoliata

Constants, not dominant

Vaccinium ovalifolium
Vaccinium membranaceum
Lonicera utahensis
Tiarella unifoliata
Clintonia uniflora
Viola glabella
Streptopus amplexifolius
Rubus pedatus
Veratrum eschscholtzii
Pyrola secunda
Osmorhiza purpurea
Tiarella trifoliata
Streptopus streptopoides
Listera caurina
Dicranum fuscescens
Hypnum circinale
Scapania bolanderi

Preferents, continued

Viola glabella
Streptopus amplexifolius
Osmorhiza purpurea
Lycopodium clavatum
Ribes lacustre
Scapania bolanderi
Bryum sandbergii

This vegetation unit is considered a subalpine climatic variant of the Oplopanax - Adiantum forest type described by Orloci (1961). Edaphic conditions of the two appear very similar; both occur marginal to mountain streams where there is abundant and rapidly moving seepage near the surface. Restriction to this particular habitat severely limits the distribution of this forest type and its subalpine variant. Floristic differences are not great between the two, except that *Thuja plicata* is rare or lacking in the subalpine variant and amabilis fir is much more common. In the herbaceous layer, *Adiantum pedatum* is replaced by *Gymnocarpium dryopteris* in the Subalpine Zone. *Lonicera utahensis* in the subalpine variant further distinguishes it from the related association at lower altitudes. It is important to distinguish the subalpine *Oplopanax* sites from the *Oplopanax* forest type of flood-plains at lower elevations (*Piceeto - Oplopanacetum*, Orloci 1961). The latter develops on an entirely different habitat, and its origin, development and stability are unlike the association under discussion here.

Insufficient mensurational data were available to obtain reliable stand table and diameter-class volume data. Average coverage by the tree layer was estimated to be only 51 per cent. Many openings are present because of frequent windfall. The abundant moisture supply in the association may encourage shallow-rootedness which, in turn, could explain the high incidence of windfall. Despite the relatively sparse tree cover, gross volumes per acre are high because of large individual tree volumes. The four 1/5-acre plots average 15,688 cubic feet per acre, with western hemlock and amabilis fir contributing most of the volume. Yellow cedar is not abundant because some of the sample plots occurred below the lower altitudinal limit of this species on Paul Ridge. Sitka spruce are few in number on this association but contribute a large volume. A spruce 158 feet tall and 43.7 inches at breast height was recorded on one of these plots at an altitude of 3760 feet.

Average height of the tallest tree is 139 feet for mountain hemlock, 138 for balsam fir, 128 for western red cedar and 127 for western hemlock. Amabilis fir has the greatest site index of 101 feet, western hemlock 95, western red cedar 95, and mountain hemlock only 78. On this association mountain hemlock is clearly confined to higher portions of the habitat where drainage is better, whereas amabilis fir occurs throughout.

Large openings in the upper canopy encourage a dense shrub layer. It is dominated by Oplopanax horridus (Plate I, B), Vaccinium alaskaense and Abies amabilis. The constant species that provide most coverage in the C layer are Athyrium filix-femina, Gymnocarpium dryopteris, and Streptopus roseus.

Mnium nudum is the most significant moss in the ground layer, and other species that characterize the moist conditions of this habitat are: Hypnum circinale, Scapania bolanderi, Bryum sandbergii, Eurhynchium stokesii, Moerckia blyttii and Plagiothecium undulatum. Hookeria lucens, which occurs only sporadically, also indicates abundant seepage at or near the surface.

There are usually no rocks exposed on this association, and decayed wood is occupied by many of the bryophytes listed above. Lepidozia reptans, Cephalozia media, Blepharostoma trichophyllum and Ptilidium pulcherrimum are also widespread on decaying windfalls.

Corticolous bryophytes were not studied in sufficient detail to detect differences from those on trees of the mesic Vaccinium alaskaense association which often occurs adjacent to the moist Oplopanax ravines.

(5) Subalpine Lysichitum association (Chamaecypareto - Lysichitetum)

Reference: Synthesis Table V

Characteristic combination of species:

Constant dominants

Chamaecyparis nootkatensis
Tsuga heterophylla
Abies amabilis
Vaccinium alaskaense
Lysichitum americanum
Mnium nudum
Rhytidiadelphus loreus

Exclusives

Coptis asplenifolia

Constants, not dominant

Tsuga mertensiana
Menziesia ferruginea
Rubus pedatus
Clintonia uniflora
Carex laeviculmis
Veratrum eschscholtzii
Blechnum spicant
Athyrium filix-femina
Streptopus roseus
Streptopus amplexifolius
Cornus canadensis
Listera cordata
Rhytidiopsis robusta
Plagiothecium undulatum

Selectives

Lysichitum americanum
Sphagnum squarrosum

Preferents

Carex laeviculmis
Veratrum eschscholtzii
Listera cordata
Habenaria saccata
Nephrophillidium crista-galli
Mnium nudum
Rhytidiadelphus loreus
Plagiothecium undulatum

Constants, not dominant, cont'd.

Sphagnum squarrosum
Dicranum fuscescens
Pellia epiphylla

Preferents, continued

Pellia epiphylla
Mnium spinulosum
Conocephalum conicum
Sphagnum girgensohnii
Hypnum dieckii

Lysichitum americanum occurs in a number of different bioclimatic zones because it grows on habitats in which edaphic controls prevail over climatic influences. The coastal subalpine Lysichitum association differs floristically from others previously described by a similar name for the Douglas-fir zone on the east coast of Vancouver Island, for the Interior Western Hemlock Zone, or for the Coastal Western Hemlock Zone (Forestry Handbook for British Columbia 1959, Orloci 1961). It is most closely related to the Vaccinium alaskaense - Lysichitum forest type of the Coastal Western Hemlock Zone (see Table VIII), but Picea sitchensis and Thuja plicata are replaced by Chamaecyparis nootkatensis in the subalpine counterpart.

It occurs only near the lower limits of the Subalpine Zone and is restricted to areas where seepage is abundant, permanent and near the surface. Therefore, it is most common on concave, lower slopes.

Average coverage by the tree layer was estimated at 66 per cent. The impeded drainage and poor aeration result in a low total volume of only 8,345 cubic feet per acre. For volume, decreasing order of importance for the tree species is western hemlock, yellow cedar, mountain hemlock and balsam fir. Western hemlock has an average maximum height of 111 feet, followed by mountain hemlock. When age is considered, mountain hemlock shows the highest site index of 71 feet, western hemlock 65 feet, yellow cedar 61 feet and amabilis fir only 57 feet.

Amabilis fir is the most numerous tree in the small diameter classes but is rarely larger than the 21-inch class. Most of the volume in large diameter classes is from yellow cedar and western hemlock. Western white pine and western red-cedar are sporadic trees in this association.

Vaccinium alaskaense is the most important species in the shrub layer, and regeneration of the four common tree species make up the most of the remaining cover.

On such habitats there are groupings of herbaceous species in the wettest portions quite distinct from the combination of species which occurs on the elevated, more acid humps. Sample plots as large as 1/5-acre have the disadvantage of covering both microhabitats and an unusual combination of species may result in the synthesis tables unless previous stratification is made in the list of species. In the wettest portions of this association Lysichitum americanum, Clintonia uniflora and Veratrum eschscholtzii typify the success of geophytes. Most of the remaining species in Synthesis Table V are associated with Lysichitum in the moist depressions, but the following are more common near the clumps of trees where there is some raw humus development and where depth to seepage is greater: Rubus pedatus, Pyrola secunda, Streptopus streptopoides, Cornus canadensis, Maianthemum dilatatum, Vaccinium spp., Menziesia ferruginea, Goodyera oblongifolia and Sorbus occidentalis.

On moist depressions Mnium nudum, Sphagnum squarrosum, Pellia epiphylla and Plagiothecium undulatum predominate, but Rhytidiadelphus loreus, Rhytidiopsis robusta and Dicranum fuscescens are locally abundant on drier prominences.

The primary lignicolous bryophytes are Dicranum fuscescens, Hypnum circinale, Ptilidium pulcherrimum, Rhytidiadelphus loreus, Scapania bolanderi, Lophocolea heterophylla and Rhytidiopsis robusta. On very moist logs and rocks Hypnum dieckii differentiates this wet association from those which are moist, mesic or dry.

Corticolous bryophytes and lichens are similar to those described for the Streptopus association.

e. Moor Habitat

Areas with stagnant water are included here and only one association is described for this category.

(6) Eriophorum - Sphagnum association (Eriophoreto - Sphagnetum)

References: Synthesis Table IV and Plate II, B

Characteristic combination of species:

Constants, none

Exclusives

Eriophorum angustifolium
Carex aquatilis

Selectives, none

Preferents

Scirpus caespitosus
Sphagnum plumulosum
Scapania uliginosa
Sphagnum mendocinum
Calliergonella cuspidata
Polytrichum commune

The characteristic combination of species above is very tentative because this association was not studied in sufficient detail. It occurs sporadically in the Subalpine Zone and there was great floristic variation in the five plots that were analysed. This association is most frequent in the lower subzone, but it may sometimes occur in the upper subzone and even fragmentarily in the Alpine Zone.

This association begins to develop in open stagnant water or on slopes where drainage is severely impeded. Carex aquatilis and Drepanocladus exannulatus characterize the first stage of development (Plate II, B), and later stages are dominated by Eriophorum angustifolium, Sphagnum plumulosum and S. mendocinum.

On one of these moor areas there was a slight slope of four degrees, which was sufficient to improve drainage, and common species of the *Leptarrhena - Caltha leptosepala* association were associated with *Eriophorum angustifolium* and *Carex aquatilis*. This association requires further study for an understanding of its ecological and phytosociological features.

B. Upper Subzone

In this part of the Subalpine Zone trees grow only on dry and mesic habitats which have a relatively short duration of snow. Wet and moist habitats, often because of their topographic position, have such a long duration of snow that trees are unable to develop.

1. Chionophobous Associations

Chionophobous communities are those which are relatively intolerant to great accumulations and long duration of snow. In the upper subzone, the two associations which contain trees are placed in this category.

a. Dry Habitat

The lithic subassociation of the *Cladothamnus* association occupies dry habitats in both the upper and lower subzones. Floristic features are not markedly different in the upper subzone from those described for the subassociation at lower elevations. Total volume is usually less than 2000 cubic feet per acre and species such as *Phyllodoce empetriformis*, *Cassiope mertensiana*, *Vaccinium deliciosum* and *Luetkea pectinata* are much more prominent on this subassociation in the upper subzone.

b. Mesic Habitat

This habitat may have a considerable amount of rock outcrop but it always occurs on a slope position and the soils are generally deeper than in the drier lithic habitat of the upper subzone (Brooke 1964).

(7) Vaccinium membranaceum - Rhododendron association (Tsugeto - Vaccinietum membranacei)

Reference: Synthesis Table VI, Plates I, E and III, C

Characteristic combination of species:

Constant dominants

Tsuga mertensiana
Abies amabilis
Vaccinium membranaceum
Rhytidiopsis robusta

Exclusives, none

Selectives

Rhododendron albiflorum

Constants, not dominant

Phyllodoce empetriformis
Vaccinium deliciosum
Orthocaulis floerkii

Preferents

Vaccinium membranaceum

This association is floristically similar to the Engelmann Spruce - Alpine Fir - Black Huckleberry association of the Interior Subalpine Zone (Arlidge 1955) and is related to vegetation types described by Daubenmire (1952) in northern Idaho. Tsuga mertensiana, Rhododendron albiflorum and Vaccinium membranaceum are amongst the climax dominants in subalpine areas of inland mountains, and in this study the Vaccinium membranaceum - Rhododendron association was best developed in the portions of Garibaldi Park which were furthest from the Strait of Georgia.

This association may develop on somewhat different habitats depending upon altitude. Its optimal development, at an altitude of 3900 feet, is shown in Plate III, C. At the altitudinal tree limit (near 6000 feet in this study), the same association develops as a topographic climax only on drier, more exposed ridges (Plate I, E).

When this association was confined to a narrow ridge it was often impossible to establish a sample plot as large as 1/5-acre. Only the five sample plots that were of standard 1/5-acre size were used in the summaries of mensurational data (Figure 25 and Table XII).

Average gross volume is 6,451 cubic feet per acre, with mountain hemlock accounting for 67 per cent. Average height of the tallest tree is 86 feet for mountain hemlock, 71 feet for amabilis fir and 58 feet for yellow cedar. Site indices could not be accurately calculated, but for each species it is less than 40 feet at 100 years.

Mountain hemlock is the only species represented in all diameter classes. Yellow cedar has a very low average number of trees in the smallest diameter class, in contrast to its abundance at this size in the lithic subassociation of the Cladothamnus association. Both yellow cedar and amabilis fir are only sporadically present in diameter classes over 13 inches.

Basal snow-crook is common on tree trunks, particularly where the slope is great, and the stems of tall shrubs are permanently appressed by the weight of snow. Vaccinium membranaceum, Rhododendron albiflorum and Tsuga mertensiana are the main species in the shrub layer.

As in the mesic Vaccinium alaskaense association of the lower subzone, the herbaceous layer is poorly developed. There are only a few chamaephytes and small woody phanerophytes in the C layer.

The constant occurrence of Rhytidiopsis robusta on humus clearly differentiates the ground layer of this association from that on non-forested associations in the upper subzone, whereas Orthocaulis floerkii as a constant species distinguishes the humicolous layer from that in forested associations at lower altitudes. Lichens are numerous by species but provide little surface coverage, and species of Rhacomitrium are uncommon on humus. When this association occurs near its upper limit on ridges, the humicolous bryophyte layer is very sparse with the result that average coverage by bryophytes is the lowest of any multi-layered association in the Subalpine Zone.

Rock surfaces support Andreaea rupestris, Rhacomitrium heterostichum, Diplophyllum taxifolium, Kiaeria falcata, Cladonia bellidiflora, Pilophoron hallii and Lecidea spp.

Decayed wood is not plentiful but is mainly covered by Dicranum scoparium, Ptilidium pulcherrimum, Rhytidiopsis robusta and Cladonia bellidiflora. Cetraria stenophylla and Ptilidium pulcherrimum occur on both Rhododendron and Vaccinium stems but are more abundant on the latter. At the lower altitudinal limits of this association, Lescuraea baileyi also occurs on the stems of Vaccinium.

Corticolous species are few; Parmeliopsis hyperopta, Ptilidium pulcherrimum and Dicranum fuscescens are the main species below average winter snow level on the trunks of mountain hemlock. Alectoria sarmentosa and Sphaerophorous globosus occur higher up on the tree trunks. The only recorded occurrence of Letharia vulpina in this study was on the bark-free dead branches of yellow cedar of this association.

2. Chionophilous Associations

Those associations that develop in habitats of relatively long snow duration are described below. Trees, as such, are lacking but tree species may be present in dwarf form (Figure 20). Two categories, moderately and strongly chionophilous associations, are discussed below.

a. Moderately Chionophilous Associations

Habitats with snow duration intermediate between that on forested areas and that in late snow-patch areas would be similar to 'early snow-patch' habitats as described by Dahl (1956). The vegetation on these areas of medium snow duration is considered to be moderately chionophilous in the present classification.

i. Dwarf Tree Association

Tree species in this association are rarely over ten feet tall.

They are often leaning (Plate III, B) and usually have a snow-crook at the base of the stem. Although dwarfed and somewhat deformed from the forces of snow, tree species are not so severely misshapen as in true krummholz of alpine areas. A more or less erect stem can develop in tree species of the association described below, whereas krummholz of higher altitudes is more closely appressed to the ground, probably as a result of greater exposure to wind.

(8) Dwarf *Tsuga* association (*Nano-Tsugetum mertensianae*)

Reference: Synthesis Table VII and Plate I, F

Two subassociations are recognized and described below for this association.

(8a) Typical subassociation (subassoc. *nano-tsugetosum mertensianae*)

Characteristic combination of species:

Constant dominants

Tsuga mertensiana
Phyllodoce empetriformis
Cassiope mertensiana
Luetkea pectinata
Orthocaulis floerkii

Selectives

Deschampsia atropurpurea

Constants, not dominant

Vaccinium deliciosum
Deschampsia atropurpurea
Dicranum fuscescens

Preferents

Luetkea pectinata
Hippuris montana

Ths most important environmental feature distinguishing the two subassociations here is the relative lack of seepage in the typical subassociation.

Successional relationships of this association were discussed by Brink (1959) but its floristic details have not been previously elaborated. The typical subassociation occurs on warmer exposures or on elevated areas where snow duration is less than on the adjacent *Phyllodoce* - *Cassiope* association (Figure 19 and Plate I, F). Conversely, near its lower limit this association occurs on topography that favours longer snow duration than in the surrounding lithic subassociation of the Cladothamnus association. Even in the lower subzone, collection of cold air in depressions and ravines can create conditions which maintain a dwarf Tsuga association. This association was sampled at an altitude as low as 3300 feet on Mount Seymour; mountain hemlock there was only five feet tall at an age of 93 years.

The dominance of mountain hemlock physiognomically distinguishes this vegetation unit from the surrounding small shrub associations of the upper subzone. Some hemlocks were over six feet tall in every plot sampled, but height growth is extremely slow. At an altitude of 4000 feet mountain hemlock was 12 feet tall at 50 years of age, and at 4750 feet it was only four feet tall at 100 years of age (Figure 20).

The combined coverage by dwarf Tsuga mertensiana, Phyllodoce empetriformis and Cassiope mertensiana allows little room for other shrubs. Neither Vaccinium deliciosum nor V. membranaceum are well represented in this association. Deschampsia atropurpurea, always with a low species significance and sociability, is a selective species.

The ability of mountain hemlock to occur as a pioneer on relatively bare soil allows this association to develop in some places without much previous humus accumulation. The high presence values of pioneers such as Lycopodium sitchense and Crocynia membranacea indicate that this is a relatively early stage in vegetational development. By contrast, on the Vaccinium deliciosum association organic accumulations are deeper, and Lycopodium and Crocynia are already eliminated or infrequent.

Rhacomitrium heterostichum, R. canescens, Orthocaulis floerkii, Dicranum fuscescens, Kiaerkia falcata, Crocynia membranacea and Cladonia squamosa are the most important humicolous bryophytes and lichens.

Rhacomitrium heterostichum is also the dominant moss on rock surfaces but Rhizocarpon geographicum, Andreaea rupestris, Grimmia apocarpa and various unidentified crustose lichens are also common.

No mosses develop on trunks of the dwarf Tsuga in this association.

(8b) Luetkea subassociation (subassoc. luetkeetosum pectinatae)

Reference: Synthesis Table VII

Characteristic combination of species, as in typical subassociation, with differentiating species as below.

The two subassociations described here are good examples of similar vegetation types developing on quite different habitats. The typical subassociation occurs on a variety of topographic positions and is often well developed on prominences where there is no benefit from seepage (Plate I, F). In contrast, the Luetkea subassociation is restricted to concave areas where seepage is available through all of the short growing season. Physiognomic differences are slight between the two subassociations and there are few species differences. The presence of Hippuris montana and Carex nigricans, and the better development of Luetkea pectinata reflect the more abundant moisture of the Luetkea subassociation; the absence of Crocynia membranacea and Cladonia squamosa further differentiates it from the typical subassociation.

In both cases, humus is very shallow and poorly developed, but the improved moisture supply allows the increased occurrence of Pellia neesiana and Lophozia porphyroleuca on the Luetkea subassociation.

Rock surfaces in the typical subassociation are covered with species similar to those on rocks of the Phyllodoce - Cassiope association. On the Luetkea subassociation the main coverage on rocks is by Gymnomitrium concinnatum, Rhacomitrium heterostichum, Diplophyllum taxifolium, Kiaeria falcata and Andreaea nivalis.

ii. Small Shrub Associations

The two associations described below are also considered to be moderately chionophilous. They are usually on habitats which are moist because of melting snow until about mid-July, but they become mesic toward the end of the summer. Tree species, even in dwarf form, are very uncommon on these associations.

(,) Vaccinium deliciosum association (Vaccinietum deliciosi)

Reference: Synthesis Table VIII

Characteristic combination of species:

Constant dominants

Vaccinium deliciosum
Phyllodoce empetriformis
Cassiope mertensiana
Dicranum fuscescens
Orthocaulis floerkii
Rhytidiopsis robusta

Selectives

Cetraria islandica

Constants, not dominant

Tsuga mertensiana
Vaccinium membranaceum
Luetkea pectinata
Cetraria islandica

Preferents

Vaccinium deliciosum

Relatively pure patches of Vaccinium deliciosum occur adjacent to areas of Phyllodoce empetriformis and Cassiope mertensiana but Vaccinium appears unable to tolerate such a long snow duration as these low evergreen shrubs. The Vaccinium deliciosum association has floristic characteristics transitional towards the Vaccinium membranaceum - Rhododendron association, which is an indication that it is less chionophilous than the Phyllodoce - Cassiope association in the Subalpine Zone. The zonation and distribution of Vaccinium deliciosum are often a result of differences in the length of growing season, and its frequent concentration along small temporary streams also indicates that this species is less xerophytic than Phyllodoce or Cassiope.

The relatively deep soil and the well developed humus layer on this association provide improved moisture conditions. Even though tree species are not abundant, the deep humus layer, the lack of pioneer species such as Lycopodium sitchense, and the constant occurrence of Rhytidiopsis robusta and Vaccinium membranaceum indicate that vegetational development is well advanced here. This association is more closely related, floristically, to forested communities than it is to the *Phyllodoce* - *Cassiope* association, and for this reason is not found at higher altitudes in the Alpine Zone. It is a characteristic association of the upper subzone of the Subalpine Mountain Hemlock Zone.

There is a well-developed shrub layer which is dominated by *Vaccinium deliciosum*. The layer less than six inches in height (C) is occupied largely by this same species and by *Phyllodoce empetriformis*. *Cassiope mertensiana* is reduced in total cover degree by the increased shading of *Vaccinium* over six inches tall. *Lycopodium sitchense* is entirely absent, in contrast to the other small shrub association at this altitude.

Dicranum fuscescens and *Orthocaulis floerkii* are the dominant humicolous species but the occurrence of *Rhytidiopsis robusta* and *Cetraria islandica* differentiate this layer from that in the *Phyllodoce* - *Cassiope* association. *Cladonia bellidiflora* is the only prominent lichen in the humus layer, and *Cetraria stenophylla* is abundant on the stems of *Vaccinium deliciosum* near ground level.

Bryophytes and lichens on rock surfaces are similar to those on the *Phyllodoce* - *Cassiope* association.

(10) *Phyllodoce* - *Cassiope* association (*Phyllodoceto* - *Cassiopetum mertensianae*)

Reference: Synthesis Table IX and Plate II, D

Characteristic combination of species:

Constant dominants

Phyllodoce empetriformis
Cassiope mertensiana
Vaccinium deliciosum
Dicranum fuscescens
Orthocaulis floerkii

Exclusives and Selectives, none

Constants, not dominant

Luetkea pectinata

Preferents

Phyllodoce empetriformis
Cassiope mertensiana
Lycopodium sitchense
Gymnomitrium varians
Kiaeria falcata
Crocynia membranacea

This vegetation unit was previously studied by McAvoy (1929, 1931), Brink (1959) and Archer (1963). It is the mesic association in the Alpine Zone (Archer 1963), but in the Subalpine Zone it occurs on moist habitats. Its occupation of concave topographic positions with temporary seepage in the Subalpine Zone is in sharp contrast to its development in the Alpine Zone on convex or flat relief without seepage.

The two topographically distinct habitats on which this association occurs in the two bioclimatic zones influence not only the moisture relationships but also snow duration. On both habitats in the two different zones the snow remains for nine to ten months of the year. However, relative to other topographic positions and vegetation units, the Phyllodoce - Cassiope association is chionophobous in the Alpine Zone but moderately chionophilous in the Subalpine Zone.

In the Alpine Zone, Phyllodoce empetriformis and Cassiope mertensiana are the dominant species of this association; in the Subalpine Zone, the association becomes more diversified by the invasion of taller shrubs or tree species. There is a greater proportion of Vaccinium deliciosum and Tsuga mertensiana, and lesser amounts of Cassiope mertensiana when this association occurs within the Subalpine Zone. If there is a B layer developed, mountain hemlock is the dominant species, but Chamaecyparis nootkatensis, Vaccinium deliciosum, V. membranaceum and Sorbus occidentalis may also occur over six inches in height.

In its early phases this association contains a high proportion of Luetkea pectinata, Lycopodium sitchense, Crocynia membranacea, Kiaeria falcata, and Gymnomitrium varians. The constant dominant bryophytes, Dicranum fuscescens and Orthocaulis floerkii, are lacking only during the initial phase of development. When Tsuga mertensiana and Vaccinium deliciosum occur on this association, Rhytidiopsis robusta may also develop beneath them. Rock surfaces are partially covered with Rhacomitrium heterostichum, R. canescens, Andreaea rupestris, Rhizocarpon geographicum, Lecidea sp., Marsupella ustulata, Umbilicaria torrefacta and Gymnomitrium concinnatum.

Cetraria stenophylla, which is very common on twigs of Vaccinium deliciosum, rarely occurs in the Phyllodoce - Cassiope association.

iii. Herb Association

Only one association is placed in this group. It occurs where water is permanently at or near the surface. Where there is a surface flow of water snow melt is hastened. Thus, a slightly longer growing season separates this association from nearby strongly chionophilous associations.

(11) Leptarrhena - Caltha leptosepala association (Leptarrheneto - Calthetum leptosepalae)

Reference: Synthesis Table IV, Plate II, A

Characteristic combination of species:

Constant dominants

Leptarrhena pyrolifolia
Erigeron peregrinus
Caltha leptosepala
Parnassia fimbriata
Rhytidiadelphus squarrosus
Drepanocladus exannulatus
Philonotis fontana

Constants, not dominant

Carex spectabilis

Exclusives

Caltha leptosepala

Selectives

Salix commutata
Leptarrhena pyrolifolia
Erigeron peregrinus
Parnassia fimbriata
Epilobium alpinum
Equisetum palustre
Petasites frigidus
Rhytidiadelphus squarrosus
Drepanocladus exannulatus
Philonotis fontana

Preferents

Carex spectabilis
Mitella pentandra
Juncus mertensianus
Arnica latifolia
Tofieldia glutinosa
Veronica serpyllifolia
Cratoneuron commutatum
Campylium stellatum

The Leptarrhena - Caltha association is floristically similar to the alpine forb meadow described by Brink (1959) for the Black Tusk area of Garibaldi Park, and the hygrophytic associations described by Archer (1963) for the Alpine Zone.

The floristic similarities of this seepage association with the Lysichitum seepage associations at lower altitudes indicate the predominance of edaphic controls over microclimatic influence in such habitats (Table VIII, Chapter III).

When this association occurs on the margins of a stream different combinations of species occur in bands parallel to the open water. Petasites frigidus and Drepanocladus exannulatus represent very early stages in the development of this association closest to the stream (Plate III, D); Leptarrhena pyrolifolia, Erigeron peregrinus, Caltha leptosepala, Parnassia fimbriata, Rhytidiadelphus squarrosus and Mnium nudum characterize the late stages of the association after organic accumulations have raised the surface further above stream level. Sphagnum plumulosum occurs in this association if seepage is impeded.

Luetkea pectinata, Phyllodoce empetriformis, Cassiope mertensiana, Gaultheria humifusa, and Chamaecyparis nootkatensis are the first species from other associations to invade the margins of the Leptarrhena - Caltha association.

b. Strongly Chionophilous Associations

This category includes late snow-patch associations of the Subalpine Zone where snow may remain as late as the first week in August. The associations of this group are characterized by their physiognomic simplicity and by their small number of constituent species.

(12) Saxifraga tolmiei association (Saxifragetum tolmiei)

Reference: Synthesis Table VIII, Plates III, E and II, F

The characteristic combination of species was not determined because this association is more typical of alpine conditions and was insufficiently sampled in the Subalpine Zone. It was observed only locally on Paul Ridge and on a recently glaciated colluvial talus slope near The Lions.

This association is the first to occur on unstable colluvial slopes, with coarse-textured soils. The sparse C layer is dominated by Saxifraga tolmiei and Luzula wahlenbergii in the earliest stages of development. Phyllodoce empetriformis may occur sporadically as a pioneer in portions of the slope which are locally stable. In later stages of development, Juncus drummondii, Carex spectabilis, Luetkea pectinata, Cryptogramma crispa, Athyrium alpestre and Saxifraga ferruginea occur.

The ground layer is dominated during all stages by Gymnomitrium varians (Plate II, F), and Oligotrichum hercynicum is a constant species. Polytrichum norvegicum, Kiaeria blyttii and Pohlia drummondii were also recorded. If rocks became stabilized on these slopes, they are occupied mostly by Andreaea nivalis.

The occurrence of species such as Athyrium alpestre, Carex spectabilis, Luetkea pectinata, Gymnomitrium varians, Polytrichum norvegicum, Pohlia drummondii and Andreaea nivalis indicate that the long snow cover provides plentiful moisture to the habitat during the short growing season. They also indicate the floristic similarities to other snow-patch associations discussed below.

(13) Carex nigricans association (Caricetum nigricantis)

Reference: Synthesis Table VIII

Characteristic combination of species:

Constant dominants	Constants, not dominant
Carex nigricans	Deschampsia atropurpurea Polytrichum norvegicum
Exclusives	
Polytrichum norvegicum	

Selectives	Preferents
Carex nigricans	Juncus drummondii
Kiaeria blyttii	Saxifraga tolmiei

This association reaches its optimal development in the Alpine Zone but it is briefly mentioned here because of its presence in upper portions of the Subalpine Zone.

It occupies depressions where the snow remains between 9 and 10 months of the year. Soil depth is usually over 50 cm. because in many cases this association occupies former ponds which are now filled by deep accumulations of fine-textured soils. The short growing season limits the number of species, and vegetational development is extremely slow on such habitats.

In the Subalpine Zone, the most important species of this association are Carex nigricans, Deschampsia atropurpurea, Juncus drummondii and Carex spectabilis. Luetkea pectinata, Phyllodoce empetriformis and Cassiope mertensiana are the earliest invaders. The latter species would be absent on well developed examples of this association in the Alpine Zone (Archer 1963).

In the ground layer, Polytrichum norvegicum, Kiaeria blyttii and Pohlia drummondii are the main species.

(14) Polytrichum norvegicum association (Polytrichetum norvegici)
Reference: Synthesis Table VIII

The characteristic combination of species was not determined because this is a typically alpine association which occurs only fragmentarily in the Subalpine Zone. Floristic data from two sample plots are shown in Synthesis Table VIII to indicate environmental and phytosociological similarities of this association with the Carex nigricans association.

Depressions with the extreme maximum of snow duration (at least until the first week of August) are dominated by Polytrichum norvegicum.

However, in the Subalpine Zone this association often occurs in a mosaic with the Carex nigricans association on moist habitats with fine-textured soils.

Similar late snow-patches have been studied in detail by European scientists (Braun-Blanquet 1932, Krajina 1933, Gjaerevoll 1950), and in British Columbia, Shaw (1916) and McAvoy (1929, 1931) have discussed successional relationships between Polytrichum norvegicum and Carex nigricans. Archer (1963) also discussed associations for these species. However, these references pertain to areas with altitudes usually greater than the Subalpine Zone of this study.

CHAPTER V

COMPARISONS OF THE ASSOCIATIONS

This chapter presents basic mensurational data grouped according to the associations just described. Comparisons of life-forms on each association are also presented in tabular and graphic form. The data are not discussed in detail since their main purpose is to complement the descriptions of the associations, and to allow comparisons with similar data from other bioclimatic zones.

A. Mensuration

The greatest average volume occurs on the typical subassociation of the *Streptopus* association with nearly 18,000 cubic feet per acre, and the least on the lithic subassociation of the *Cladothamnus* association with less than 3,000 cubic feet per acre. The largest individual tree volumes occur on the subalpine *Oplopanax* association but the total volume per acre is reduced on this site by the high number of windfall (Table XII).

The association of optimum development for each tree species is:

the mesic *Vaccinium alaskaense* association for mountain hemlock;

the typical subassociation of the *Streptopus* association for amabilis fir;

the degraded subassociation of the *Streptopus* association for yellow cedar;

and the subalpine *Oplopanax* association for western hemlock.

The relative importance of each tree species in every association is indicated by the total volumes. Mountain hemlock is the major species in the

TABLE XII

Averages of gross volume, maximum height and site index for the major species on each association

	LYSICHITUM	OPLOPANAX	STREPTOPUS	Degraded STREPTOPUS	VACCINIUM ALASKAENSE	Hygric CLADOTHAMNUS	Lithic CLADOTHAMNUS	VACC. MEMBR.- RHODODENDRON
No. of Plots	6	4	13	6	9	5	12	5
Avge. Gross Vol. cu. ft./acre:								
All species incl. sporadics	8,345	15,688	17,951	15,014	12,081	5,466	2,657	6,451
mountain hemlock	1,820	1,850	4,131	4,483	5,910	3,004	1,931	4,286
amabilis fir	890	4,053	9,903	3,758	2,809	890	357	1,619
yellow cedar	2,172	323	1,055	6,006	1,366	1,459	344	406
western hemlock	2,273	6,991	2,646	289	1,996	-	-	-
Total for major species	7,155	13,217	17,735	14,536	12,081	5,353	2,632	6,311
Total for sporadic species	1,190	2,471	216	478	-	113	25	140
Avge. ht. tallest tree on plot								
mountain hemlock	102	139	135	111	109	84	71	86
amabilis fir	83	138	142	117	87	76	45	71
yellow cedar	97	91	114	116	78	73	44	58
western hemlock	111	127	102	78	98	-	-	-
Avge. site index, at 100 yrs.								
mountain hemlock	71	78	76	67	65	46	44	40
amabilis fir	57	101	93	74	65	49	40	40
yellow cedar	61	?	72	66	45	44	40	40
western hemlock	65	95	69	?	54	-	-	-

Vaccinium alaskaense, the Cladothamnus and the Vaccinium membranaceum - Rhododendron associations; amabilis fir predominates in the typical Streptopus subassociation; amabilis fir predominates in the typical Streptopus subassociation; yellow cedar shows the highest volume of the four species in the degraded Streptopus subassociation; and western hemlock is the main species in the subalpine Lysichitum and Oplopanax associations.

The sporadic species which account for the extra volume on some associations are as follows:

on the Lysichitum association, western white pine and western red-cedar;
on the subalpine Oplopanax association, Sitka spruce and Douglas-fir;
on the Streptopus association, western red-cedar;
on the Cladothamnus association, western hemlock;
and on the Vaccinium membranaceum - Rhododendron association, alpine fir, western white pine and western hemlock.

Eis (1962a) showed that there was a fairly constant decrease in site index with increasing altitude on associations that have a wide altitudinal range. Consequently, site indices of subalpine species are very low. Only with amabilis fir on the Oplopanax association is site index over 100 feet at 100 years, and in many cases it is less than 50 for all species (Table XII).

The number of trees and the gross volume in cubic feet per acre are shown for the various diameter classes of each species in Figure 25[1]. The important features from these graphs were already discussed in the association descriptions of Chapter IV.

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[1]Some changes in nomenclature and organization were made after Figure 25 was reproduced. C. Mesic Vaccinium should read C. Vaccinium alaskaense; E. Vaccinium membranaceum - Rhododendron. F. Cladothamnus is based on the five sample plots shown for the hygric subassociation in Synthesis Table I plus five sample plots (101, 104, 43, 19 and 21) that were later grouped in the lithic subassociation. G. Lithosolic Cladothamnus should read Lithic Cladothamnus and, as shown in Figure 25, the data for this group are based only on the seven sample plots originally classified as lithic.

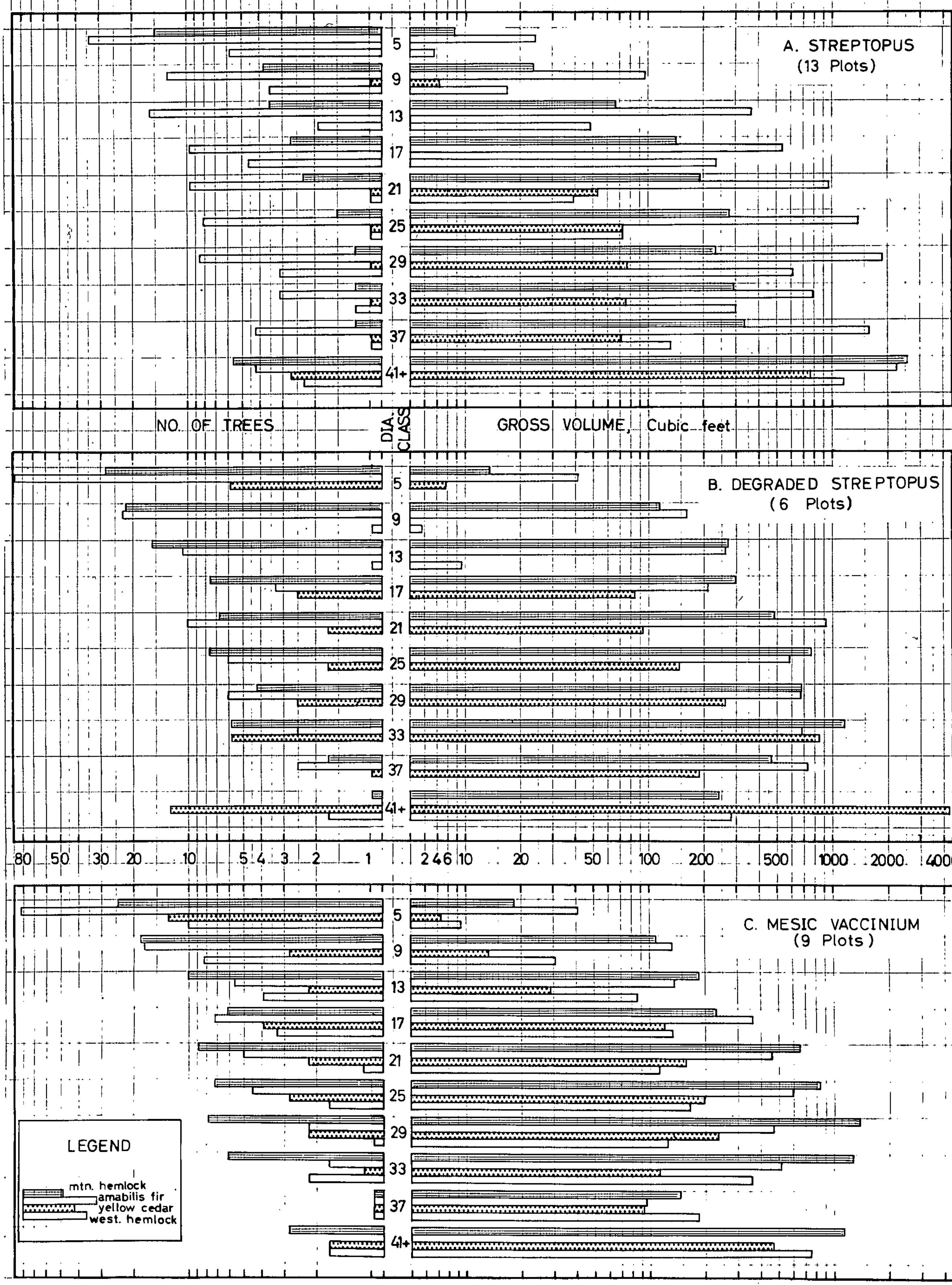

Figure 25. Number of trees over 3 inches d.b.h. and gross cubic-foot volume, per acre, by 4-inch diameter classes, for 4 species in various associations. Figure continued next page.

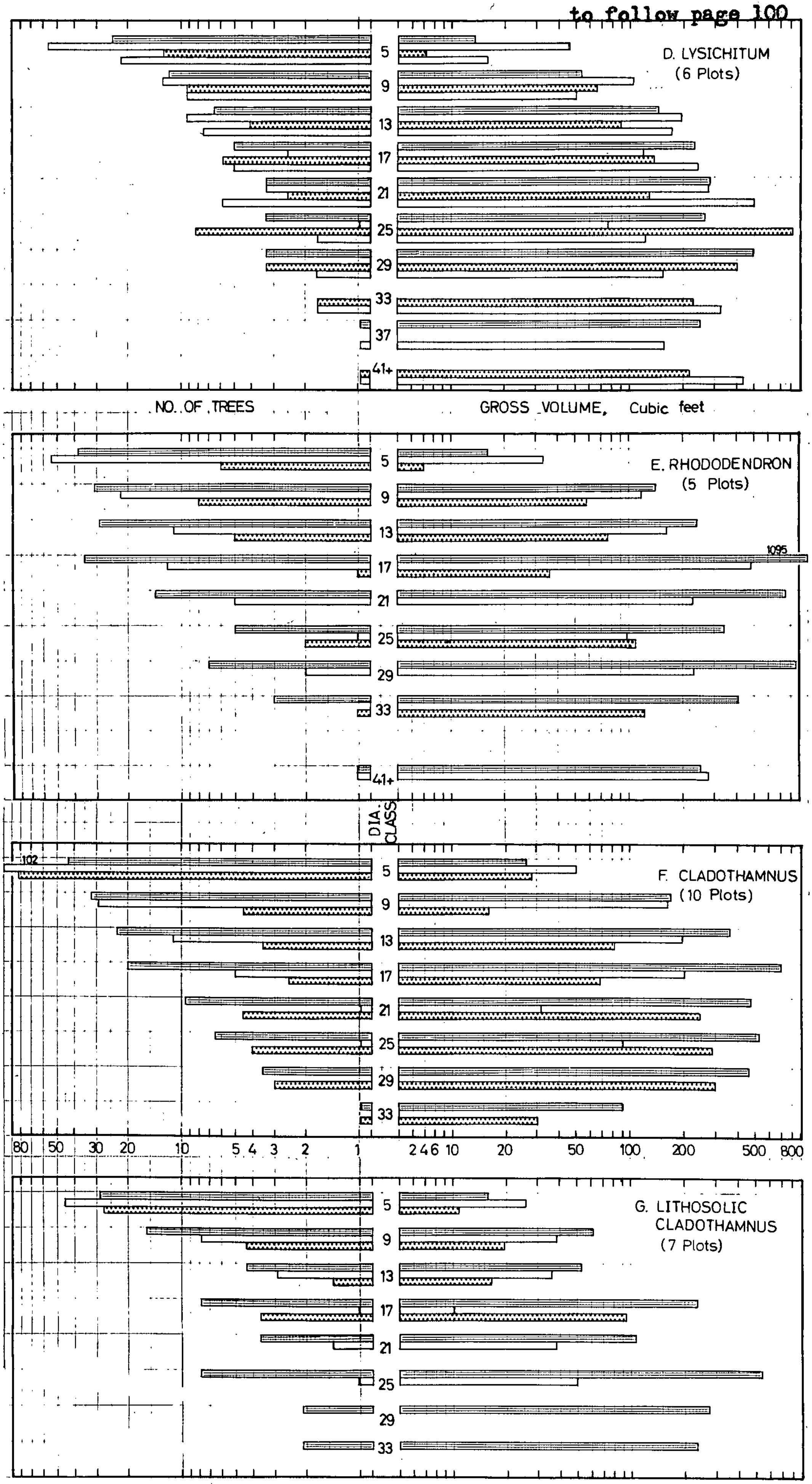

Figure 25. continued

B. Life-forms

Raunkiaer's life-form system, as modified by Krajina (1933) and used by Orloci (1961), served to group the species of the study area as follows:

Macrophanerophytes (Pm)	Chamaephytes (Ch)	Lichens (L)
Deciduous nanophanerophytes (Pnd)	Hemicryptophytes (H)	Bryophytes (B)
Evergreen nanophanerophytes (Pne)	Geophytes (G)	

Life-forms were weighted by total cover degree with the same scale as used by Orloci (1961), and the results are directly comparable to those in the Coastal Western Hemlock Zone (Table XIII, Figures 26 and 27).

The most striking feature when one considers the number of species in each life-form is the absence of therophytes (T) in all associations of the zone. In the comparison of associations, hemicryptophytes are most numerous on the four wettest associations. Geophytes are few throughout the whole zone and are absent on the Carex nigricans association where the growing season is too short for the successful growth of species which must rejuvenate from below ground surface every year. The number of lichens is greatest in the dry and mesic associations of the upper subzone (Figure 26).

The physiognomy of each association is more clearly portrayed when life-forms are weighted by total cover degree (Figure 27). Macrophanerophytes have an obvious concentration in the associations near the lower limits of the zone. Deciduous shrubs are most abundant on the Cladothamnus, Vaccinium membranaceum - Rhododendron and Vaccinium alaskaense associations, and evergreen nanophanerophytes are important only on the chionophilous associations of the upper subzone. Based on cover degree, geophytes are important only on the subalpine Lysichitum and Oplopanax associations where there is abundant seepage. The high proportion of hemicryptophytes on the moist and wet Carex nigricans, Leptarrhena - Caltha, and Eriophorum - Sphagnum associations sharply differentiates them from adjacent associations on drier habitats.

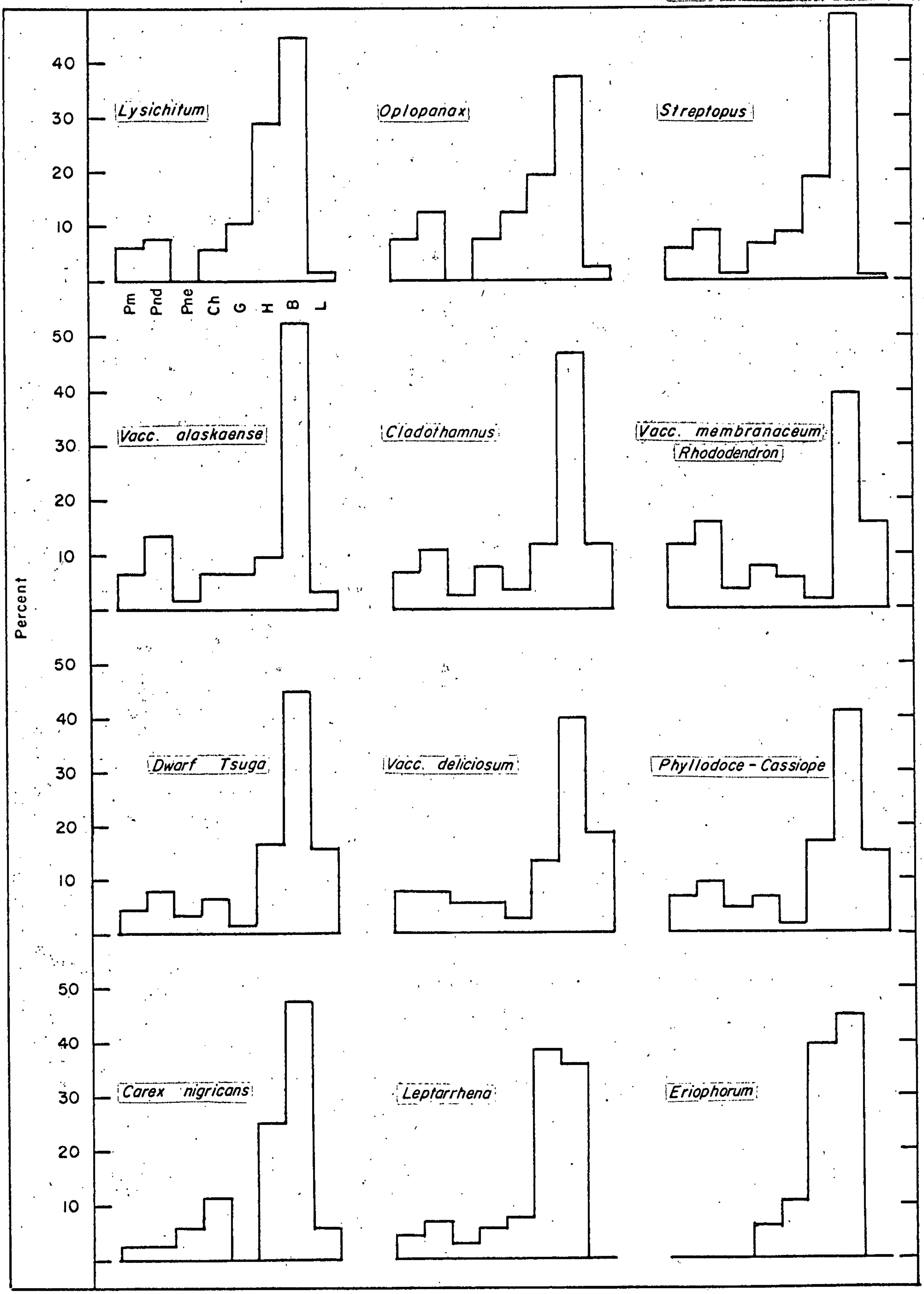

Figure 26. Percentage distribution of 8 life-forms on each association, by number of species.

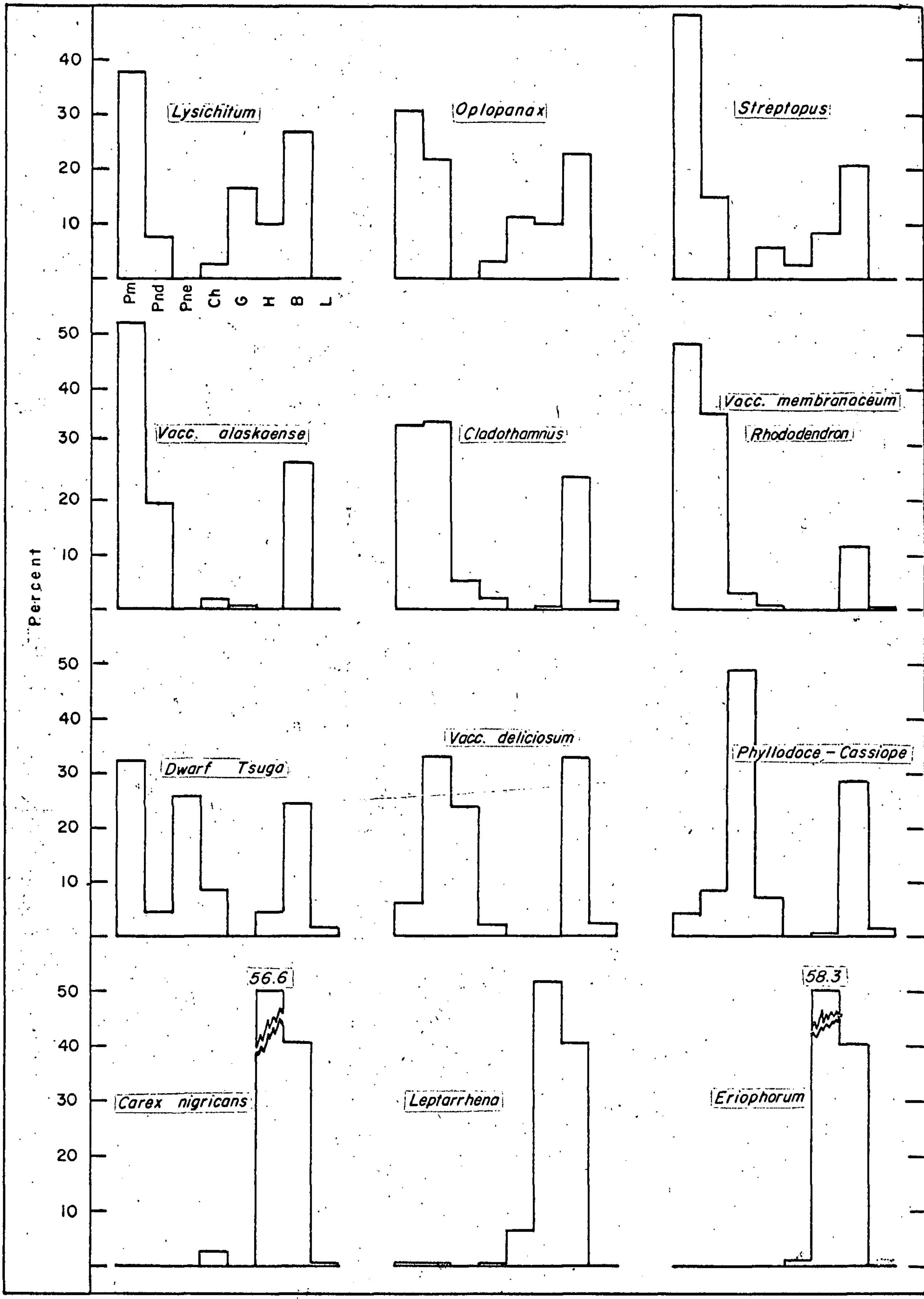

Figure 27. Percentage distribution of 8 life-forms on each association, weighted by total cover degree.

When bryophytes are considered collectively as one life-form, there are no great differences between associations (Table XIII). Therefore, humicolous bryophytes were further categorized into growth-forms in an attempt to reveal further floristic differences in the habitats.

Closeness of the entire moss plant to the habitat surface is considered to give bryophytes high sensitivity to changes in substrate or microclimate. This has been recognized by ecologists for some time, but bryophytes have usually been considered on an individual species basis. Only recently have there been demonstrations of correlations between growth-forms and habitat (Giningham and Birse 1957). All species identified from the Coastal Subalpine Zone were grouped into the following growth-forms (see Checklist, Appendix I).

(1) Cushions (Cu) - compact, dome-shaped groups.

(2) Tall turfs, branches erect (Te) - parallel, upright shoots over 2 cm.

(3) Tall turfs, divergent branches (Td) - laterals whorled or scattered.

(4) Short turfs (t) - as (2), but under 2 cm.

(5) Mats (M) - horizontally interwoven shoots.

(6) Thread-like forms (Mt) - as (5), but delicate and sparsely branched.

(7) Thalloid mats (Th) - as in thalloid liverworts.

(8) Wefts (W) - Luxuriant and loosely intertwined shoots.

The growth-forms of humicolous bryophytes are presented for each association in Table XIII. There was no statistical evaluation of differences, but some correlations of growth-form with habitat are distinguishable. Cushions are absent from the table because only humicolous species were classified. The amount of exposed rock increases with altitude and the proportion of cushions, as represented by the genera Andreaea and Grimmia, is greater in the upper subzone because they are restricted to rock surfaces. Mats, which are abundant in shaded habitats at lower altitudes, are unimportant in the Subalpine Zone and are absent from late snow-patch associations. There are few species classed as wefts, but the widespread occurrence of Rhytidiopsis robusta gives this group a high total cover degree in the forested associations of the lower subzone. There is a marked increase in the total cover by short turfs with increasing altitude, and the group is best represented by Polytrichum norvegicum beneath late snow-patches. Thalloid mats are restricted to moist seepage associations, and the tall turfs with divergent branches occur only on areas of plentiful seepage or poor drainage.

The correlations of growth-form with habitat, even if subjective, are in agreement with those reported by Horikawa and Ando (1952) and Gimingham and Birse (1957). If the ecological significance of growth-forms were more carefully examined, it may be possible to use bryophytes as ecological indicators without requiring precise species identification. This would encourage their use in practical ecological investigations.

CHAPTER VI

RELATIONSHIPS AND SUCCESSIONAL DEVELOPMENT OF ASSOCIATIONS

The development and transformation of plant associations can be most clearly understood from long-term observations of specific vegetational units. In the absence of this ideal, much must depend upon circumstantial evidence such as the presence of invading species. Fortunately, in subalpine and alpine areas there are more bare initia than at lower altitudes and in the upper subzone it is possible to observe the origin and early development of associations on a variety of habitats. A problem in the upper portions of the Subalpine Zone is that the time since glaciation is so short that development towards a 'vegetational climax' is probably not very well advanced. In the lower subzone, there has been greater development towards a uniform forest on mesic habitats, with the result that earlier stages of development are already obscured. This chapter proposes hypothetical developmental changes which may be expected in the associations of the upper and lower subzones. The upper subzone is discussed first to provide details of early stages which are less clearly revealed at lower elevations in the zone.

In this chapter, a 'climax' association is depicted for each subzone as the successionally most advanced type of vegetation now existing under mesic conditions. The earliest steps in succession, which were not studied in detail, are referred to as 'stages', and within the limits of some associations developmental 'phases' are recognized (Braun-Blanquet 1932).

Present altitudinal distribution of the various associations provides indirect information on actual and potential successional trends within the Subalpine Zone. As a guide to the discussion which follows, the altitudinal range of each association, based on the distribution of sample plots in this study, is shown in Figure 28. Associations which are known to occur above or below the altitudes sampled by plot are extended by broken lines. The occurrence of associations at lower altitudes in the Seymour - Grouse - Hollyburn study area than in Garibaldi Park is clearly shown (Figure 28).

Present topographic position of various associations in relation to one another also gives circumstantial evidence of developmental trends in the vegetation. A topographic sequence of the main associations in the upper subzone and their relation to duration of snow cover is shown in Figure 29. Vegetational differences associated with the environmental gradient of decreasing snow duration in Figure 29 indicate potential successional changes if there should be, for example, macroclimatic changes that would cause a decrease in average annual snow duration.

The proposed successional trends are diagramatically summarized in Figure 30. This figure should not be interpreted too literally. In some cases, the length of the lines separating units imply only typographical convenience, and where the lines are accompanied by a question mark one or more unknown developmental stages have been omitted. Increasing elevation is implied from left to right in the figure, and increased vegetational development is indicated from bottom to top. The various initia and the pioneer associations on them are placed near the bottom of the page, whereas the most successionally advanced associations for the two subzones and for the Alpine Zone appear as 'climaxes' near the top. Altitudinal ranges of the 'climax' associations are shown separately for the portion of the study area which includes Seymour, Grouse, Hollyburn and Cathedral Mountains and for that which includes Paul Ridge and Diamond Head in Garibaldi Park. Convex glacial drift initia are afforded the highest position in the chart because vegetational development is most rapid there. For example, mountain hemlock may grow

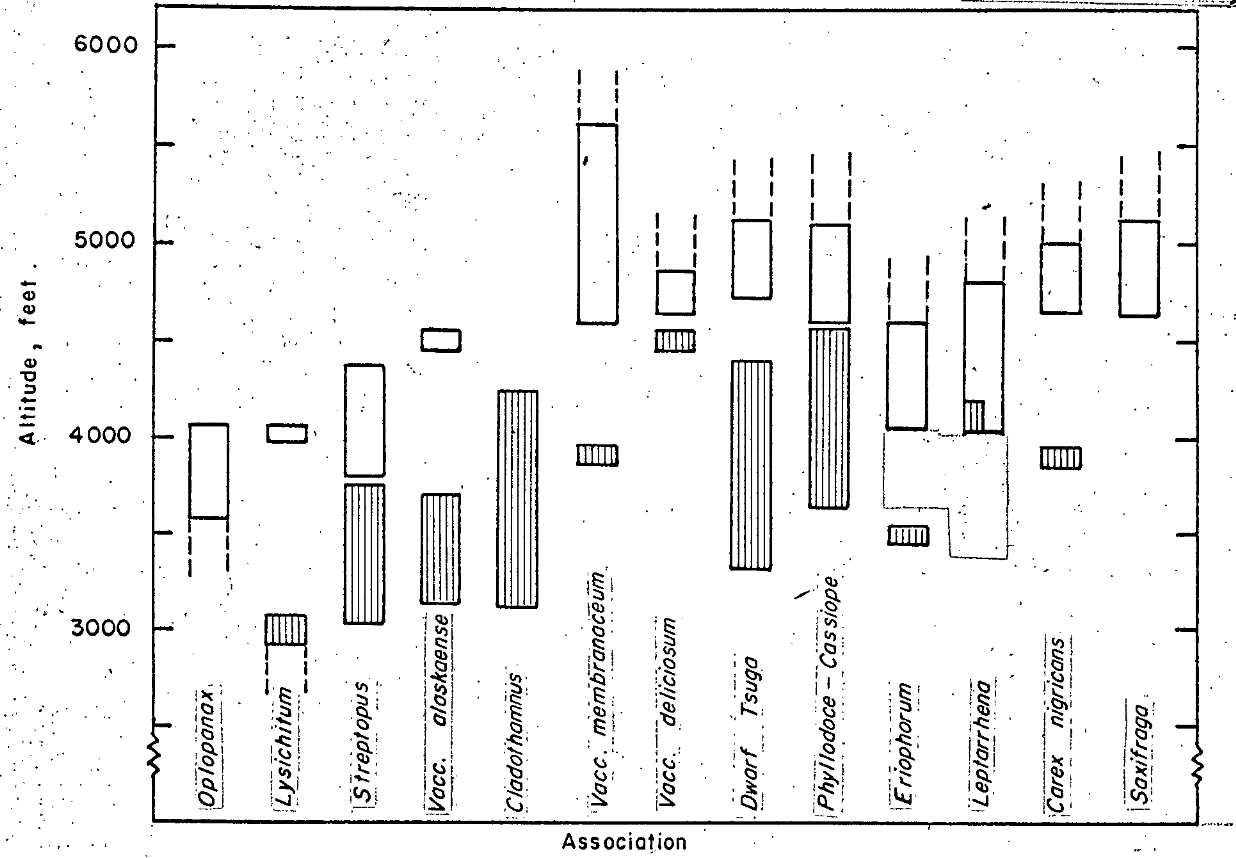

Figure 28. Altitudinal distribution of sample plots, by association, for Seymour-Grouse-Hollyburn study area (lined bars) and for Garibaldi study area (open bars)

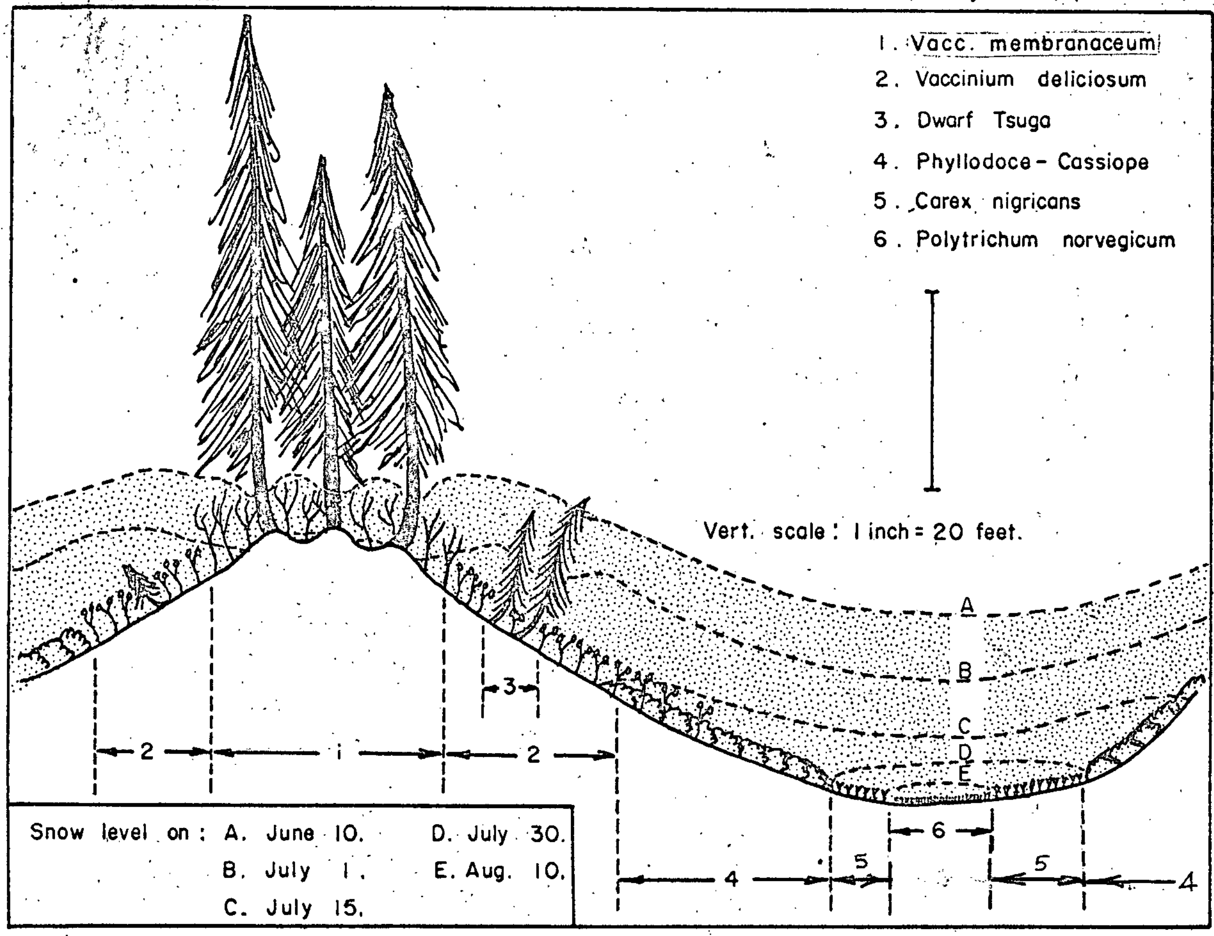

Figure 29. Topographic sequence of some associations and their relation to duration of snow cover.

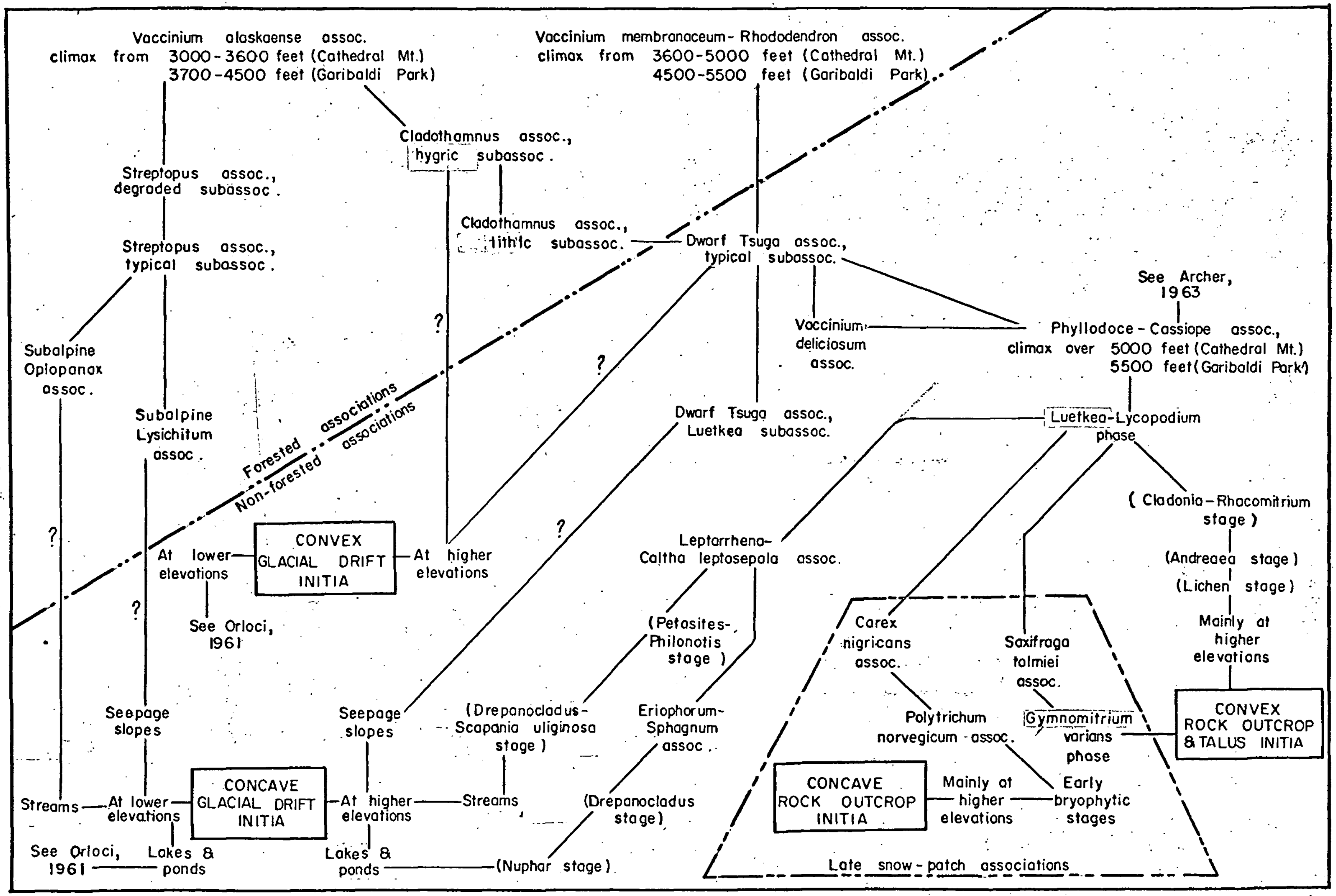

Figure 30. Successional trends in the Coastal Subalpine Zone, Southern British Columbia.

to follow page 105

directly as a pioneer on morainal material and a multi-layered association may develop in a short time. Concave initia, if covered by water, pass through a much longer period of development before they are occupied by complex terrestrial associations and are, therefore, placed near the bottom of the page. This generalization does not apply, of course, to concave glacial drift seepage slopes where vegetational colonization and development may be relatively rapid. Because rock outcrop initia are more widespread at higher elevations, they are placed to the right of the chart. Development is extremely slow there, especially in concave areas where the greater snow accumulation allows a growing season of only a few weeks.

A. Upper Subzone

Non-forested associations outnumber those with trees in the upper subzone because of the short time since glaciation and because of the high annual accumulation of snow which prevents forest development. This allows ready recognition of several distinct initia.

On convex rock outcrop and talus initia, early stages of development are indicated by Rhizocarpon geographicum, Pilophoron hallii, Cetraria hepatizon, Umbilicaria phaea, U. torrefacta and Lecidea spp. especially on the most exposed rock surfaces. These exposed rock surfaces are the most xeric habitats in the Subalpine Zone. Rocks which are covered with snow for 9 to 10 months of the year are less xeric and are colonized by bryophytes rather than lichens. Andreaea nivalis is the most abundant species in such cases. Weathering products from the rock surfaces and organic accumulations from bryophytes and lichens allow colonization by additional species, and when Cladonia and Rhacomitrium species are well established on such surfaces, chamaephytic species are able to invade.

Surface accumulations of wind-borne mineral and organic matter on late snow-banks result in the formation of deeper soil profiles in depressions. On side slopes of the depressions, soils are shallower and are composed very largely of organic matter. These soil differences correlate strongly with vegetation differences but one does not necessarily explain the other. Major (1961) stressed that both vegetation and soil differences can be correlated with environmental variables of the ecosystem. In concave areas of the upper subzone, snow duration is the most important environmental variable controlling the vegetation, and its relation to the present distribution of some associations is shown in Figure 29.

Gjaerevoll (1950), Dahl (1956), and Churchill and Hanson (1958) warned that the dynamic approach to vegetation problems is unpromising in stable communities where autogenic influences are limited by a factor such as snow duration. Dahl (1956) pointed out that no succession can take place between vegetation zones around such snow-patches because the climate is relatively constant and because developmental changes in the vegetation will not alter the over-riding ecological factor, the effect of snow cover. He suggested that the problem should be attacked by describing the vegetation in different zones and relating the differences to environmental factors. If the important environmental factors can be influenced by the activity of the plants, dynamic relationships will emerge.

These precautions apply more to the Alpine Zone (Archer 1963) where the controls by snow are strongest. In the Subalpine Zone, most snow patches disappear early enough to allow Carex nigricans to develop, and purely bryophytic associations are absent. Marginal invasion of chamaephytes such as Luetkea pectinata and Lycopodium sitchense can be observed in Carex nigricans associations. These chamaephytes are recognized as an early phase of the Phyllodoce - Cassiope association, and their creeping habit allows them to expand into areas of Carex without any particular preparatory change in the habitat. Marginal clumps of Phyllodoce and Cassiope are also able to invade Carex areas providing there is not a sharp environmental gradient of increasing snow duration (see Plate II, E).

A third line of development takes place at higher elevations on convex slopes of unconsolidated material. Colluvial movement and erosion may hinder the success of pioneer species on such areas, but species of high sociability such as Gymnomitrium varians can withstand the instability by moving downslope with the soil (Plate II, F). Larger stones, which have a slower rate of movement on such slopes, provide a small area of greater stability on their lower side. Saxifraga tolmiei, Luzula wahlenbergii, and occasionally Tsuga mertensiana or Phyllodoce empetriformis, can establish on the lower side of such obstructions (Plate III, E), but orientation of the vegetation in a clustered downslope pattern, rather than a continuous pattern, testifies to the active downward movement of the surface soil. The pioneer species on such areas have an autogenic influence in the consolidating, rather than constructive, sense (Braun-Blanquet 1932).

Small subalpine ponds will gradually close in as a result of silt accumulation or from marginal organic accumulations. Drepanocladus exannulatus and Carex aquatilis are the first important constructive species because they are able to grow successfully below water (Plate II, B). Anaerobic conditions retard decomposition with the result that organic matter and organic acids accumulate here. This allows the invasion of Sphagnum and other moor species. Only five Eriophorum - Sphagnum areas were encountered in this study, and they were so floristically variable that a proper synthesis was impossible. Species composition indicated a transition to the Leptarrhena - Caltha association in one case, and towards Carex spectabilis in other cases. Dahl (1956) denied the development of similar moors into communities of dryland succession. He stated that an equilibrium stage is reached at a certain thickness of peat which is determined by climate. Successional relationships of this moor association are unclear for this study area without further investigations.

A distinct association develops on the margins of subalpine streams and on areas of abundant seepage. Drepanocladus exannulatus and Scapania uliginosa grow submersed in streams, and on the immediate margins of the streams Philonotis fontana and Petasites frigidus predominate. These are early stages which will develop towards a moist, herbaceous Leptarrhena - Caltha association, as organic matter accumulates and raises the surface of the habitat further above the level of the stream. This development will be favoured in sluggish streams with low erosive power. There are small ravines in the Subalpine Zone which were formerly drained by temporary surface streams and which are now occupied by a platform of Leptarrhena pyrolifolia, Caltha leptosepala and other herbs. Seepage is abundant but there is no surface movement or accumulation of water after Leptarrhena pyrolifolia is established. This association is flanked by the same chamaephytes which invade other early associations.

The foregoing paragraphs and the lines in Figure 30 indicate at least four avenues by which early associations may hypothetically develop towards the Luetkea - Lycopodium phase of the Phyllodoce - Cassiope association. In all cases, development is extremely slow. This is clearly shown in Plate III, F where secondary succession has covered only half of the bare ground surface 16 years after the Carex nigricans sod was removed for roofing material. All of the associations discussed to this point are more typically alpine, but they form an important part of the subalpine mosaic of vegetation and must be considered as preliminary stages in the development of the more complex subalpine associations.

At altitudes of approximately 5000 feet and over (5500 feet in

Garibaldi Park), mesic habitats are occupied by the Phyllodoce - Cassiope association. This is a good example of an association which assumes distinctly different positions in the developmental sequence in the two different bioclimatic zones. In the Alpine Zone, succession will not advance beyond this association on mesic habitats; in the Subalpine Zone it is only an intermediate stage in the development towards forested associations. This difference is related to the occurrence of this association on two distinct topographies in the two bioclimatic zones, as discussed in Chapter IV.

The remaining associations in the upper subzone are distributed in narrow biotic zones as shown in Figure 16, 17, 18, 19 and 29, or over broader areas where there are differences in snow duration as a result of exposure or topographic configuration. The Vaccinium deliciosum association occurs in an intermediate position between the Phyllodoce - Cassiope association and the more highly developed associations along gradients of snow duration (Figure 17), but it is usually very restricted in size and distribution. This environmentally controlled zonation need not imply that Vaccinium deliciosum is a necessary successional stage after Phyllodoce and Cassiope. Autogenic changes in the Phyllodoce - Cassiope association do not necessarily make the habitat more suitable for Vaccinium deliciosum; if they did, this species would be more widespread in the upper subzone. Environmental influences that would lessen snow duration are the main potential changes that would favour Vaccinium deliciosum.

Development from the Phyllodoce - Cassiope association towards one with larger life-forms and with a greater diversity of species is occurring in many parts of the upper subzone (Plates I, F and II, C). This particular stage of subalpine succession has already been discussed in detail by Brink (1959) and similar development was noted by Vechten (1960) in the Central Oregon Cascades where mountain hemlock forest is advancing slowly into meadows and some other areas. Brink (1959) discounted the influence of warming from larger trees because in many areas where dwarf mountain hemlock is invading the nearest mature trees are several hundred yards away and the short hemlock has little or no influence on snow duration until tree height exceeds late spring snow depths (5 to 10 feet). Both of the above authors considered the establishment of short trees in the subalpine heath to be a reflection of climatic moderation over the last one or two centuries. There is no reason to doubt this hypothesis on the basis of observations in the present study.

The invasion of mountain hemlock into Phyllodoce - Cassiope areas marks an important stage in development. Tree species, even if extremely slow-growing, can create conditions detrimental to pre-existing species. Cassiope mertensiana is strongly shade intolerant and will decrease in significance and vigour as mountain hemlock increases. Conversely, the increased protection will encourage species such as Rhytidiopsis robusta, Vaccinium membranaceum and occasionally Rubus pedatus. Mountain hemlock is the first species in the successional sequence with the ability to influence microclimate by hastening snow-melt in late May and June. This influence encourages Vaccinium membranaceum and allows the invasion of Rhododendron albiflorum. Vaccinium membranaceum is the most successful of these two species in places where the humus remains relatively undeveloped. This species was observed on a few occasions, especially in the Luetkea subassociation of the dwarf Tsuga association where moisture is abundant, to survive even on bare mineral soil. Rhododendron albiflorum requires a deep, acid raw humus and it grows best on the large humps of organic matter which occur around clumps of trees in the upper subzone. The unusual restriction of the Vaccinium membranaceum - Rhododendron association (Plate I, E) suggests that it is a topographic climax (Daubenmire 1943) near its upper limit, whereas at lower elevations in the upper subzone this association is the most mature type of vegetation on mesic habitats (Plate III, C).

It is not well distributed yet in the higher limits of the upper subzone because the great snow accumulation restricts it to certain topographic situations there.

On Mount Seymour, the Vaccinium membranaceum - Rhododendron association contains little or no Rhododendron albiflorum, because this is more typically an interior subalpine species. It is noticeably more abundant in the Garibaldi Park area which is further inland. To some extent, the same applies to Vaccinium membranaceum which is a frequent species of interior subalpine areas (Arlidge 1955), but it is more frequent in coastal areas than is Rhododendron albiflorum.

The pattern of vegetation in the upper subzone on Mount Seymour is a mosaic of the lithic Cladothamnus subassociation which occurs on topographic prominences, fragments of the Vaccinium membranaceum - Rhododendron association, and the Phyllodoce - Cassiope and dwarf Tsuga associations. The abundant dwarf mountain hemlock in this part of the study area is an indication that, with time, forested associations will be more widespread in the upper part of the Subalpine Zone.

The lithic Cladothamnus subassociation, which was described as a dry edaphic component of both subzones, is mainly restricted to the Seymour - Grouse - Hollyburn study area. It is not present on the Quaternary dacitic volcanics or on the older metavolcanic rocks of Paul Ridge and Diamond Head (Figure 4). This may reflect a parent material influence on the distribution of Cladothamnus pyrolaeflorus, because Paul Ridge is not beyond the range of this coastal species; it was encountered again on the Cloudburst quartz diorites (Mathews 1958) further inland near Mamquam Lake in Garibaldi Park.

The high proportion of Phyllodoce, Cassiope, Vaccinium deliciosum and lichens on the lithic Cladothamnus subassociation indicates its affinities to earlier stages of development in the upper subzone. However, further development of this subassociation is hindered by its confinement to exposed, dry ridges or prominences.

B. Lower Subzone

During Pleistocene glacial recession when some portions of the Subalpine Zone were still covered with mountain glaciers, early successional stages similar to those described above were probably evident in the lower subzone. Important differences would have been a thicker mantle of drift, more extensive areas of drift initia, and fewer bare rock initia in the lower subzone. These differences, combined with presently smaller annual accumulations of snow and a longer time since glacial recession, have allowed more complex associations to develop here than in the upper subzone.

On dry habitats, which are now occupied by the lithic Cladothamnus subassociation, successional changes towards the hygric Cladothamnus subassociation and the Vaccinium alaskaense association occur as organic accumulations and continuing weathering processes deepen the soil. Because of the restriction of the lithic Cladothamnus subassociation to upper portions of convex slopes, moisture from lateral seepage is not plentiful but the development of an impervious layer in the soil profile makes moisture from precipitation more effective.

Early stages of development in seepage habitats are now obscure. However, the presence of subalpine and alpine species (Senecio triangularis, Parnassia fimbriata and Valeriana sitchensis) in Lysichitum sites of the lower subzone indicates that this association is a more highly developed and forested counterpart of the wet Leptarrhena - Caltha association of the upper subzone (Table VIII). The associations on seepage slopes or adjacent to open streams contain the greatest numbers of species, but such associations in the lower subzone are much richer in species than their upper subzone counterparts.

This is partly a result of climatic differences, but there are probably also edaphic changes with altitude on such habitats. Wilcox et al. (1957) found for both stream water and seepage water that it had a higher pH and a higher salt content than did water in the same drainage basin at higher elevations. These chemical changes would encourage additional species of autogenic importance in seepage habitats at lower elevations.

In moist and wet habitats there is a progressive trend towards better drainage similar to that described by Orloci (1961) and Lesko (1961), and development in the lower subzone leads towards the mesic _Vaccinium alaskaense_ association (Figure 30). With increased humus accumulation and greater soil maturation the lower subzonal climax association may be able to develop at higher altitudes within the zone in the future. However, such an altitudinal extension would probably also require macroclimatic changes because snow accumulations at present impose strong altitudinal limitations on certain species and associations.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Of the 90 forest sections described for the forest regions of Canada (Rowe 1959), the briefest description is given for the Coastal Subalpine section of British Columbia. This brevity reflects the paucity of published information on tree species and cover types of the section. The strong climatic and topographic controls of vegetation patterns and succession, the great physiognomic variety of associations and the undisturbed natural vegetation make the Subalpine Mountain Hemlock Zone an excellent area for studies of land, vegetation and climatic relationships. The main purposes of this thesis were to describe the vegetation and to determine the most important climatic controls of zonal limits, tree distribution, biotic zonation and vegetational development. Most of the data presented will serve as basic information for future detailed studies and will allow floristic and climatic comparisons to be made with other bioclimatic zones. The main findings of the study are summarized and discussed below.

(1) The Subalpine Mountain Hemlock Zone in southern British Columbia cannot be precisely defined altitudinally because its upper and lower limits may vary as much as 1000 feet through topographic and climatic influences. In this study, the zonal limits were placed at 3000 feet and 5000 feet in the Seymour - Grouse - Hollyburn - Cathedral Mountain area near the Strait of Georgia, and at 3700 feet and 5500 feet in the Paul Ridge - Diamond Head portion of Garibaldi Park. Thirty-seven per cent of the land area may be classed as subalpine in the physiographic unit between Howe Sound, Burrard Inlet and the Indian River.

(2) Various biological limits of mountain hemlock may be used to delineate and subdivide the zone. The sharp lower limit of this species is

considered the lower limit of the Subalpine Zone. The lowest 600 to 800 feet of the zone are covered with continuous forest of mountain hemlock, amabilis fir, yellow cedar and western hemlock. This continuous forest is designated as the lower subzone; thus, the upper 'forest limit' is a criterion for subzonal delineation. The upper limit of the zone is marked by the altitudinal 'tree limit' of mountain hemlock. This definition makes cartographic designation of the upper limit difficult because trees extend upward into the Alpine Zone in an interdigital pattern on favourable exposures. The irregular upper limit to the Subalpine Zone is in distinct contrast to its relatively sharp lower limit.

(3) Temperature characteristics for various altitudinal levels were determined, in part, from analyses of radiosonde data which give the altitude of the freezing isotherm (Chapter III). From such data it is possible to determine the frequency of freezing temperatures for any period of the year, and the approximate length of the frost-free season, for any altitude on a mountainside (Figure 14). To obtain equivalent information by conventional methods would require an expensive network of instruments closely spaced over a broad altitudinal range. If published radiosonde temperature data are used in combination with recently developed methods of synoptic precipitation analysis (Walker 1961), it is possible to obtain reliable temperature and precipitation data for inaccessible mountain areas.

(4) Degrees along a temperature scale may ordinarily be considered as a continuum as far as their direct influence on plant life is concerned. However, the physical changes that occur at the freezing point of water disrupt the temperature continuum at this point. This is especially significant in areas of high precipitation where freezing temperatures of a certain frequency will cause snow accumulations that greatly shorten the growing season for plants. Radiosonde data from Port Hardy, British Columbia, indicate that in winter the

freezing isotherm most frequently occurs at altitudes within the lower half of the Subalpine Zone (Chapter III). A climatic result is a sharp increase in snow duration near the altitudinal lower limit of mountain hemlock; an ecological result is the relatively sharp delineation between the Subalpine Mountain Hemlock Zone and the Coastal Western Hemlock zone.

(5) Temperature is more reliable here as a control of zonal boundaries than it is in other bioclimatic zones of British Columbia, because of the physical changes that occur at freezing point and because of the modal concentration of the freezing isotherm in a certain altitudinal band on a mountain-side (Figure 15).

(6) The irregular upper boundaries of the zone are a result of topographic influences on snow accumulation and duration. Snow accumulation increases with altitude so that near the tree limit mountain hemlock can grow only on prominences or ridges where snow accumulation is less, or on warmer exposures where the snow melts more quickly.

(7) Most of the zonal features of the vegetation can be related to the intensity, quantity and duration of snow. Small-scale biotic zonation and distribution of associations are closely related to topography through its influence on snow duration (Figures 16, 17 and 29).

(8) On the unforested associations in the upper subzone where snow is the dominant environmental influence, autogenic changes are slight. Only when mountain hemlock reaches a height greater than the May and June snow levels (5 to 10 feet) can this species have an influence by hastening snow melt and lengthening the growing season. This influence is best developed around the sporadic clumps of larger trees in the upper subzone. The combined influences of snow interception by the crowns and greater melting near the clumps because of greater heat absorption result in an important lengthening of the growing season around these clumps (Plate I, D). Subalpine species which require a

snow-free season of at least three months, such as Vaccinium membranaceum and Rhododendron albiflorum, are largely confined to such biotically created openings in the snow cover or to exposures which favour early melting of the snow.

(9) There are strong altitudinal influences on tree growth in the Subalpine Zone. Site index is nearly always less than 100 feet at 100 years, and is often less than 50. Although tree heights are much reduced with increasing altitude, diameters at breast height do not show a proportionate decrease. The result is a marked increase in taper of tree trunks with increasing altitude (Chapter III).

(10) Snow creep, particularly on steep slopes, causes many trees in the small diameter classes to have a basal snow-crook. Mountain hemlock and yellow cedar are most strongly affected by this deformation probably because they retain more branches near the ground than amabilis fir does. These lower branches provide a greater surface area against which the forces of snow can act (Chapter III).

(11) On the basis that a fully turgid plant is in the most satisfactory condition for growth and other physiological responses (Kramer and Kozlowski 1960), amabilis fir growing on an exposed rock outcrop area at 4000 feet in the upper subzone is more vigorous than that in a more heavily forested site at a lower elevation (Figure 24). This statement is based on relative turgidity readings of needles from branches near ground level. In the coastal Subalpine Zone, melting snow provides soil moisture often into July and precipitation is sufficient during the remainder of the growing season so that even trees growing on shallow soils of sites with no permanent seepage can maintain a high relative turgidity. By contrast, root competition may be such for trees in a shaded forest stand that they actually have relative turgidity values lower than open-grown trees on supposedly drier sites (Chapter III). These relationships should be tested further by measurements from the upper

tree crown where the influences of suppression and shading could be eliminated.

(12) Early stages of vegetational development are still evident on several types of initia in the upper subzone because of the relatively short time since glaciation and because of limitations in vegetational development imposed by the long annual duration of snow.

(13) Most early stages of vegetation appear to develop towards the Phyllodoce - Cassiope association. At altitudes of 5000 or 5500 feet and over (Alpine Zone) this will remain as the successionally most advanced association on mesic habitats where the relief is flat or convex and without seepage. In contrast, this same association occupies concave topographic positions with temporary seepage in the Subalpine Zone. As a result of its occurrence on two distinct topographies in the two bioclimatic zones, the Phyllodoce - Cassiope association is chionophobous in the Alpine Zone but moderately chionophilous in the Subalpine Zone, when considered in relation to adjacent associations. However, in the two different zones snow duration is actually approximately the same for the association because of the different topographic positions which it occupies. These differences indicate that topography is not always reliable as a basis for ecological classification unless the influences of macroclimate are also taken into account.

(14) The Vaccinium membranaceum - Rhododendron association most closely approximates 'climax' conditions in the upper subzone (Figure 30). In altitudes where it is best developed it occupies mesic habitats (Plate III, C), but near its upper limit in the Alpine Zone this association becomes a 'topographic climax' (Daubenmire 1943) restricted to warmer exposures or to ridges between the areas of Phyllodoce and Cassiope (Plate I, E).

(15) Some species from the Coastal Western Hemlock Zone occur in the lower subzone in combination with characteristic subalpine species. This combination of species floristically differentiates the lower subzone from the

adjacent Western Hemlock Zone and from the upper subzone (Table VI). The mesic Vaccinium alaskaense association is the most representative of 'climax' development for the lower subzone. However, even if a distinct 'climax' association is recognized for the lower portions of the Subalpine Zone, there are no tree species limited specifically to this subzone so that it cannot be easily designated as a separate bioclimatic zone.

(16) In the lower subzone, early successional stages which have lead to the Vaccinium alaskaense association are more obscure than are early stages in the upper subzone. The presence of subalpine and alpine herbaceous species in Lysichitum sites of the lower subzone indicate that this association is a more highly developed and forested counterpart of the wet Leptarrhena - Caltha association of the upper subzone (Table VIII).

(17) The ability of certain species to transcend their usual altitudinal range along mountain streams or on slopes of abundant seepage (Table VIII) indicates that edaphic controls may sometimes over-ride the influences of macroclimate and altitude. This is also one reason why much of the Subalpine Zone is a mosaic of subalpine and alpine associations.

(18) Floristic data collected in this study are presented in the appended synthesis tables. As suggested by Moore (1962) these tables, as presently organized, are merely working hypotheses to be tested by further work.

(19) Mensurational data indicate that subalpine areas in south coastal British Columbia are of limited use for wood production. Extreme inaccessibility further limits utilization, with the result that recreation and watershed management are the principle land-uses for the area. Subalpine areas are particularly important for watershed protection because mountain hemlock grows mainly in areas of high watershed value (Dahms 1958) and natural mountain hemlock forests have a spacing which is thought to be optimum for snow catch and snow release (Church 1942). For these reasons alone, an understanding of ecological conditions in the Subalpine Mountain Hemlock Zone is important.

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APPENDIX I

Checklist of Vascular Plants from the Subalpine Zone

Checklist of Lichens from the Subalpine Zone

Checklist of Bryophytes from the Subalpine Zone

Checklist of Vascular Plants from the Subalpine Zone, (collected from 2900 feet to 6000 feet above sea level, between latitude 49°22' and 49°56' and longitude 122°56' to 123°12', north of Vancouver, B. C.)

Species are grouped into major life-form categories for three approximate altitudinal levels: (1) Species of lower elevations that occur also in the lower portions of the subalpine zone; (2) subalpine species; and (3) species of the subalpine-alpine transition. These three categories are not precisely defined, so that the placing of a species in one does not necessarily preclude its occurrence in another. Nomenclature and authorities for the names are those given in the manuals that were used for identification. Publications that were used for this purpose are listed in a separate section of the bibliography.

(1) Species of lower elevations that occur also in the subalpine zone:

MACROPHANEROPHYTES (MP)

Abies amabilis (Dougl.) Forbes
Picea sitchensis (Bong.) Carr.
Pinus contorta Dougl. ex Loud.
Pinus monticola Dougl.
Pseudotsuga menziesii (Mirb.) Franco
Sambucus pubens Michx.
Taxus brevifolia Nutt.
Thuja plicata D. Don.
Tsuga heterophylla (Raf.) Sarg.

NANOPHANEROPHYTES - deciduous (NPd)

Alnus crispa (Ait.) Pursh. ssp. sinuata (Regel) Hult.
Amelanchier alnifolia (Nutt.) Nutt.
Lonicera utahensis S. Wats.
Menziesia ferruginea Smith
Oplopanax horridus (Smith) Miq.
Ribes bracteosum Dougl.
Ribes lacustre (Pers.) Poir.
Rubus spectabilis Pursh
Vaccinium alaskaense Howell
Vaccinium membranaceum Dougl. ex Hook.
Vaccinium ovalifolium Smith
Vaccinium parvifolium Smith

CHAMAEPHYTES (CH)

Cornus canadensis L.
Gaultheria ovalifolia Gray
Kalmia polifolia Wang.
Linnaea borealis L.
Lycopodium clavatum L.
Lycopodium selago L.
Moneses uniflora (L.) A. Gray
Pyrola secunda L.
Rubus pedatus J. E. Smith

Selaginella wallacei Hieron.
Vaccinium uliginosum L.

HEMICRYPTOPHYTES (H)

Adenocaulon bicolor Hook.
Adiantum pedatum L.
Agrostis aequivalvis Trin.
Agrostis alba L.
Agrostis exarata Trin.
Agrostis idahoensis Nash
Agrostis scabra Willd. var. geminata (Trin.) Swallen
Agrostis thurberiana Hitchc.
Anaphalis margaritacea (L.) B. & H.
Athyrium filix-femina (L.) Roth.
Blechnum spicant (L.) Roth.
Botrychium multifidum (Gmel.) Rupr.
Boykinia elata (Nutt.) Greene
Calamagrostis canadensis (Michx.) Beauv.
Campanula rotundifolia L.
Carex ablata Bailey
Carex aquatilis Wahl.
Carex hoodii Boott.
Carex laeviculmis Meinsh.
Carex physocarpa Presl.
Claytonia sibirica Pursh
Coptis asplenifolia Salisb.
Dryopteris austriaca (Jacq.) Woynar
Elymus glaucus Buckl.
Epilobium angustifolium L.
Galium triflorum Michx.
Goodyera oblongifolia Raf.
Heuchera glabra Willd.
Hordeum brachyantherum Nevski
Juncus effusus L.
Juncus filiformis L.
Luzula parviflora (Ehrh.) Desv.
Melica smithii (Porter) Vasey
Mimulus guttatus DC. var. depauperatus (Gray) Grant
Mitella breweri Gray
Mitella pentandra Hook.
Osmorhiza chilensis H. & A.
Petasites frigidus (L.) Fries var. palmatus (Ait.) Cronq.
Pleuropogon refractus (Gray) Benth.
Polypodium vulgare L. ssp. columbianum Gilbert
Polystichum munitum (Kaulf.) Presl.
Stellaria crispa Cham. & Schl.
Tiarella laciniata Hook.
Tiarella trifoliata L.
Tiarella unifoliata Hook.
Tofieldia glutinosa (Michx.) Pers.
Trisetum cernuum Trin.
Viola glabella Nutt.
Viola orbiculata Geyer
Viola palustris L.

GEOPHYTES (G)

Clintonia uniflora (Schult.) Kunth.
Corallorhiza mertensiana Bongard
Dicentra formosa (Andr.) Walp.
Equisetum arvense L.
Equisetum palustre L.
Gymnocarpium dryopteris (L.) Newm.
Habenaria dilatata (Pursh.) Hook.
Habenaria saccata Greene
Lilium columbianum Hanson
Listera caurina Piper
Listera cordata (L.) R. Br.
Lysichitum americanum Hult. & St. John
Maianthemum dilatatum (Wood) Nels. & McB.
Nuphar polysepalum Engelm.
Streptopus amplexifolius (L.) DC.
Streptopus roseus Michx.
Streptopus streptopoides (Ledeb.) F. & R.
Veratrum eschscholtzii A. Gray

(2) Subalpine species:

MACROPHANEROPHYTES (MP)

Abies lasiocarpa (Hook.) Nutt.
Chamaecyparis nootkatensis (D. Don.) Spach.
Pinus albicaulis Engelm.
Tsuga mertensiana (Bong.) Carr.

NANOPHANEROPHYTES - deciduous (NPd)

Cladothamnus pyrolaeflorus Bong.
Rhododendron albiflorum Hook.
Ribes acerifolium Howell
Sorbus occidentalis (S. Wats.) Greene
Spiraea densiflora Nutt.
Vaccinium deliciosum Piper

CHAMAEPHYTES (CH)

Gaultheria humifusa (Grah.) Rydb.
Lycopodium sitchense Rupr.

HEMICRYPTOPHYTES (H)

Agrostis rossae Vasey
Caltha leptosepala DC.
Carex illota Bailey
Carex mertensii Prescott
Carex phaeocephala Piper
Carex rossii Boott.
Carex spectabilis Desv.
Cheilanthes gracillima D. C. Eaton

Cryptogramma crispa (L.) R. Br.
Epilobium latifolium L.
Eriophorum angustifolium Roth.
Hippuris montana Ledeb.
Juncus drummondii E. Meyer
Juncus mertensianus Bong.
Nephrophyllidium crista-galli (Menzies) Gilg.
Osmorhiza purpurea (Coult. & Rose) Suksd.
Polystichum lonchitis (L.) Roth.
Saxifraga mertensiana Bong.
Scirpus caespitosus L. var. collosus Bigel.
Senecio triangularis Hook.
Trientalis arctica Fisch.
Veronica serpyllifolia L. var. humifusa (Dickson) Vahl.

(3) Species of the Subalpine-alpine transition:

NANOPHANEROPHYTES - deciduous (NPd)

Salix commutata Bebb.

NANOPHANEROPHYTES - evergreen (NPe)

Cassiope mertensiana (Bong.) G. Don.
Juniperus communis L. var. montana Ait.
Phyllodoce empetriformis (Smith) D. Don.
Phyllodoce glanduliflora (Hook.) Coville

CHAMAEPHYTES (CH)

Antennaria alpina (L.) Gaertn. var. media (Greene) Jeps.
Empetrum nigrum L.
Luetkea pectinata (Pursh.) Kuntze
Penstemon davidsonii Greene var. menziesii (Keck) Cronq.
Penstemon procerus Dougl. var. tolmiei (Hook.) Cronq.
Phlox douglasii Hook.
Saxifraga tolmiei T. & G.
Sedum divergens S. Wats.
Sibbaldia procumbens L.
Vaccinium caespitosum Michx.

HEMICRYPTOPHYTES (H)

Anemone occidentalis Wats.
Athyrium alpestre (Hoppe) Rylands
Arnica latifolia Bong. var. gracilis (Rydb.) Cronq.
Arnica latifolia Bong. var. latifolia Cronq.
Carex nigricans C. A. Meyer
Carex preslii Steud.
Carex pyrenaica Wahl.
Castilleja hispida Benth.
Castilleja parviflora Bong. var. albida (Penn.) Owenby
Deschampsia atropurpurea (Wahl.) Scheele.
Epilobium clavatum Trel.
Erigeron peregrinus (Pursh.) Greene ssp. callianthemus (Greene) Cronq. var. angustifolius (Gray) Cronq.

Erigeron peregrinus (Pursh.) Greene ssp. callianthemus (Greene) Cronq. var. scaposus (T. & G.) Cronq.
Hieracium gracile Hook.
Juncus parryi Engelm.
Leptarrhena pyrolifolia (D. Don.) R. Br.
Lupinus arcticus S. Wats.
Luzula wahlenbergii Rupr.
Mimulus lewisii Pursh.
Oxyria digyna (L.) Hill
Parnassia fimbriata Konig.
Pedicularis bracteosa Benth.
Pedicularis ornithorhyncha Benth.
Phleum alpinum L.
Poa arctica R. Br.
Potentilla flabellifolia Hook.
Ranunculus verecundus Robinson
Saxifraga arguta D. Don
Saxifraga ferruginea Grah.
Saxifraga lyallii Engler
Trisetum spicatum (L.) Richt.
Valeriana sitchensis Bong.
Veronica wormskjoldii R. & S.

GEOPHYTES (G)

Epilobium alpinum L.

Checklist of Lichens from the Subalpine Zone

(Nomenclature and authorities taken from the second checklist of lichens of Continental United States and Canada, by Hale and Culberson, 1960.)

Alectoria ochroleuca (Ehrh.) Nyl.
Alectoria pubescens (L.) Howe
Alectoria sarmentosa Ach.
Caloplaca sp.
Cetraria glauca (L.) Ach.
Cetraria hepatizon (Ach.) Vain
Cetraria islandica (L.) Ach.
Cetraria stenophylla (Tuck.) Merr.
Cladonia bellidiflora (Ach.) Schaer.
Cladonia carneola Fr.
Cladonia chlorophaea (Florke) Spreng.
Cladonia coniocraea (Florke) Sandst.
Cladonia deformis (L.) Hoffm.
Cladonia ecmocyna (Ach.) Nyl.
Cladonia gracilis (L.) Willd.
Cladonia pacifica Ahti
Cladonia pleurota (Florke) Schaer.
Cladonia rangiferina (L.) Web.
Cladonia squamosa (Scop.) Hoffm.
Cornicularia californica (Tuck.) Du Rietz
Cornicularia divergens Ach.
Crocynia membranacea (Dicks.) Zahlbr.
Dermatocarpon miniatum (L.) Mann.
Icmadophila ericetorum (L.) Zahlbr.
Lecanora sp.
Lecidea sp.
Lecidea granulosa (Ehrh.) Ach.
Letharia vulpina (L.) Hue
Lobaria linata (Ach.) Rabenh.
Lobaria oregana (Tuck.) Mull. Arg.
Mycoblastus sanguinarius (L.) Norm.
Parmelia enteromorpha Ach.
Parmeliopsis hyperopta (Ach.) Vain.
Peltigera aphthosa (L.) Willd.
Peltigera canina (L.) Willd.
Pilophoron hallii (Tuck.) Vain.
Rhizocarpon geographicum (L.) DC.
Solorina crocea (L.) Ach.
Sphaerophorus globosus (Huds.) Vain.
Stereocaulon tomentosum Fr.
Umbilicaria phaea Tuck.
Umbilicaria torrefacta (Lightf.) Schrad.

Checklist of Bryophytes from the Subalpine Zone

Nomenclature and authorities taken from Grout (1940), Andrews (1940) and Evans (1940). Species grouped by growth-forms according to Gimingham and Birse (1957).

(1) Cushions (c):

Andreaea blyttii Schimp.
Andreaea nivalis Hook.
Andreaea rupestris Hedw.
Grimmia alpestris Nees
Grimmia apocarpa Hedw.

(2) Tall turfs, branches erect (Te):

Bryum sandbergii Holz.
Dicranum bonjeani De Not.
Dicranum fuscescens Turn.
Dicranum muhlenbeckii Bry. Eur.
Dicranum scoparium Hedw.
Drepanocladus aduncus (Hedw.) Warnst.
Drepanocladus exannulatus (Gumb.) Warnst.
Drepanocladus fluitans (Hedw.) Warnst.
Hygrohypnum ochraceum (Turn.) Loeske
Mnium affine Bland.
Mnium nudum Williams
Mnium punctatum Hedw.
Mnium spinulosum Bry. Eur.
Oligotrichum aligerum Mitt.
Oligotrichum parallelum (Mitt.) Kindb.
Plagiochila asplenioides (L.) Dumort.
Pogonatum alpinum (Hedw.) Rohl.
Pogonatum contortum (Schwaegr.) Sull.
Pogonatum urnigerum (Hedw.) Beauv.
Polytrichum commune Hedw.
Rhacomitrium aciculare Brid.
Rhacomitrium canescens Brid.
Rhacomitrium heterostichum (Hedw.) Brid.
Rhacomitrium patens (Hedw.) Huben.
Rhacomitrium varium Lesq. & James
Scouleria aquatica Hook.

(3) Tall turfs, short divergent branches (Td):

Campylium stellatum (Hedw.) Lange & C. Jens.
Philonotis fontana (Hedw.) Brid.
Sphagnum compactum DC.
Sphagnum girgensohnii Russow
Sphagnum magellanicum Brid.
Sphagnum mendocinum Sull. & Lesq.
Sphagnum robustum (Russow) Roll
Sphagnum squarrosum Pers.
Sphagnum teres (Schimp.) Angstr.

(4) Short turfs (t):

Aulacomnium androgynum Schwaegr.
Aulacomnium palustre (Web. & Mohr) Schwaegr.
Bryum spp.
Buxbaumia indusiata Brid.
Dichodontium olympicum Ren. & Card.
Dicranella heteromalla (Hedw.) Schimp.
Dicranella squarrosa (Schrad.) Schimp.
Dicranoweisia crispula (Hedw.) Lindb.
Dicranum strictum Schleich.
Diplophyllum albicans (L.) Dumort.
Diplophyllum obtusifolium (Hook.) Dumort.
Diplophyllum plicatum Lindb.
Diplophyllum taxifolium (Wahlenb.) Dumort.
Ditrichum montanum Leiberg
Kiaeria blyttii (Schimp.) Broth.
Kiaeria falcata (Hedw.) Hagen
Kiaeria starkei (Web. & Mohr) Hagen
Marsupella sparsifolia (Lindb.) Dumort.
Marsupella ustulata (Huben.) Spruce
Oligotrichum hercynicum (Hedw.) Lam. & De Cand.
Pohlia drummondii (C. Mull.) Andrews
Pohlia nutans (Hedw.) Lindb.
Polytrichum juniperinum Hedw.
Polytrichum norvegicum Hedw.
Polytrichum piliferum Hedw.

(5) Mats (M):

Bazzania ambigua (Lindenb.) Trevis.
Bazzania tricrenata (Wahl.) Trevis.
Brachythecium asperrimum Mitt.
Brachythecium plumosum (Sw.) Bry. Eur.
Brachythecium washingtonianum (Eaton) Grout
Cratoneuron commutatum (Hedw.) Roth
Hookeria lucens (Brid.) Smith
Hypnum circinale Hook.
Hypnum dieckii Ren. & Card.
Hypnum subimponens Lesq.
Plagiothecium denticulatum (Hedw.) Bry. Eur.
Plagiothecium elegans (Hook.) Sull.
Plagiothecium piliferum (Sw.) Bry. Eur.
Plagiothecium pulchellum (Hedw.) Bry. Eur.
Plagiothecium sylvaticum (Brid.) Bry. Eur.
Plagiothecium undulatum (Hedw.) Bry. Eur.
Porella roellii Steph.
Scapania americana K. Mull.
Scapania bolanderi Aust.
Scapania uliginosa (Sw.) Dumort.
Scapania umbrosa (Schrad.) Dumort.
Scapania undulata (L.) Dumort.

(6) Thread-like forms (Mt):

Barbilophozia barbata (Schmid.) Loeske
Barbilophozia lycopodioides (Wallr.) Loeske
Blepharostoma trichophyllum (L.) Dumort.
Calypogeia neesiana (Massal. & Carest.) K. Mull.
Calypogeia trichomanis (L.) Corda
Cephalozia lammersiana (Hueb.) Spruce
Cephalozia leucantha Spruce
Cephalozia media Lindb.
Eurhynchium stokesii (Turn.) Bry. Eur.
Gymnomitrium concinnatum (Lightf.) Corda
Gymnomitrium varians (Lindb.) Schiffn.
Harpanthus scutatus (Web. & Mohr.) Spruce
Heterocladium heteropteroides Best
Heterocladium procurrens (Mitt.) Rau & Hervey
Isopaches bicrenatus (Schmid.) Buch
Leiocolea obtusa (Lindb.) Buch
Lepidozia reptans (L.) Dumort.
Lescuraea baileyi (Best & Grout) Lawton
Lescuraea patens (Lindb.) Arn. & Jens.
Lescuraea radicosa (Mitt.) Moenkem.
Lophocolea heterophylla (Schrad.) Dumort.
Lophozia alpestris (Schleich.) Evans
Lophozia incisa (Schrad.) Dumort.
Lophozia porphyroleuca (Nees) Schiffn.
Nardia scalaris (Schrad.) S. F. Gray
Orthocaulis binsteadii (Kaal.) Buch
Orthocaulis floerkii (Web. & Mohr.) Buch
Orthocaulis kunzeanus (Huben) Buch
Plectocolea obovata (Nees) Mitt.
Pleuroclada albescens (Hook.) Spruce
Pseudisothecium (= Isothecium) stoloniferum (Hook.) Grout
Pterigynandrum filiforme Hedw.
Ptilidium californicum (Aust.) Underw. & Cook
Ptilidium ciliare (L.) Nees
Ptilidium pulcherrimum (Weber) Hampe
Radula complanata (L.) Dumort.

(7) Thalloid mats (Th):

Conocephalum conicum (L.) Dumort.
Moerckia blyttii (Moerck) Brockm.
Pellia epiphylla (L.) Corda
Pellia neesiana (Gottsche) Limpr.
Riccardia multifida (L.) S. F. Gray

(8) Wefts (W):

Antitrichia curtipendula (Hedw.) Brid.
Calliergonella cuspidata (Brid.) Loeske
Hylocomium splendens (Hedw.) Bry. Eur.
Pleurozium schreberi (Brid.) Mitt.
Rhytidiadelphus loreus (Hedw.) Warnst.
Rhytidiadelphus squarrosus (Hedw.) Warnst.
Rhytidiopsis robusta (Hook.) Broth.

APPENDIX II

Multiple regression analyses of the incidence of basal snow-crook on amabilis fir, mountain hemlock and yellow cedar

Multiple Regression Analyses of the Incidence of Basal Snow-crook on Amabilis Fir, Mountain Hemlock and Yellow Cedar.

The following variables were considered:

X_1 - steepest slope on sample plot, in degrees

X_2 - elevation, in hundreds of feet

X_3 - length of slope above, coded:
1 - no slope above
2 - 1 chain or less
3 - 1 to 2 chains
4 - 3 to 4 chains
5 - 4 to 10 chains
6 - over 10 chains

X_4 - basal area per acre, in square feet

X_5 - crown closure of A layer, in percent

X_6 - aspect, coded according to amount of heat received. Chapter 21 and Figure 99 (Geiger 1957) were used for this purpose. The divisions shown for a clear day in Figure 99 were coded so that the coldest north slope had a value of 10 and the warmest southwest slope a value of 95.

X_7 - duration of snow, in weeks

Y - percentage of trees, in the 10-inch diameter class or less, with basal snow-crook.

Only sample plots that had at least 10 trees in the 10-inch class or less and which had uniform slope were used. Thirty-three sample plots fulfilled these requirements for amabilis fir, and the same number was used in the analysis for mountain hemlock and yellow cedar. This allowed use of the same programmed computer instructions for both analyses.

For amabilis fir, the regression equation is:

$$Y = .5728X_1 - .6168X_2 + .3492X_3 + .0337X_4 - .3556X_5 + .0255X_6 + 1.5401X_7 - 24.189$$

Correlation coefficients show that steepness of slope (X_1) is correlated with the percentage of snow-crook at the .01 level of probability, and basal area (X_4) at the .05 level. The regression equation for the most important variable, steepness of slope, is $Y = 5.465 + .6896X_1$.

The table below summarizes the correlation matrix for amabilis fir:

	Independent Variables						
	1	2	3	4	5	6	7
X 1	-	N	N	N	N	N	N
2		-	N	N	N	N	**
3			-	**	**	N	N
4				-	**	N	N
5					-	N	N
6						-	N
7							-
Y	**	N	N	*	N	N	N

N - not significantly correlated
* - significantly correlated (.05 level)
** - highly significant (.01 level)

Amongst the independent variables, elevation shows a high correlation with duration of snow, as one would expect in the Subalpine Zone. Length of slope above a sample plot is positively correlated with basal area and crown closure, since the most productive stands usually occur on lower or mid-portions of seepage slopes.

For mountain hemlock and yellow cedar the regression equation and correlation matrix are as follows:

$$Y = .8770X_1 - 2.5326X_2 + .2310X_3 - .0281X_4 + .0122X_5$$

$$+ .1748X_6 + 5.0545X_7 - 59.150$$

	Independent Variables						
	1	2	3	4	5	6	7
X 1	-	N	N	N	N	N	N
2		-	N	N	N	N	**
3			*	**	**	N	N
4				-	**	N	N
5					-	N	N
6						-	N
7							-
Y	**	N	N	N	N	N	N

For these species, only steepness of slope was significantly correlated with snow-crook. The regression equation for this variable alone is $Y = 20.491 + .7906X_1$.

APPENDIX III

Table XIII

Table XIV

Explanation and Legend for Synthesis Tables

Synthesis Tables I to IX

TABLE XIII

Life-form distributions by number of species and by total cover degree for each association (columns 1 to 8). Columns 9 to 15 show a further breakdown of humicolous bryophytes (column 8) into growth-forms

	1	2	3	4	5	6	7	8		9	10	11	12	13	14	15
	Pm	Pnd	Pne	Ch	G	H	L	B	Sum	Te	W	Mt	t	M	Td	Th
Subalpine Lysichitum association:																
No. species	7	8	-	6	12	33	2	46	114	10	5	13	2	10	4	2
%	6.1	7.7	-	5.3	10.5	28.9	1.8	44.2		8.8	4.4	11.4	1.8	8.8	3.5	1.8
Tot. cov. deg.	900	185	-	53	388	246	-	646	2418	304	184	13	-	71	54	20
%	37.3	7.6	-	2.2	16.1	10.2	-	26.8		12.6	7.5	0.5	-	2.9	2.2	0.8
Subalpine Oplopanax association:																
No. species	6	10	-	6	10	15	2	29	78	7	3	7	4	7	-	1
%	7.7	12.8	-	7.7	12.8	19.2	2.6	37.2		9.0	3.8	9.0	5.1	9.0	-	-
Tot. cov. deg.	348	252	-	37	132	122	-	265	1156	169	77	4	1	13	-	1
%	30.1	21.8	-	3.2	11.4	10.6	-	22.9		14.6	6.7	0.3	-	1.1	-	-
Streptopus association:																
No. species	6	9	1	7	9	19	1	49	101	10	3	16	5	11	2	2
%	5.9	8.9	1.0	6.9	8.9	18.8	1.0	48.5		9.9	3.0	15.8	4.9	10.9	2.0	2.0
Tot. cov. deg.	2405	755	-	294	125	430	-	1011	5020	402	470	43	1	52	10	33
%	47.9	15.0	-	5.8	2.5	8.6	-	20.2		8.0	9.3	0.9	-	1.0	0.2	0.7
Vaccinium alaskaense association:																
No. species	4	8	1	4	4	6	2	32	61	7	3	11	2	9	-	-
%	6.6	13.1	1.6	6.6	6.6	9.8	3.3	52.5		11.5	4.9	18.0	3.3	14.7	-	-
Tot. cov. deg.	1158	425	-	35	12	2	2	591	2226	308	227	45	2	9	-	-
%	52.0	19.1	-	1.6	0.6	0.1	0.1	26.6		14.5	10.2	2.0	-	0.4	-	-
Cladothamnus association:																
No. species	5	8	2	6	3	9	9	36	78	9	3	13	6	4	1	-
%	6.4	10.2	2.6	7.7	3.8	11.5	11.5	46.2		11.5	3.8	16.7	7.7	5.1	1.3	-
Tot. cov. deg.	1625	1659	253	103	2	15	53	1173	4883	684	382	91	14	2	-	-
%	33.3	34.0	5.2	2.1	-	0.3	1.1	24.1		14.0	7.8	1.9	0.3	-	-	-
Vaccinium membranaceum - Rhododendron association:																
No. species:	6	8	2	4	3	1	8	21	53	6	2	6	3	4	-	-
%	11.3	15.1	3.8	7.6	5.7	1.9	15.1	39.6		11.3	3.8	11.3	5.7	7.6	-	-
Tot. cov. deg.	1127	835	73	18	-	-	6	277	2336	193	51	33	-	-	-	-
%	48.3	35.8	3.1	0.8	-	-	0.2	11.9		8.3	2.2	1.5	-	-	-	-
Dwarf Tsuga association:																
No. species	3	5	2	4	1	11	10	29	65	8	2	9	8	1	-	1
%	4.6	7.7	3.1	6.3	1.5	16.9	15.4	44.7		12.3	3.1	13.8	12.3	1.5	-	1.5
Tot. cov. deg.	766	95	615	200	1	112	32	579	2400	290	9	191	79	-	-	10
%	32.0	4.0	25.6	8.3	-	4.7	1.3	24.1		12.1	0.4	8.0	3.3	-	-	0.4
Vaccinium deliciosum association:																
No. species	3	3	2	2	1	5	7	15	38	5	1	5	3	1	-	-
%	7.9	7.9	5.3	5.3	2.6	13.2	18.4	39.5		13.2	2.6	13.2	7.9	2.6	-	-
Tot. cov. deg.	66	368	264	22	-	-	24	362	1106	224	59	74	5	-	-	-
%	6.0	33.2	23.9	2.0	-	-	2.2	32.8		20.2	5.3	6.7	0.4	-	-	-
Phyllodoce - Cassiope association:																
No. species	4	6	3	4	1	11	10	27	66	6	2	9	7	3	-	-
%	6.1	9.1	4.5	6.1	1.5	16.7	15.1	41.0		9.1	3.0	13.6	10.6	4.5	-	-
Tot. cov. deg.	144	265	1500	219	-	9	48	880	3065	446	38	231	165	-	-	-
%	4.7	8.6	49.0	7.1	-	0.3	1.5	28.7		14.5	1.2	7.5	5.4	-	-	-
Carex nigricans association:																
No. species	1	1	2	4	-	6	1	10	25	2	-	4	3	-	1	-
%	4.0	4.0	8.0	16.0	-	24.0	4.0	40.0		8.0	-	16.0	12.0	-	4.0	-
Tot. cov. deg.	-	-	1	11	-	504	-	372	888	26	-	10	286	-	50	-
%	-	-	-	1.2	-	56.7	-	42.0		2.9	-	1.1	32.3	-	5.6	-
Leptarrhena - Caltha leptosepala association:																
No. species	3	5	2	4	6	29	-	27	76	9	2	3	5	2	4	2
%	4.0	6.6	2.6	5.3	7.9	38.2	-	35.6		11.8	2.6	4.0	6.6	2.6	5.3	2.6
Tot. cov. deg.	10	10	-	5	131	1012	-	789	1957	335	251	3	52	8	132	8
%	0.5	0.5	-	0.2	6.7	51.8	-	40.3		17.1	12.8	0.1	2.7	0.4	6.7	0.4
Eriophorum - Sphagnum association:																
No. species	-	-	-	2	4	15	-	17	38	3	2	4	2	3	4	-
%	-	-	-	5.3	10.5	39.5	-	44.8		7.9	5.3	10.5	5.3	7.9	10.5	-
Tot. cov. deg.	-	-	-	1	10	545	-	379	935	85	7	1	1	25	260	-
%	-	-	-	0.1	1.1	58.3	-	40.5		9.1	0.8	-	-	2.7	27.8	-

TABLE XIV

Average estimated coverage by each vegetation layer and by rock, in percent

	LYSICHITUM	OPLOPANAX	STREPTOPUS	Degraded STREPTOPUS	VACCINIUM ALASKAENSE	Hygric CLADOTHAMNUS	Lithic CLADOTHAMNUS	VACC. MEMBR.-RHODODENDRON	Dwarf TSUGA	Dwarf TSUGA - LUETKEA	VACCINIUM DELICIOSUM	PHYLLODOCE - CASSIOPE	CAREX NIGRICANS	LEPTARRHENA	ERIOPHORUM - SPHAGNUM	SAXIFRAGA
Avge. cover, %:																
In A layer	66	51	68	64	69	43	24	59	-	-	2	-	-	-	-	-
B layer	51	70	52	64	59	90	75	84	75	35	28	10	-	2	-	-
C layer	66	53	40	16	8	16	37	13	66	88	80	85	79	87	89	13
D_h layer	72	65	43	53	48	64	60	31	55	48	59	56	59	85	67	12
By rock	1	-	1	1	2	2	12	2	12	6	10	11	1	-	-	60

Explanation and Legend for Synthesis Tables

1. In some cases more than one association appears on a synthesis table, mainly for typographical convenience. In the case of the Polytrichum norvegicum association and the Saxifraga tolmiei association, which were not studied by sufficient plots, a grouping is made with the Carex nigricans association because of floristic similarities.

2. Plot locations are designated by the following abbreviations:
   R. M. - Round Mountain (Paul Ridge), Garibaldi Park
   G. - Grouse Mountain
   H. - Hollyburn Ridge
   S.M. - Seymour Mountain
   Dia. H. - Diamond Head area, Garibaldi Park

3. Landforms are numerically coded:
   1 - concave
   2 - uniform slope
   3 - convex (ridge)
   4 - flat to undulating (rock outcrop)
   5 - complex

4. Wind exposure was estimated on the basis of topographic position. An exposed ridge was given a high value on a scale of 10, whereas a protected ravine would have a rating of 5 or 6. Three values appear in the Synthesis Tables: A, exposure of the tree layer to the wind; B, exposure of the shrub layer; and C, exposure of the herbaceous and low woody layer.

5. Estimated coverage, in per cent, is given for each layer and each sub-layer in the vegetation and for decayed wood and rock. Average coverage by each layer is summarized for each association in Table XIV.

6. A quadrat 1/2m. x 1/2m. was located in each corner of the rectangular sample plots. All coniferous seedlings were tallied on these, to give an estimate of regeneration per square meter.

7. Species are grouped by layer and sub-layer, usually in decreasing order of presence and decreasing order of total cover degree. In some cases, differentiating species are grouped to indicate subassociation differences.

8. Species ratings are given by three figures (e.g. 4.+.2 or 6.7.2.) which represent species significance, sociability and vigour. The species significance scale and its appropriate cover degree ratings are standardized with those of Orloci (1961) to allow direct floristic comparisons between the two bioclimatic zones.

The following scales were used for floristic evaluation:

Species Significance			Corresponding cover degree in %
+	Very sparsely present, dominance very small		0
1	Sparsely present, dominance small		0
2	Very scattered, dominance small		1
3	Scattered to plentiful		5
4	Often, dominance 1/20 to 1/10 of plot		10
5	Often, dominance 1/5 to 1/4 of plot		25
6	Any no. of individuals, dominance	1/4 to 1/3	33
7	" " " " "	1/3 to 1/2	50
8	" " " " "	1/2 to 3/4	75
9	" " " " "	over 3/4	95
10	" " " " "	100% of plot	100

Sociability

+ Growing singly
1 Grouped or tufted, groups up to 16 sq. cm.
2 Group larger, up to 1/16 sq. m.
3 Group, 1/8 to 1/4 sq. m.
4 " 1/3 to 2/3 " "
5 " 1 to 2 sq. m.
6 " 5 to 20 " "
7 " 25 to 50 " "
8 " 100 " "
9 " 200 to 250" "
10 At least 500 sq. m.

Vigour

0 - none
+ - poor
1 - fair
2 - good
3 - excellent

9. Five presence classes are used:

5 - species which occur in 81-100% of the plots (constants)
4 - species which occur in 61-80% of the plots
3 - species which occur in 41-60% of the plots
2 - species which occur in 21-40% of the plots
1 - species which occur in 20% or less of the plots (sporadics)

Sporadic species are listed separately, by vegetation layer at the end of each table with a notation of their floristic rating and the plot on which they occurred.

10. Fidelity is given only for the layer in which a species shows the highest total cover degree. For example, Abies amabilis is normally rated only in the A layer.

11. Total cover degree was calculated for each species on an association by totaling the cover degree values of the species significance ratings on each plot.

12. Life-forms (and growth forms for bryophytes) are abbreviated according to the descriptions in Chapter V.

SYNTHESIS TABLE I   Cladothamnus association (Tsugeto - Cladothamnetum)

		Hygric subassociation					Lithic subassociation															
Plot number		01	03	20	26	42	101	104	43	19	21	08	24	28	09	124	12	27				
Plot size (acre)		1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5				
Date		22/6 1959	3/9 1959	20/8 1959	9/9 1959	27/7 1960	20/9 1960	22/7 1961	11/10 1961	28/7 1959	2/9 1959	10/8 1959	27/8 1959	1/9 1959	11/8 1959	9/7 1961	29/7 1959	30/8 1959				
Locality (see legend)		SM	SM	SM	SM	SM	G	H	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM				
Latitude		49 22	49 22	49 22	49 23	49 22	49 24	49 23	49 22	49 22	49 22	49 22	49 23	49 23	49 22	49 23	49 23	49 23				
Longitude		122 57	122 57	122 57	122 57	122 57	123 05	123 11	122 57	122 57	122 57	122 56	122 57	122 57	122 56	122 57	122 56	122 57				
Landform (see legend)		2	2	2	2	2	2	3	3	3	3	2	4	4	4	4	4	3 (5)				
Slope above (est. ft.)		400	60	400	50	300	60	-	-	-	-	-	-	-	-	-	-	-				
Area of assoc. (acre)		1	1	1	1/2	1	1	3/4	1/3	1/2	1/3	2	1	1/3	2	1/5	1/2	1/4				
Altitude (ft.)		3380	3510	3380	3525	3200	4220	3220	3180	3360	3400	3130	3600	3730	3200	4075	3860	3650				
Aspect		S25E	N80E	S20W	S10W	S80W	S	W	S20W	S15E	S20W	N20E	?	S10W	S05E	S50W	S40W	?				
Slope (degrees)		25	22	10	30	8	15	3	21	-	-	7	15	10	8	20	8	-				
Wind exposure (A-B-C)		6-5-2	7-5-2	6-3-1	8-6-4	8-6-4	9-6-2	8-4-1	8-5-2	7-6-1	7-4-2	6-6-2	7-6-4	8-7-3	6-6-3	9-8-5	7-7-3	8-7-4				
Snow cover (months)		7	7	7	7	7½	7½	7	7	7	7	7	7	7	7	8	7	7				
% coverage:																						
By vegetation layer A_1		15	17	)	5	)	)	)	)	3	)	)	)	)	5	)	1	)				
A_2		35	20	)35	30	)8	)20	)65	)25	12	)20	)6	)12	)10	)	)15	)	)15				
A_3		15	15	15	30	20	40	40	12	10	5	10	3	2	)5	)	)8	)				
A		50	40	40	60	25	50	75	35	20	23	12	12	10	10	15	7	15				
B_1		20	50	17	50	20	50	40	35	30	20	20	10	7	35	40	10	8				
B_2		90	65	65	75	90	70	85	80	80	88	45	60	60	50	60	40	55				
B		95	95	80	85	95	85	90	90	90	92	60	60	65	75	90	40	60				
C		10	7	20	10	35	5	5	30	5	20	60	80	70	55	30	25	65				
D_H		70	75	60	40	75	50	60	85	90	50	50	75	50	60	40	40	65				
D_L		3	I	7	2	5	4	1	2	2	1	1	1	1	1	1	1	1				
D_R		5	1	1	1	-	2	1	1	4	4	1	1	15	1	12	35	4				
D		78	76	68	42	80	55	62	88	96	55	50	76	65	61	52	75	70				
By decayed wood		5	1	10	4	5	6	3	4	3	1	1	1	1	1	2	1	1				
By rock		7	2	2	1	-	4	2	1	5	6	1	30	7	2	25	50	6				
Tallest tree on plot (ft.):																						
Western hemlock		-	-	73	-	-	-	54	-	-	-	-	-	-	-	-	-	-				
Mountain hemlock		92	72	81	102	74	70	78	72	72	78	90	73	74	77	54	53	59				
Amabilis fir		87	70	77	72	74	61	63	56	50	24	67	60	34	34	15	26	54				
Yellow cedar		83	77	66	61	70	25	72	81	60	66	56	49	26	46	15	15	19				
Regeneration (no./sq. meter)																						
Mountain hemlock		-	-	-	?	-	-	3	-	-	-	-	-	-	-	-	-	-				
Amabilis fir		-	-	-	?	13	16	7	1	-	-	-	-	-	-	1	-	-				
Yellow cedar		-	-	-	?	1	-	13	2	-	-	-	-	-	-	-	-	-				
Total soil depth (cm.)		82	39	59	79	33	92	?	26	25	42	37	47	35	43	?	42	33				
Depth to bottom of A_h (cm.)		33	13	21	9	12	18	?	?	7	13	15	24	6	29	?	10	5				
Depth to seepage, if present		80	-	-	-	-	-	?	?	-	40	-	40	-	-	?	-	30				
A layer:	Sub-layer																		Pres.	Fid.	Tot. c.d.	Life-form
Tsuga mertensiana	1	5.+.2	4.7.1	)	+.2	)	)	)	)	2.+.1	)	)	)	)	4.+.2	)	+.2	)	5	2	454	Pm
	2	5.+.2	5.6.1	)5.7.2	5.7.2	)3.+.2	)4.+.1	)6.8.2	)5.7.2	4.6.1	)5.6.1	)4.7.1	)5.+.2	)4.7.2	)	)5.+.+	)	)5.7.1				
	3	4.6.2	3.+.1	4.6.1	4.7.1	4.7.2	4.7.1	5.7.2	4.7.2	4.6.2	3.6.1	3.+.2	+.2	+.1	)1.+.2	)	)3.6.1	)				
No. trees over 3 in./acre		125	195	120	135	105	140	115	170	165	105	65	70	65	90	60	75	70				
Basal area, sq. ft./acre		156	185	111	154	116	152	130	143	118	115	84	99	101	65	102	66	65				
Gross volume, cu. ft./acre		3844	3875	1946	3564	2191	2586	2807	2734	2154	2359	2024	2136	1940	1278	1422	834	986				
Abies amabilis	1	+.2	+.2	)	-	)	)	)	)	-	-	) +.1	) +.2	-	-	-	-	)	5		122	Pm
	2	+.2	+.1	)5.7.2	4.+.2	)1.+.1	)4.+.1	)4.+.2	)3.+.1	+.1	-	)	)	-	)+.2	-	)2.+.1	)+.1				
	3	1.+.2	4.6.1	3.+.1	4.7.1	1.+.1	5.7.1	4.7.1	2.+.1	1.+.1	-	2.+.1	+.2	1.+.1	)	-	)	)				
No. trees over 3 in./acre		90	180	80	165	70	140	125	140	85	110	80	60	45	60	20	70	75				
Basal area, sq. ft./acre		41	40	56	73	23	126	40	36	19	13	37	12	12	14	3	34	12				
Gross volume, cu. ft./acre		936	558	1317	1290	348	1494	636	546	188	57	606	138	98	82	19	296	137				

. . . . continued

SYNTHESIS TABLE 1 Cladothamnus association, continued

Plot number	Sub-layer	01	03	20	26	42	101	104	43	19	21	08	24	28	09	124	12	27	Pres.	Fid.	Tot. c.d.	Life-form
		Hygric subassociation					Lithic subassociation															
A layer, continued:																						
Chamaecyparis nootkatensis	1	-	4.+.1		-		-			-		-	-	-	-	-	-	-	4		80	Pm
	2	6.7.2	-	)2.+.1	+.2	)1.+.2	-	)5.8.2	)2.+.1	2.+.1	)+.1	-	-	-		-	-	-				
	3	1.+.2	+.1	+.1	2.+.1	2.+.2	-	-	+.+	-	1.+.1	4.6.1	+.2	-	)1.+.2	-	-	-				
No. trees over 3 in./acre		115	120	110	160	100	70	75	95	120	75	65	50	35	30	25	40	15				
Basal area, sq. ft./acre		136	75	57	66	75	9	66	36	53	29	48	8	5	7	5	6	2				
Gross volume, cu. ft./acre		3041	1459	920	800	1076	46	1274	730	650	393	760	76	21	92	49	26	8				
Totals, including sporadics:																						
No. trees over 3 in./acre		335	495	315	460	275	650	340	405	380	290	210	180	145	130	105	185	160				
Basal area, sq. ft./acre		335	300	230	293	214	287	244	215	190	157	170	119	118	86	110	106	79				
Gross volume, cu. ft./acre		7842	5892	4327	5654	3615	4126	4916	4010	2992	2809	3390	2350	2059	1452	1490	1156	1131				
B layer:																						
Tsuga mertensiana	1	4.6.2	5.6.1	4.6.1	5.6.1	3.7.2	4.6.1	3.+.2	3.+.1	3.6.1	3.6.1	5.6.2	2.6.2	2.6.1	5.6.1	4.6.+	2.5.1	3.6.1	5		399	Pm
	2	1.6.1	2.+.1	2.6.1	4.6.1	1.6.2	2.+.+	1.+.+	2.+.1	2.+.2	3.6.1	7.8.2	6.7.2	7.8.1	6.7.1	3.5.+	4.6.1	5.7.1				
Vaccinium membranaceum	2	6.7.3	3.5.2	4.6.2	5.7.2	4.5.2	5.6.3	3.5.2	4.6.2	6.7.3	4.7.2	5.7.2	5.7.2	5.7.2	5.7.2	5.6.3	5.7.2	5.7.2	5	2	341	Pnd
Cladothamnus pyrolaeflorus	1	-	1.4.3	-	-	-	-	-	-	-	1.5.3	-	-	-	-	-	-	-	5	4	329	Pnd
	2	5.6.2	7.7.3	5.7.3	5.7.2	5.7.3	7.7.3	4.6.2	4.6.3	2.5.3	7.7.3	1.6.2	-	4.7.2	1.6.1	6.6.1	3.4.2	4.7.2				
Chamaecyparis nootkatensis	1	4.6.1	5.6.1	4.6.1	6.7.1	3.7.2	5.6.1	4.+.1	4.6.1	4.7.+	4.6.1	3.6.1	2.6.1	2.6.1	5.6.1	5.6.+	2.5.+	1.6.+	5	2	301	Pm
	2	2.6.1	1.6.1	3.6.1	4.6.1	2.6.2	1.+.1	3.+.1	5.5.1	2.+.1	3.6.1	4.7.1	4.6.2	2.6.1	3.6.1	4.6.+	3.6.+	2.6.+				
Vaccinium alaskaense	2	6.7.2	6.6.2	5.6.2	3.7.2	7.8.3	2.5.1	6.7.3	6.6.2	6.7.2	4.6.2	1.6.2	-	2.6.1	3.6.2	1.+.+	1.5.2	6.7.2	5	2	295	Pnd
Abies amabilis	1	4.6.2	7.7.1	2.6.1	5.6.1	3.7.2	6.7.1	6.7.1	5.6.1	2.6.1	4.6.1	2.6.2	2.6.2	2.6.1	2.6.2	3.6.+	2.5.1	4.6.1	5	2	221	Pm
	2	2.6.2	3.6.1	3.6.1	4.6.1	2.6.2	3.+.1	2.+.1	3.+.1	3.5.1	4.6.1	3.6.2	3.6.2	2.6.1	3.6.2	1.+.+	3.6.1	2.6.1				
Menziesia ferruginea	1	-	1.4.3	-	-	+.3	-	1.+.3	-	-	1.6.3	-	-	-	-	-	-	-	5	3	105	Pnd
	2	2.6.2	3.6.2	3.6.2	2.6.2	4.6.3	3.5.2	5.6.3	2.5.2	3.5.2	6.7.3	3.6.2	2.5.2	2.6.2	3.6.2	2.4.1	1.6.1	2.6.1				
Vaccinium ovalifolium	2	2.6.1	2.5.1	1.1.2	4.7.2	1.5.1	+.1	3.5.2	2.5.1	2.4.1	2.5.1	3.6.2	1.4.1	2.6.1	3.6.2	-	-	1.4.1	5	2	31	Pnd
Sorbus occidentalis	1	-	-	+.2	+.2	+.3	2.+.3	+.2	-	-	-	-	-	-	-	+.2	-	-	5	3	8	Pnd
	2	+.2	+.1	2.+.2	2.5.2	+.2	1.+.1	+.2	-	2.5.2	2.5.1	1.+.2	1.+.2	2.+.2	1.+.2	1.+.2	2.5.1	+.1				
Vaccinium deliciosum	2	-	-	-	-	2.6.2	2.5.2	-	-	-	-	4.6.2	4.8.3	3.6.2	3.6.2	4.5.3	4.7.2	2.6.2	3	2	53	Pnd
Rhododendron albiflorum	1	-	-	-	2.5.3	-	2.6.3	-	-	-	-	-	-	-	-	-	-	-	2	2	119	Pnd
	2	2.6.2	-	-	6.7.3	-	6.7.3	7.7.3	-	-	1.6.2	-	-	-	-	-	-	-				
Pinus monticola	2	-	-	-	-	+.1	-	+.+	-	-	-	-	-	-	-	-	-	-	1	1	-	Pm
C layer:																						
Vaccinium membranaceum		2.+.2	2.+.1	4.5.2	3.4.2	2.3.2	3.+.2	+.1	1.+.2	2.+.3	3.6.2	5.7.2	5.6.2	4.7.2	4.6.2	2.+.1	-	4.6.1	5		110	Pnd
Rubus pedatus		2.3.2	2.3.2	4.3.2	2.+.2	4.3.3	3.+.1	3.+.2	4.3.2	2.+.1	2.+.2	3.5.2	1.4.2	3.3.1	2.5.2	+.+	1.2.2	1.+.1	5	2	56	Ch
Abies amabilis		+.+	2.+.1	2.+.1	2.+.1	2.+.1	3.+.1	1.+.1	3.+.1	1.+.1	1.+.1	2.+.1	1.+.2	1.+.1	1.+.2	+.+	-	2.+.1	5		16	Pm
Cladothamnus pyrolaeflorus		+.1	1.+.2	2.3.2	2.+.1	2.+.2	-	1.+.1	2.+.2	1.3.2	2.+.2	1.2.2	-	1.3.2	1.+.2	1.+.+	+.2	2.3.2	5		6	Pnd
Sorbus occidentalis		-	+.1	2.+.+	1.+.2	+.+	1.+.1	-	+.+	-	1.+.1	1.+.1	+.1	1.+.1	1.+.2	1.+.+	+.+	1.2.1	5		1	Pnd
Vaccinium alaskaense		2.+.1	2.+.1	4.5.2	2.4.2	4.4.2	1.+.1	1.+.1	1.+.2	1.+.2	2.5.1	-	-	-	-	-	-	3.6.1	4		29	Pnd
Tsuga mertensiana		-	-	2.+.2	1.+.1	-	1.+.+	-	+.+	-	1.+.1	3.+.2	2.4.2	4.5.3	2.+.2	1.+.+	-	4.5.1	4		18	Pm
Gaultheria humifusa		2.+.2	+.1	1.1.2	1.+.1	2.2.2	1.3.2	1.2.2	4.4.3	-	2.3.2	-	1.+.1	-	3.3.2	1.+.1	-	-	4	3	18	Ch
Vaccinium ovalifolium		-	1.+.2	-	3.4.2	-	-	+.+	-	-	1.2.1	-	+.1	1.+.+	-	-	-	1.2.1	3		5	Pnd
Chamaecyparis nootkatensis		-	-	1.+.1	-	-	1.+.1	-	2.+.1	-	1.+.1	+.+	1.+.1	2.+.1	1.+.1	-	-	1.+.1	3		2	Pm
Menziesia ferruginea		+.1	1.+.2	-	-	2.+.2	-	-	-	1.3.2	1.+.2	1.+.1	-	-	1.+.2	-	-	-	3		1	Pnd
Blechnum spicant		+.+	1.+.2	-	-	+.+	-	+.+	-	+.+	-	+.+	+.+	+.+	+.+	-	-	-	3	1	1	H
Cornus canadensis		-	-	1.+.2	-	1.+.1	-	+.+	3.+.2	-	-	-	-	-	2.5.2	-	-	-	2	2	6	Ch
Veratrum eschscholtzii		+.1	-	2.5.2	+.+	+.+	1.+.1	-	-	-	-	-	-	-	+.1	-	-	-	2	1	1	G
Goodyera oblongifolia		-	+.1	-	-	-	-	-	+.2	+.2	-	-	-	-	-	-	1.2.1	-	2	2	-	H
Phyllodoce empetriformis		1.+.1	1.+.2	2.3.2	1.+.1	1.2.1	1.+.+	+.+	1.3.2	1.2.2	3.6.1	4.3.1	6.7.2	6.8.3	2.3.2	5.5.2	5.8.3	6.7.2	5	2	166	Pne
Vaccinium deliciosum		-	-	-	2.6.2	2.5.2	1.+.1	-	-	-	4.6.2	7.8.3	7.9.3	6.8.3	7.7.3	4.6.2	4.3.2	4.6.2	4	2	226	Pnd
Cassiope mertensiana		-	-	-	+.1	-	-	-	-	+.+	2.4.+	4.3.2	5.6.2	5.7.2	2.3.1	3.3.2	4.7.3	4.6.2	3	2	87	Pne
Luetkea pectinata		-	-	-	+.2	-	1.+.2	-	-	-	-	3.4.2	3.5.2	3.5.1	3.6.2	2.+.2	1.2.1	2.2.2	3	2	22	Ch
Carex nigricans		-	-	-	-	-	-	-	-	-	-	2.6.1	2.6.1	3.6.1	+.2	1.4.1	-	2.6.1	2	1	8	H
Lycopodium sitchense		-	-	-	-	-	1.+.1	-	-	1.2.1	-	2.+.2	-	1.2.2	1.+.2	-	-	+.+	2	2	1	Ch
D layer (humicolous):																						
Dicranum fuscescens		5.6.2	5.6.2	5.6.2	2.5.2	7.6.3	6.6.3	6.6.3	7.6.3	7.6.3	1.2.1	6.4.2	2.5.2	-	6.6.2	5.4.3	2.3.2	4.4.2	5	2	395	Te
Rhytidiopsis robusta		6.6.3	6.7.2	5.6.2	5.7.2	4.5.2	3.3.2	7.7.3	5.6.3	4.4.2	5.5.2	4.4.2	3.6.2	4.3.2	4.5.2	3.2.2	5.3.2	4.6.2	5	2	316	W

.... continued

SYNTHESIS TABLE I, continued — Cladothamnus association

Plot number	01	03	20	26	42	101	104	43	19	21	08	24	28	09	124	12	27	Pres.	Fid.	Tot. c.d.	Life-form
	Hygric subassociation					Lithic subassociation															
D layer (humicolous), continued:																					
Dicranum scoparium	-	4.6.2	4.6.2	6.7.2	1.1.1	-	-	1.1.2	-	7.6.3	4.6.1	7.7.3	7.8.2	1.3.2	-	4.3.2	6.7.3	4	2	256	Te
Orthocaulis floerkii	+.2	2.1.2	1.2.2	2.3.2	2.5.2	3.2.2	-	4.3.2	2.2.2	2.2.2	4.2.2	4.2.2	4.2.2	1.+.2	4.4.3	1.2.2	4.3.2	5	2	70	Mt
Lophocolea heterophylla	1.3.2	1.1.2	1.2.2	1.1.2	-	1.1.2	-	1.2.2	1.2.2	1.1.2	-	-	-	-	-	-	-	3	2	-	Mt
Diplophyllum taxifolium	1.3.2	1.1.2	1.2.2	1.2.2	1.3.2	1.1.2	-	1.1.1	-	1.1.2	-	1.2.1	-	1.1.2	-	-	1.1.2	4	2	-	t
Abies amabilis	1.+.1	-	1.+.1	1.+.1	1.+.1	1.+.+	1.+.1	2.+.1	1.+.1	+.1	-	1.+.1	-	-	-	-	2.+.1	4		1	Pm
Cladonia bellidiflora	+.1	1.+.1	+.1	1.1.2	-	1.+.+	-	2.2.2	1.1.2	1.1.2	2.+.2	4.4.2	2.3.2	2.+.2	1.1.2	1.+.2	3.2.2	5	2	19	L
Rhytidiadelphus loreus	3.3.2	3.5.2	4.5.3	4.5.2	3.3.2	-	1.2.1	4.3.2	-	3.4.2	2.3.2	-	-	2.4.2	1.1.2	-	-	4	2	52	W
Lescuraea baileyi	-	1.3.2	-	1.1.2	2.2.2	1.+.1	+.1	3.3.2	-	2.2.2	1.1.2	1.1.2	1.1.2	1.1.2	1.1.2	-	-	4	3	7	Mt
Cephalozia media	2.4.2	1.2.2	1.1.2	2.1.2	-	-	-	-	1.2.2	1.1.2	-	1.1.2	-	1.1.2	-	-	-	3	2	2	Mt
Blepharostoma trichophyllum	1.2.2	1.1.2	1.2.2	1.1.2	-	-	-	-	1.2.2	1.2.2	-	-	-	-	-	-	-	2	2	-	Mt
Chamaecyparis nootkatensis	+.+	-	+.1	-	1.+.1	-	1.+.1	-	2.+.1	-	-	-	+.1	-	-	-	-	2		1	Pm
Plagiochila asplenioides	1.3.2	1.3.2	3.6.2	+.1	-	-	-	1.3.2	-	-	-	-	-	-	-	-	-	2	2	5	Te
Ptilidium californicum	1.3.2	-	-	1.1.2	-	1.1.2	-	-	-	1.1.2	1.2.2	1.1.2	-	-	-	-	1.1.2	3	2	-	Mt
Plagiothecium elegans	1.1.2	1.2.2	2.5.2	2.2.2	-	1.2.2	-	-	-	1.1.1	1.2.2	1.2.2	1.2.2	-	-	-	1.2.2	3	2	1	M
Heterocladium procurrens	1.2.2	-	-	1.2.2	-	-	-	1.+.2	1.2.2	1.2.2	-	-	-	-	-	-	1.2.2	2	2	-	Mt
Mnium spinulosum	1.3.2	1.1.2	-	1.1.2	-	-	-	-	1.3.3	1.2.2	-	1.1.2	-	-	-	1.1.2	1.2.2	3	2	-	Te
Cladonia squamosa	-	-	-	-	-	-	-	-	1.1.2	-	1.1.2	4.2.2	-	-	1.1.2	2.2.2	1.3.2	3	2	11	L
Cladonia rangiferina	-	-	1.1.1	-	1.2.2	-	-	1.1.2	+.1	1.3.1	3.3.1	+.1	1.1.1	3.3.2	1.1.1	-	1.3.2	4	3	10	L
Rhacomitrium heterostichum	-	-	-	-	-	-	-	-	1.1.2	-	-	3.4.2	1.3.2	-	1.3.2	3.3.2	2.3.2	2	2	11	Te
Pleurozium schreberi	-	1.1.2	3.5.2	-	2.1.1	-	+.+	1.2.2	1.3.2	-	3.4.2	-	-	2.3.2	2.1.2	2.3.2	1.4.2	4	3	14	W
Kiaeria blyttii	-	-	-	1.2.2	-	-	-	-	-	-	-	2.5.1	4.5.2	-	-	-	2.4.2	2	1	12	t
Rhacomitrium canescens	-	-	-	-	-	-	-	3.5.2	-	2.3.2	-	3.4.3	-	3.4.2	-	2.3.2	-	2	2	17	Te
Lepidozia reptans	-	2.3.2	-	1.1.2	-	-	-	-	-	1.1.2	-	-	-	1.1.2	-	-	-	2	2	1	Mt
Brachythecium sp.	-	1.1.2	-	-	-	-	-	-	1.2.2	-	1.1.2	-	1.2.2	-	-	-	-	2	2	-	M
Bryum sp.	-	-	1.2.2	1.2.2	-	1.1.2	-	-	-	1.3.2	-	1.1.1	1.1.2	-	1.2.2	-	1.1.2	3	2	-	t
Vaccinium sp.	1.+.1	-	-	-	+.1	-	1.+.1	-	-	-	1.+.1	-	1.+.1	-	1.+.+	-	1.+.1	3		-	Pnd
Crocynia membranacea	-	-	-	1.1.2	-	-	-	-	-	-	-	2.1.2	1.1.2	1.1.2	-	1.1.2	1.1.2	2	2	1	L
Cladonia pleurota	-	1.1.2	-	-	-	-	-	-	-	-	1.1.2	3.4.2	-	3.+.2	1.1.1	-	2.2.2	2	2	11	L

Sporadic species:

A layer:
Pm Tsuga heterophylla 20(+.2); 104(4.+.1)

B layer:
Pm Tsuga heterophylla 01(+.1)

C layer:
H Agrostis aequivalvis 09(+.1)
H Carex laeviculmis 20(1.1.1)
G Clintonia uniflora 01(2.+.1); 43(1.+.2)
H Cryptogramma crispa 12(1.1.1)
H Deschampsia atropurpurea 24(+.1); 28(+.1); 12(+.+)
H Hippuris montana 24(3.6.2); 28(2.5.2)
G Listera caurina 01(+.1); 20(+.+); 104(1.+.+)

C layer, continued:
Ch Penstemon davidsonii 12(+.2)
Pm Pinus monticola 08(+.+)
Pnd Rhododendron albiflorum 104(1.+.1)
H Saxifraga ferruginea 124(+.1); 12(+.2)

D layer (humicolous):
Mt Anastrepta orcadensis 01(1.+.2)
M Bazzania tricrenata 01(1.2.2); 20(2.5.2); 19(1.4.2)
Mt Calypogeia neesiana 26(1.1.2)
L Cladonia gracilis 08(1.1.2); 09(2.1.2); 12(1.3.2);
L C. coniocraea 12(1.1.2); 21(1.2.2) 27(1.3.2)
Ch Gaultheria humifusa 01(1.+.2)
Te Bryum sandbergii 26(1.3.2)
M Hypnum circinale 20(1.3.2); 26(1.1.2); 21(1.1.+)
L Lobaria linata 26(+.1); 43(+.1); 21(1.2.2)

D layer (humicolous), continued:
Mt Lophozia alpestris 21(1.1.2)
Mt Lophozia incisa 26(1.1.2)
t Marsupella sparsifolia 21(2.2.2); 24(1.4.2); 27(2.3.2)
Te Mnium punctatum 03(1.+.1); 20(1.+.+); 26(1.+.1)
M Plagiothec. undulatum 01(1.3.2); 03(1.1.2); 21(+.+)
Mt Plectocolea obovata 03(2.1.2); 27(4.3.2)
Te Pogonatum alpinum 26(1.1.2); 19(1.1.2); 21(1.1.2)
t Pohlia sp. 124(1.1.2)
t Polytrichum juniperinum 09(+.1)
Ch Rubus pedatus 01(1.+.1)
Pnd Sorbus occidentalis 12(+.+)
Td Sphagnum plumulosum 42(1.1.2)
Pm Tsuga mertensiana 43(+.+); 104(+.+)
L Peltigera canina 27(1.1.)

SYNTHESIS TABLE II *Vaccinium alaskaense* association (*Abieteto - Tsugetum mertensianae*)

Plot number		123	106	15	16	50	25	29	83	82				
Plot size (acre)		1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5				
Date		11/10 1961	29/7 1961	21/8 1959	16/7 1959	26/7 1960	8/9 1959	11/9 1959	22/8 1960	22/8 1960				
Locality (see legend)		SM	H	SM	SM	SM	SM	SM	RM	RM				
Latitude		49 22	49 24	49 22	49 22	49 22	49 23	49 23	49 46	49 46				
Longitude		122 57	123 11	122 57	122 57	122 57	122 57	122 57	123 02	123 02				
Landform (see legend)		2	2	2	2	2	2	2(3)	3(5)	3(5)				
Slope above (est. ft.)		400	500	400	150	500	200	100	-	-				
Area of assoc. (acre)		1	4	1	1	3/4	1/3	1/2	1/2	1/2				
Altitude (ft.)		3150	3430	3200	3275	3050	3625	3700	4540	4530				
Aspect		S60E	S30W	S17W	N80W	S50E	W	S60W	S70W	?				
Slope (degrees)		17	20	5	25	15	29	35	4	4-20				
Wind exposure (A-B-C)		6-4-2	6-3-3	6-5-2	5-4-1	7-6-4	7-5-2	7-6-2	8-3-2	8-3-2				
Snow cover (months)		7	7½	7	7½	6½	7½	7½	8	8				
% coverage:														
By vegetation layer A_1		20	70	26	15	8	35	25	40	40				
A_2		50	40	22	15	60	25	20	30	15				
A_3		40	5	28	40	40	10	20	-	10				
A		95	95	65	50	85	60	50	60	60				
B_1		45	4	12	20	40	30	40	3	2				
B_2		80	8	45	80	20	30	45	45	45				
B		95	12	50	95	50	55	80	48	47				
C		15	12	6	8	6	5	10	2	4				
D_H		80	5	60	65	70	50	25	35	40				
D_L		8	3	15	25	20	8	5	15	15				
D_R		-	1	-	1	-	4	1	4	2				
D		88	8	65	90	90	62	30	50	57				
By decayed wood		10	15	25	25	25	10	10	30	20				
By rock		1	1	-	1	-	6	1	5	3				
Tallest tree on plot (ft.)														
Western hemlock		-	128	104	-	-	-	-	-	-				
Mountain hemlock		99	138	102	99	87	115	94	128	119				
Amabilis fir		23	121	88	82	70	76	92	126	104				
Yellow cedar		77	-	-	89	101	90	32	-	-				
Regeneration (no./sq. meter):														
Mountain hemlock		-	-	?	?	60	?	?	-	-				
Amabilis fir		2	118	?	?	2	?	?	34	9				
Yellow cedar		1	-	?	?	11	?	?	-	-				
Total soil depth (cm.)		?	?	61	42	102	100	34	55	67				
Depth to bottom of A_h (cm.)		?	?	20	10	35	20	13	13	10				
Depth to seepage, if present		?	?	-	-	-	80	-	-	-				
A layer:	Sub-layer										Pres.	Fid.	Tot. c.d.	Life-form
Tsuga mertensiana	1	4.+.1	5.+.2	5.+.3	4.7.2	-	6.8.2	5.7.2	5.7.3	7.7.3	5	2	388	Pm
	2	4.+.1	+.2	4.+.2	+.2	4.7.2	5.7.2	5.7.2	1.+.2	5.7.2				
	3	5.+.1	+	4.7.2	4.7.2	+.+	1.+.1	5.7.2	-	4.+.2				
No. trees over 3 in./acre		130	15	90	130	60	100	195	30	85				
Basal area, sq. ft./acre		92	128	163	151	39	304	346	147	273				
Gross volume, cu. ft./acre		2178	4880	4850	4524	1023	10218	8720	5790	11005				
Abies amabilis	1	-	+.1	+.2	-	-	-	4.+.2	6.7.2	1.+.1	5	2	187	Pm
	2	-	7.8.2	+.1	+.2	1.+.+	4.+.1	+.2	6.7.2	1.+.+				
	3	-	4.8.2	4.+.1	4.7.2	2.+.+	4.6.1	4.6.1	-	1.+.+				
No. trees over 3 in./acre		-	105	85	100	105	185	410	70	25				
Basal area, sq. ft./acre		-	161	40	40	23	91	115	254	40				
Gross volume, cu. ft.?acre		-	7469	944	842	376	1794	2050	10640	1434				
Tsuga heterophylla	1	+.1	7.9.1	2.+.2	-	3.+.2	-	-	-	-	3	2	136	Pm
	2	5.7.1	+.1	4.7.2	+.1	4.7.1	-	-	-	-				
	3	4.+.1	-	+.2	1.+.1	5.7.1	-	-	-	-				
No. trees over 3 in./acre		85	25	75	20	95	-	-	-	-				
Basal area, sq. ft./acre		66	240	111	38	138	-	-	-	-				
Gross volume, cu. ft./acre		1292	8802	2820	1245	3822	-	-	-	-				
Chamaecyparis nootkatensis	1	4.+.2	-	-	2.+.1	2.+.3	+.1	-	-	-	3	2	102	Pm
	2	5.7.2	-	-	1.+.1	7.7.3	-	-	-	-				
	3	3.+.1	-	-	-	4.+.2	+.1	+.1	-	-				
No. trees over 3 in./acre		115	-	-	35	75	40	20	-	-				
Basal area, sq. ft./acre		156	-	-	131	225	56	2	-	-				
Gross volume, cu. ft./acre		2726	-	-	3498	4872	1154	12	-	-				
Totals, including sporadics:														
No. trees over 3 in./acre		380	145	250	285	335	325	625	100	110				
Basal area, sq. ft./acre		321	529	314	359	425	451	463	401	313				
Gross volume, cu. ft./acre		6248	21150	8614	10109	10093	13166	10782	16430	12439				
B layer:														
Vaccinium alaskaense	2	7.7.3	4.6.2	5.6.3	8.9.2	4.6.3	3.5.2	4.7.2	5.6.2	4.6.2	5	2	220	Pnd
Abies amabilis	1	4.+.1	3.+.1	4.6.2	3.6.1	5.6.1	5.7.1	6.7.1	3.+.2	1.+.+	5		188	Pm
	2	3.+.1	4.6.1	3.6.2	4.6.2	1.6.2	4.6.2	4.6.1	4.5.2	4.5.2				
Tsuga mertensiana	1	5.6.1	-	3.6.2	3.6.1	4.6.2	4.7.1	4.6.2	2.+.1	-	5		88	Pm
	2	1.+.1	-	2.+.2	3.+.1	1.+.1	4.6.2	3.+.1	2.5.1	1.+.+				
Vaccinium membranaceum	2	1.+.1	1.+.2	+.1	2.5.2	-	4.6.2	5.7.2	5.7.3	5.7.3	5	2	86	Pnd
Menziesia ferruginea	2	6.6.3	-	+.1	3.6.1	2.6.3	4.6.2	4.7.2	+.1	-	4	2	59	Pnd
Vaccinium ovalifolium	2	-	-	1.5.1	1.5.1	-	1.5.1	4.6.2	1.4.1	1.+.+	4	2	10	Pnd

. . . . continued

SYNTHESIS TABLE II, continued Vaccinium alaskaense association

Plot number	Sub-layer	123	106	15	16	50	25	29	83	82	Pres.	Fid.	Tot. c.d.	Life-form
B layer, continued:														
Tsuga heterophylla	1	3.+.1	+.+	4.6.2	+.1	4.6.1	-	-	-	-	3		26	Pm
	2	+.+	+.+	2.2.2	+.1	1.+.1	-	-	-	-				
Chamaecyparis nootkatensis	1	4.6.1	-	-	1.+.1	2.+.1	2.7.1	1.+.1	-	-	3		17	Pm
	2	3.+.1	-	-	1.+.1	1.+.2	1.+.1	1.+.1	-	-				
Sorbus occidentalis	1	-	-	-	-	+.3	-	+.3	-	-	3	2	-	Pnd
	2	-	+.+	-	+.1	-	1.+.1	1.+.2	-	-				
Cladothamnus pyrolaeflorus	2	-	-	-	1.5.1	-	1.5.2	4.7.2	-	-	2	2	10	Pnd
Rhododendron albiflorum	2	-	-	-	-	-	4.6.2	1.+.2	-	-	2	2	10	Pnd
C layer:														
Rubus pedatus		4.3.2	4.3.2	2.2.2	3.3.2	2.+.2	2.3.2	3.3.2	1.+.1	-	5	2	33	Ch
Vaccinium alaskaense		2.+.1	2.+.2	3.+.2	3.2.2	2.+.2	2.4.1	2.3.2	2.3.2	1.3.2	5		16	Pnd
Abies amabilis		1.+.1	3.+.2	3.+.2	2.+.2	1.+.2	2.+.1	2.+.1	1.+.1	2.5.1	5		14	Pm
Vaccinium membranaceum		1.+.1	+.1	-	2.1.2	-	3.4.2	3.3.2	2.3.2	2.3.2	4		13	Pnd
Clintonia uniflora		4.6.3	+.+	2.3.2	1.1.2	2.+.2	-	2.+.2	-	-	4	2	13	G
Blechnum spicant		+.1	-	-	+.1	2.+.1	2.+.+	+.1	-	-	3	1	2	H
Menziesia ferruginea		-	-	-	+.1	2.+.2	1.+.1	1.+.1	-	-	3		1	Pnd
Cornus canadensis		2.+.1	-	-	+.1	1.+.2	-	-	-	-	2	2	1	Ch
Tsuga mertensiana		-	-	-	1.+.1	-	+.1	1.+.2	1.+.1	-	3		-	Pm
Goodyera oblongifolia		1.+.3	-	-	-	1.+.1	+.2	-	-	-	2	2	-	H
Pyrola secunda		+.2	-	-	+.1	1.+.1	-	-	-	-	2	2	-	Ch
Streptopus streptopoides		-	+.1	+.1	-	+.2	-	-	-	-	2	2	-	H
Tsuga hetereophylla		-	1.+.1	2.+.2	-	1.+.2	-	-	-	-	2		-	Pm
Corallorhiza mertensiana		-	-	-	+.2	+.1	-	-	-	-	2	2	-	G
Listera caurina		-	-	-	+.1	+.+	-	-	-	-	2	2	-	G
Sorbus occidentalis		-	-	-	+.1	-	+.1	1.+.1	-	-	2		-	Pnd
Phyllodoce empetriformis		-	-	-	1.+.1	-	1.2.1	1.3.2	-	+.+	3	1	-	Pne
D layer (humicolous):														
Rhytidiopsis robusta		7.7.3	2.3.2	5.6.3	5.6.2	7.6.3	3.6.2	4.4.2	3.2.2	2.3.2	5	2	172	W
Abies amabilis		1.+.1	2.+.1	1.+.1	1.+.2	2.+.1	+.1	1.+.1	1.+.1	-	5		2	Pm
Dicranum fuscescens		1.1.2	3.3.2	-	8.9.2	6.6.3	-	2.2.2	5.5.3	6.7.3	4	2	172	Te
Rhytidiadelphus loreus		5.4.2	-	5.6.2	1.2.1	3.4.2	+.2	1.1.2	-	-	4	2	55	W
Blepharostoma trichophyllum		1.1.2	+.2	-	2.6.2	+.2	1.1.2	3.3.2	1.1.2	-	4	2	6	Mt
Cephalozia media		1.1.2	1.1.2	-	1.1.2	1.1.2	1.1.2	3.3.2	1.1.2	-	4	2	5	Mt
Calypogeia neesiana		-	1.3.2	+.2	1.1.2	2.3.2	1.1.2	2.2.2	1.2.2	-	4	2	2	Mt
Lophocolea heterophylla		1.1.2	-	1.1.2	1.1.2	1.1.2	-	2.2.2	-	1.1.2	4	2	1	Mt
Lepidozia reptans		1.1.2	1.2.2	1.1.2	-	1.1.2	1.2.2	-	-	1.1.2	4	2	-	Mt
Dicranum scoparium		5.4.3	-	5.6.2	-	1.1.3	6.7.3	7.6.2	-	-	3	2	133	Te
Orthocaulis floerkii		-	-	-	-	-	1.1.2	1.3.2	4.3.2	4.4.2	3	2	20	Mt
Plagiothecium elegans		-	-	1.2.2	-	1.1.2	2.2.2	2.2.2	-	2.2.2	3	2	3	M
Hypnum circinale		-	-	2.3.2	-	1.3.2	1.3.2	2.3.2	1.1.2	-	3	2	2	M
Cladonia bellidiflora		-	-	-	-	+.+	1.+.2	+.1	2.1.2	2.2.2	3	2	2	L
Mnium spinulosum		2.3.2	-	-	1.2.2	1.3.2	1.3.2	-	-	-	3	2	1	Te
Ptilidium pulcherrimum		-	-	-	-	1.1.2	1.1.2	1.+.2	-	1.1.2	3	2	-	Mt
Vaccinium spp.		-	+.+	+.2	1.1.2	-	+.1	-	-	-	3		-	Pnd
Lophozia incisa		-	-	-	-	-	-	+.2	-	4.6.2	2	2	10	Mt
Plagiothecium undulatum		2.3.2	-	-	-	2.5.2	-	-	-	-	2	2	2	M
Bazzania tricrenata		2.2.3	-	2.2.2	-	1.2.2	-	-	-	-	2	2	2	M
Kiaeria blyttii		-	-	-	-	-	2.2.2	2.3.2	-	-	2	1	2	t
Mnium punctatum		-	-	2.3.2	1.2.1	1.1.2	-	-	-	-	2	2	1	Te
Plectocolea obovata		-	-	-	-	-	2.1.2	1.1.2	-	-	2	2	2	Mt
Bryum sp.		-	-	-	-	-	+.2	2.3.2	-	-	2	2	1	Te
Chamaecyparis nootkatensis		1.+.1	-	-	-	+.1	-	-	-	-	2		-	Pm
Cladonia coniocraea		-	-	-	-	-	-	1.1.2	1.+.2	-	2	2	-	L
Bryum sandbergii		-	-	-	-	-	1.5.2	-	1.+.1	-	2	2	-	Te
Scapania bolanderi		1.1.+	-	-	-	-	-	-	1.1.2	-	2	2	-	M
Brachythecium sp.		1.3.2	-	-	-	-	1.3.2	-	-	1.2.2	2	2	-	M
Pleurozium schreberi		1.1.+	-	-	+.2	-	-	-	-	+.+	2	2	-	W
Lescuraea baileyi.		-	-	-	-	+.+	1.2.2	1.1.2	-	-	2	2	-	Mt
Plagiothecium denticulatum		1.1.2	-	-	-	+.2	-	-	-	1.2.2	2	2	-	M
Tsuga mertensiana		1.+.1	1.+.1	1.+.1	-	-	-	-	-	-	2		-	Pm
Diplophyllum taxifolium		1.3.2	-	-	-	-	+.2	1.1.2	-	-	2	2	-	t

Sporadic species:

A layer, none

B layer, none

C layer:
H Carex nigricans 82(1.6.+); 29(1.5.+)
Pm Chamaecyparis nootkatensis 50(1.+.+)
Pnd Cladothamnus pyrolaeflorus 16(1.+.1); 29(1.+.1)
Ch Luetkea pectinata 29(2.4.2)
Pnd Rhododendron albiflorum 25(+.2)
Pnd Rubus spectabilis 25(+.+)
H Streptopus amplexifolius 29(+.1)
H Tiarella unifoliata 29(+.1)
Pnd Vaccinium ovalifolium 25(1.3.1); 29(2.+.2)
G Veratrum eschscholtzii 29(+.1)

D layer, humicolous
M Bazzania ambigua 83(1.1.2)
Mt Eurhynchium stokesii 50(1.1.2)
M Plagiochila asplenioides 123(1.5.2)
Te Rhacomitrium heterostichum 82(1.1.2)
Pm Tsuga heterophylla 50(1.+.+)

SYNTHESIS TABLE III   Streptopus association (Abieteto - Streptopetum)

	Typical subassociation (subassoc. abietetoso - streptopetosum)													Degraded subassociation (subassoc. chamaecyparetosum)					
Plot number	13	14	17	51	85	37	44	107	34	102	103	36	66	07	02	10	11	125	06
Plot size (acre)	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5
Date	16/7 1959	31/8 1959	22/7 1959	8/9 1960	29/8 1960	9/8 1960	19/7 1961	29/7 1961	28/7 1960	20/9 1960	20/9 1960	9/8 1960	8/8 1960	12/8 1959	8/8 1959	14/8 1959	20/7 1960	11/9 1961	13/8 1959
Locality (see legend)	SM	SM	SM	SM	RM	RM	SM	H	SM	G	G	RM	RM	SM	SM	SM	SM	H	SM
Latitude	49 22	49 22	49 22	49 22	49 46	49 46	49 22	49 24	49 22	49 23	49 23	49 46	49 46	49 22	49 22	49 22	49 22	49 24	49 22
Longitude	122 57	122 57	122 57	122 58	123 03	123 03	122 57	123 11	122 58	123 05	123 05	123 03	123 03	122 57	122 57	122 56	122 56	123 11	122 57
Landform (see legend)	2	2	2	1-(2)	2	1-(2)	2	2	2	2	2	2	2	2	2(5)	2	2	2	2
Slope above (est. ft.)	250	300	1500	500	150	250	300	400	400	300	400	200	600	200	300	200	300	300	120
Area of assoc. (acre)	2/3	2	1	1/4	1	1/2	1/2	1	3/4	1/2	1	1/2	3/4	2	2/3	3/5	3/4	1	3/4
Altitude (ft.)	3070	3025	3050	3280	4360	4120	3330	3500	3330	3725	3710	4300	3780	3260	3400	3150	3220	3480	3330
Aspect	N70W	S80W	N75W	S15W	N40W	N50W	N80W	N80W	S10W	W	W	N80W	W	S10E	S10W	S80E	S70E	S60E	S70E
Slope (degrees)	19	20	40	0-5	10	15	20	33	17	34	34	25	10	30	20	5	22	34	10
Wind exposure (A-B-C)	5-2-1	7-4-2	6-4-1	7-5-2	6-3-1	7-6-3	7-5-2	6-3-1	7-5-2	8-5-3	8-5-3	8-6-4	8-4-2	6-3-1	7-4-3	6-5-1	6-3-2	6-5-3	6-4-1
Snow cover (months)	6½	6½	7	6½	8	6½	7	7	7	7	7	6½	7	7	6½	7	6½	6½	7
% coverage:																			
By vegetation layer A_1	15	20	20	35	30	35	25	55	12	20	50	35	30	20	30	20	12	50	35
A_2	)60	60	20	15	15	30	25	15	40	20	30	20	45	12	45	25	25	35	15
A_3	)	1	25	20	20	8	20	20	30	40	30	15	20	40	25	30	20	20	25
A	70	70	50	60	55	65	55	80	75	65	85	65	85	60	75	65	50	70	65
B_1	5	10	7	10	40	20	40	4	20	8	5	10	-	40	12	20	20	20	30
B_2	75	70	60	10	55	50	50	40	40	20	20	25	35	50	40	45	35	75	50
B	75	75	65	15	85	60	80	44	55	28	25	35	35	80	45	60	45	85	70
C	75	50	40	55	30	25	50	40	40	40	45	18	10	25	7	12	15	10	25
D_H	55	25	55	70	60	50	80	5	35	25	10	40	55	75	30	65	45	45	60
D_L	2	10	30	8	18	5	7	1	20	9	5	6	8	7	4	10	3	2	5
D_R	-	-	1	1	2	-	-	5	1	1	-	-	-	1	1	1	2	-	1
D	57	35	85	78	80	55	87	6	55	35	15	46	63	82	35	75	50	47	65
By decayed wood	10	25	35	15	35	15	15	2	25	10	10	15	25	10	6	15	5	5	10
By rock	-	-	1	1	3	1	1	1	6	2	1	-	-	2	2	2	2	-	1
Tallest tree on plot (ft.):																			
Western hemlock	128	170	116	119	11	16	-	-	114	-	-	-	142	-	-	-	-	78	-
Mountain hemlock	-	-	125	131	154	131	132	171	112	141	141	116	-	110	110	106	114	109	117
Amabilis fir	156	170	120	127	151	157	138	121	112	134	168	146	148	101	125	142	129	110	93
Yellow cedar	-	-	122	-	-	-	92	-	130	-	-	-	129*	100	-	129	122	117	114
Regeneration (no./sq. meter)																			
West. or mtn. hemlock	?	?	?	60	1	-	142	18	48	1	4	-	3	?	?	?	-	-	?
Amabilis fir	?	?	?	45	19	68	18	82	36	23	19	33	59	?	?	?	152	23	?
Yellow cedar	?	?	?	-	-	-	-	9	-	-	-	-	2*	?	?	?	-	2	?
Total soil depth (cm.)	50	78	74	70	105	104	?	?	85	92	93	72	100	86	90	72	74	?	61
Depth to bottom of A_h (cm.)	34	14	10	36	32	20	?	?	29	12	11	21	9	25	44	10	8	?	15
Depth to seepage, if present	35	70	72	25	21	-	?	?	-	-	-	-	-	-	65	-	59	?	-
Remarks													* red-cedar						

A layer:	Sub-layer	13	14	17	51	85	37	44	107	34	102	103	36	66	Subassoc. Char. P	c.d.	07	02	10	11	125	06	Subassoc. Pres.	Subassoc. Char. c.d.	Entire association Pres.	Fid.	Tot. c.d.	Life-form
Abies amabilis	1	5.+.3	5.+.3	4.+.3	6.7.2	6.8.3	6.8.3	4.+.2	+.+	3.+.2	5.8.3	7.8.3	6.8.3	5.7.3	5		+.3	5.7.2	4.7.3	4.+.3	+.1	+.3						
	2	}4.+.3	6.8.3	-	2.+.2	+.2	6.8.2	3.7.2	5.8.3	3.+.2	5.8.3	6.8.3	5.8.3	5.7.3		57	+.2	6.7.2	5.7.2	4.7.2	3.+.1	2.+.2	5	30	5	2	918	Pm
	3	}	+.1	4.7.2	3.7.2	5.8.3	4.+.2	5.7.2	5.8.2	5.7.2	6.7.2	6.7.2	4.8.2	-			5.7.1	3.+.2	1.+.1	2.+.1	5.7.1	3.+.2						
No. trees over 3 in./acre		45	50	100	50	135	135	180	135	70	185	150	140	50			170	150	120	80	51	115						
Basal area, sq. ft./acre		124	239	96	128	286	421	204	163	73	314	481	254	135			65	276	170	122	83	35						
Gross volume, cu. ft./acre		6573	13014	3502	6220	13537	16426	7653	4624	2516	11389	20890	13164	9235			1426	9953	6842	4496	1864	820						

. . . . . continued

SYNTHESIS TABLE III, continued   Streptopus association

Plot number	Sub-layer	13	14	17	51	85	37	44	107	34	102	103	36	66	Typical Subassoc. Pres.	Typical Subassoc. Char. c.d.	07	02	10	11	125	06	Degraded Subassoc. Pres.	Degraded Subassoc. Char. c.d.	Entire association Pres.	Fid.	Tot. c.d.	Life-form
A layer, continued:																												
Tsuga mertensiana	1	-	-	+.3	3.+.2	+.3	1.+.+	5.+.3	8.9.3	3.+.2	4.+.3	+.3	1.+.2	-	4	25	4.7.2	4.+.2	-	-	5.+.3	5.7.3	5	30	5	2	432	Pm
	2	-	-	3.+.1	3.+.2	5.+.3	1.+.2	5.7.3	-	5.7.2	+.2	-	-	-			4.+.2	3.+.2	3.7.2	3.+.1	4.+.2	2.+.2						
	3	-	-	3.+.2	3.7.2	-	-	2.+.2	-	3.+.2	4.7.2	4.7.2	-	-			4.7.2	5.7.1	4.7.1	4.7.2	4.7.1	4.7.2						
No. trees over 3 in./acre		-	-	55	60	50	15	60	35	50	85	70	25	-			105	110	85	115	70	115						
Basal area, sq. ft./acre		-	-	92	84	96	56	246	335	97	330	136	38	-			208	183	87	54	140	206						
Gross volume, cu.ft./acre		-	-	2718	3172	4402	2469	8991	15090	3286	8153	4104	1316	-			6088	5111	3489	2564	3776	5873						
Chamaecyparis nootkatensis	1	-	-	3.+.2	-	-	-	+.1	-	2.+.3	-	-	-	-	2	9	2.+.2	-	4.7.3	4.+.3	5.8.3	4.7.2	5	17	3	2	113	Pm
	2	-	-	4.7.2	-	-	-	+.+	-	4.7.2	-	-	-	-			-	-	3.+.1	4.7.2	4.+.2	+.2						
	3	-	-	+.2	2.+.1	-	-	-	-	1.+.1	-	-	-	-			2.+.1	-	3.6.1	1.+.1	-	+.2						
No. trees over 3 in./acre		-	-	45	5	-	-	10	-	25	-	-	-	-			70	-	60	40	45	30						
Basal area, sq. ft./acre		-	-	232	48	-	-	96	-	208	-	-	-	-			202	-	288	294	520	18						
Gross volume, cu. ft./acre		-	-	6960	500	-	-	1336	-	4925	-	-	-	-			4174	-	7460	8138	10732	5534						
Tsuga heterophylla	1	+.2	+.3	+.2	2.+.2	-	-	-	-	3.+.3	-	-	-	4.+.2	3	27	-	-	-	-	-	-	2	2	3	2	165	Pm
	2	6.7.3 (2–3)	7.8.3	3.7.2	3.+.2	-	-	-	-	3.+.2	-	-	-	4.7.1			-	-	-	-	3.+.+	-						
	3		-	3.6.2	2.+.2	-	-	-	-	-	-	-	-	5.7.1			+.2	-	-	-	-	-						
No. trees over 3 in./acre		50	50	65	40	5	-	-	-	25	-	-	-	65			5	-	-	-	10	-						
Basal area, sq. ft./acre		319	164	65	82	-	-	-	-	76	-	-	-	120			4	-	-	-	92	-						
Gross volume, cu. ft./acre		14190	8244	2014	2862	1	-	-	-	2687	-	-	-	4405			56	-	-	-	1680	-						
Totals, including sporadics:																												
No. trees over 3 in./acre		95	100	265	155	190	155	250	170	170	270	220	165	140			350	265	265	235	380	260						
Basal area, sq. ft./acre		443	403	435	342	382	478	546	498	454	644	617	292	337			479	460	545	470	835	259						
Gross volume, cu. ft./acre		20763	21258	15194	12754	17940	18899	17980	19714	13414	19542	24988	14480	16515			11745	15072	17791	15198	18052	12227						
B layer:																												
Vaccinium alaskaense	2	8.7.3	7.8.2	6.8.2	4.6.1	4.6.2	5.7.2	6.7.2	6.7.2	5.7.2	5.6.1	5.6.1	4.6.1	5.7.2	5	29	5.7.2	5.6.2	4.6.2	5.6.3	7.7.3	5.6.2	5	27	5	2	539	Pnd
Abies amabilis	1	2.+.1	2.+.2	3.6.2	2.6.1	5.7.2	4.7.2	5.6.2	4.6.2	4.7.1	4.6.2	2.+.1	4.+.1	-	5	19	5.7.1	4.6.2	4.6.1	4.6.1	5.6.1	3.6.1	5	35	5		426	Pm
	2	5.6.1	5.7.2	4.6.2	4.6.1	4.6.1	4.6.1	4.+.1	2.6.2	2.+.1	3.+.1	2.+.1	4.+.2	4.6.1			5.7.1	4.+.1	6.7.1	4.6.1	2.+.1	4.6.1						
Tsuga mertensiana	1	-	-	2.+.1	4.7.2	5.7.2	2.+.2	4.6.2	2.+.1	3.+.1	2.6.1	3.6.2	4.5.1	-	4	11	2.6.1	3.6.2	2.5.1	3.6.1	2.+.1	2.6.1	5	11	5		176	Pm
	2	-	-	3.6.2	1.+.1	4.6.1	4.6.2	4.+.1	2.+.1	2.+.1	1.+.+	1.+.+	3.+.2	-			4.6.1	2.+.1	5.7.1	3.5.1	1.+.+	4.6.1						
Menziesia ferruginea	2	1.+.2	1.5.2	2.6.2	1.+.1	-	1.+.1	1.5.2	+.1	3.6.3	2.5.1	-	-	2.+.1	4	1	2.5.2	1.5.1	1.+.1	3.6.2	4.5.2	1.+.1	5	2	5	2	24	Pnd
Vaccinium membranaceum	2	-	-	2.6.2	-	5.6.3	2.+.1	1.+.2	3.5.1	+.1	2.+.+	3.4.1	2.5.1	-	4	4	3.6.2	1.+.1	2.5.2	3.5.2	3.5.1	2.6.2	5	3	4	2	56	Pnd
Tsuga heterophylla	1	3.+.1	4.7.2	2.+.1	3.+.1	+.+	1.+.1	-	-	1.+.1	-	-	2.+.1	-	4	4	-	+.1	-	-	-	-	1	-	3		34	Pm
	2	2.5.1	4.7.2	1.+.1	-	-	1.+.1	-	-	1.+.1	-	-	2.+.2	-			-	-	-	-	-	-						
Vaccinium ovalifolium	2	3.5.2	2.5.2	+.1	1.+.1	1.+.+	1.+.1	-	1.5.2	-	-	-	-	1.5.1	4	-	-	-	1.+.1	+.1	-	-	2	-	3	2	6	Pnd
Sorbus occidentalis	1	-	-	-	+.2	-	-	-	+.2	+.3	-	-	-	-	4	-	-	-	-	-	-	-	3	-	3	2	1	Pnd
	2	1.+.2	-	1.+.1	+.1	+.1	-	-	1.+.2	2.5.2	+.1	-	-	1.+.1			-	+.+	+.+	+.1	-	-						
Rubus spectabilis	2	4.7.2	1.5.2	-	-	-	1.+.1	-	+.1	-	2.5.1	2.5.2	-	-	3	2	-	-	-	-	-	-	0	-	2	2	12	Pnd
Cham. nootkatensis	1	-	-	-	-	-	-	1.+.1	+.+	-	-	-	-	-	2	1	3.6.1	-	+.1	+.1	1.+.1	+.1	5	1	2		11	Pm
	2	-	-	-	-	-	-	1.+.1	+.+	3.5.2	-	-	-	-			2.6.1	-	1.5.1	1.+.1	1.+.+	+.+						
Cladothamnus pyrolaeflorus	2	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	1.5.2	1.+.1	+.1	+.2	2.6.3	-	5	-	2	2	1	Pnd
Rhododendron albiflorum	2	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	+.1	-	4.6.2	-	2	5	1	1	10	Pnd
Oplopanax horridus	2	-	-	-	-	-	-	-	-	-	+.+	+.+	-	1.+.+	2	-	-	-	-	-	-	-	0	-	1	1	-	Pnd
C layer:																												
Rubus pedatus		8.8.3	5.7.2	6.7.3	2.3.2	5.3.2	4.4.2	5.6.3	4.6.2	2.2.2	4.3.2	4.3.2	4.2.2	1.4.1	5	18	4.5.2	3.5.2	4.5.2	4.6.3	4.4.3	3.6.2	5	8	5	2	285	Ch
Blechnum spicant		4.5.2	2.6.2	4.6.2	7.8.2	+.+	-	4.6.1	1.+.1	5.6.2	2.4.1	1.+.1	+.+	2.5.1	5	9	4.5.2	3.4.1	+.+	2.5.1	4.5.1	4.7.2	5	7	5	3	148	H
Streptopus roseus		1.+.2	1.+.1	3.4.2	2.+.1	2.+.2	4.5.3	1.+.2	6.6.2	1.+.1	5.3.2	5.3.2	1.5.1	3.5.3	5	8	2.+.1	-	2.+.2	2.4.3	2.4.2	2.+.2	5	1	5	3	110	H
Vaccinium alaskaense		+.2	3.6.2	4.2.2	1.+.+	2.3.2	1.+.1	3.3.2	3.+.2	3.3.2	3.+.2	3.+.2	3.+.1	1.1.2	5	4	3.5.2	2.+.2	4.5.2	3.5.2	1.+.1	3.5.2	5	4	5		72	Pnd

. . . . . continued

SYNTHESIS TABLE III, continued   Streptopus association

Plot number	13	14	17	51	85	37	44	107	34	102	103	36	66	Typical subassoc. Pres.	Typical subassoc. Char. c.d.	07	02	10	11	125	06	Degraded subassoc. Pres.	Degraded subassoc. Char. c.d.	Entire assoc. Pres.	Fid.	Tot. c.d.	Life-form
C layer, continued:																											
Abies amabilis	3.+.1	2.+.2	2.+.1	3.+.2	4.+.1	2.+.1	4.+.1	1.+.2	1.+.1	2.+.1	2.+.2	3.+.1	2.+.1	5	3	3.+.1	3.+.1	3.+.1	3.+.2	2.+.1	2.+.1	5	3	5		63	Pm
Veratrum eschscholtzii	-	-	1.+.2	3.+.2	+.1	2.4.2	2.+.2	1.+.1	1.+.1	+.+	+.+	1.+.1	+.1	5	-	1.+.1	1.+.1	+.1	+.1	+.+	1.+.3	5	-	5	2	7	G
Clintonia uniflora	2.3.3	3.5.2	4.6.3	4.5.3	-	-	2.2.2	3.5.2	4.4.2	1.+.2	1.+.2	-	3.5.2	4	5	4.6.3	3.4.2	-	-	4.3.3	5.7.3	4	12	4	2	97	G
Streptopus streptopoides	7.6.3	4.5.2	-	1.+.1	1.+.2	2.+.1	+.1	3.4.2	2.+.+	3.2.2	3.3.2	2.+.1	1.3.2	5	6	-	-	-	-	+.1	-	1	-	4	3	78	H
Vaccinium membranaceum	-	-	1.+.2	-	3.3.2	2.+.2	1.+.1	1.+.2	-	2.+.+	2.+.+	2.2.2	1.+.1	4	1	4.5.2	+.1	3.5.2	1.+.1	1.+.1	3.5.2	5	3	4		29	Pnd
Tiarella unifoliata	1.+.2	+.1	1.+.2	-	2.+.2	2.5.2	-	3.+.2	-	5.3.2	5.2.2	1.1.2	1.+.2	4	6	-	-	1.+.1	-	-	-	1	-	3	2	57	H
Tsuga mertensiana	-	-	-	1.+.2	3.+.1	-	4.+.1	-	1.+.2	1.+.+	+.1	1.+.1	-	3	2	3.+.1	2.+.1	2.+.1	-	+.+	2.3.1	5	2	3		23	Pm
Tiarella trifoliata	4.4.2	3.5.2	+.2	-	-	1.+.1	-	2.+.2	-	1.+.2	2.+.2	1.+.2	2.+.2	4	2	-	-	1.+.1	-	-	-	1	-	3	2	18	H
Athyrium filix-femina	2.5.1	1.5.2	+.+	-	+.+	-	+.+	+.1	-	3.4.2	2.4.2	-	-	4	1	-	-	-	-	-	+.+	1	-	3	2	7	H
Menziesia ferruginea	-	-	1.+.1	1.+.1	-	-	-	+.+	-	-	-	-	1.+.1	2	-	1.+.1	1.+.+	3.+.1	1.+.1	-	1.+.2	5	1	3		5	Pnd
Streptopus amplexifolius	2.+.2	1.+.+	1.+.2	+.+	-	1.+.1	-	+.1	1.+.1	+.+	+.+	-	-	4	-	+.1	-	-	+.1	-	-	2	-	3	2	1	H
Listera caurina	-	-	1.+.2	-	+.1	-	-	-	-	-	-	-	1.+.3	2	-	1.+.2	-	1.+.1	+.1	+.2	+.1	5	-	3	2	-	G
Sorbus occidentalis	-	+.1	1.+.1	-	1.+.+	+.1	-	+.+	1.+.+	--	-	-	1.+.1	3	-	-	1.+.1	-	+.1	-	1.+.1	3	-	3		-	Pnd
Gymnocarpium dryopteris	3.3.2	-	-	-	-	3.6.3	-	1.4.2	-	1.+.2	4.6.2	1.6.2	-	3	3	-	-	-	-	-	-	0	-	2	2	20	G
Cornus canadensis	+.2	+.+	2.3.2	1.+.1	-	-	-	-	2.2.2	-	-	-	2.+.1	3	-	3.+.2	-	-	-	-	-	1	5	2	2	8	Ch
Tsuga heterophylla	2.+.1	2.5.2	2.+.1	-	-	-	-	-	-	-	-	1.+.1	-	2	1	-	-	-	-	-	-	0	-	2		3	Pm
Lysichitum americanum	2.5.1	+.1	1.4.1	1.+.+	-	-	-	-	-	-	-	-	-	2	-	-	-	-	+.+	-	-	1	-	2	2	1	G
Carex laeviculmis	+.1	-	+.+	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1.6.1	+.+	-	-	2	-	2	2	-	H
Rubus spectabilis	-	+.1	-	+.+	-	1.+.+	-	-	-	-	+.1	-	-	2	-	-	-	-	-	-	-	0	-	2		-	Pnd
Chamaecyparis nootkatensis	-	-	-	-	-	-	1.+.2	-	1.+.1	-	-	-	-	1	-	-	-	-	+.+	+.+	+.1	3	-	2		-	Pm
Cladothamnus pyrolaeflorus	-	-	+.+	-	-	-	-	-	-	-	-	-	-	1	-	1.+.1	-	+.+	-	+.1	+.+	4	-	2		-	Pnd
D layer (humicolous);																											
Rhytidiopsis robusta	3.2.2	4.5.2	2.5.2	3.5.2	5.5.2	5.6.3	5.4.2	3.4.2	4.4.2	1.2.2	-	5.5.3	6.7.3	5	14	8.6.2	4.5.2	7.6.2	4.6.2	5.5.3	6.6.3	5	34	5	2	372	W
Abies amabilis	-	2.+.1	-	2.+.1	2.+.1	2.+.1	2.+.1	2.+.2	-	1.+.1	1.+.1	1.+.1	2.+.1	4	1	+.2	1.+.1	2.+.1	2.+.1	2.+.1	1.+.1	5	1	5		10	Pm
Dicranum fuscescens	1.2.1	-	2.5.2	5.6.2	-	4.5.2	7.6.3	3.3.2	4.3.2	4.3.2	2.2.2	4.5.3	4.6.2	5	12	6.5.2	2.2.2	-	2.3.2	5.5.3	-	4	15	4	2	192	Te
Mnium nudum	4.5.2	5.6.2	5.6.2	5.5.2	2.3.2	-	-	1.2.2	2.2.2	1.4.2	4.4.2	-	1.1.1	4	10	1.1.1	-	2.4.2	1.5.2	1.2.2	2.3.2	5	-	4	2	99	Te
Rhytidiadelphus loreus	2.2.2	4.5.2	1.2.2	5.6.2	-	-	5.6.2	-	5.4.2	1.1.2	1.1.2	-	1.2.2	4	8	4.5.2	4.5.2	2.5.1	1.2.1	3.3.1	2.2.2	5	5	4	2	98	W
Plagiothecium elegans	2.2.2	3.3.2	1.5.2	2.2.2	-	1.1.2	1.1.2	2.2.2	2.1.2	2.2.2	-	-	-	4	1	1.2.2	2.3.2	1.3.2	1.1.1	1.2.2	2.4.2	5	-	4	2	12	M
Hypnum circinale	1.2.2	-	-	1.2.2	2.1.2	-	2.1.2	1.2.2	1.1.2	1.1.2	1.1.2	4.3.2	1.1.2	4	1	1.2.2	1.2.2	-	-	-	-	2	-	4	2	12	M
Calypogeia neesiana	2.2.2	3.2.2	1.3.2	1.1.2	2.5.3	-	1.3.2	-	1.1.1.	1.1.2	1.2.2	1.2.2	-	4	-	2.3.2	1.1.2	-	1.2.2	-	1.4.2	4	-	4	2	8	Mt
Cephalozia media	1.1.2	-	1.1.2	1.1.2	1.1.2	2.2.2	-	-	1.1.2	-	-	1.1.1	1.1.1	4	-	1.2.2	1.2.2	2.3.2	1.1.1	1.1.2	3.3.2	5	1	4	2	7	Mt
Diplophyllum taxifolium	1.3.2	-	1.2.2	1.3.2	1.1.2	-	1.2.2	-	-	-	-	1.2.2	1.2.2	3	-	1.1.2	1.1.2	1.2.2	-	1.2.2	1.1.2	5	-	4	2	-	Mt
Plagiothecium denticulatum	1.+.2	2.2.2	-	-	1.1.2	1.1.2	3.+.2	-	-	3.2.3	4.3.3	1.1.1	-	4	3	-	1.4.2	-	-	1.1.2	-	2	-	3	3	21	M.
Mnium spinulosum	-	-	1.1.1	-	2.3.2	-	-	-	1.2.2	-	-	1.1.1	-	2	-	1.2.2	-	3.4.2	-	1.2.2	1.3.2	4	1	3	2	6	Te
Lophocolea heterophylla	1.2.2	-	1.3.2	-	1.1.2	-	-	-	1.1.2	-	-	1.1.2	1.1.2	3	-	-	1.2.2	3.2.2	1.1.1	1.1.2	2.1.2	5	1	3	2	6	Mt
Dicranum scoparium	-	4.5.3	-	-	6.6.2	-	2.5.2	-	-	-	-	-	-	2	14	-	5.6.2	4.5.2	-	-	5.6.2	3	20	2	2	104	Te
Blepharostoma trichophyllum	-	-	-	2.1.2	-	-	-	-	-	-	-	1.1.1	1.1.2	2	-	1.1.2	1.2.2.	2.3.2	-	-	3.3.2	4	1	2	2	7	Mt
Bazzania ambigua	-	+.+	-	3.3.2	-	-	-	-	-	1.1.2	-	-	1.1.2	2	1	1.2.2	-	-	-	-	1.1.2	2	-	2	3	5	Mt
Lepidozia reptans	1.2.2	2.2.2	1.1.2	-	-	-	-	-	-	-	-	-	-	2	-	1.1.2	2.3.2	1.1.2	-	-	2.1.2	4	-	2	2	3	Mt
Plagiothecium undulatum	2.3.2	2.2.2	1.3.2	1.3.3	-	-	-	-	1.1.+	-	-	-	-	2	-	-	-	-	1.1.1	1.3.1	-	2	-	2	2	2	M
Chamaecyparis nootkatensis	-	-	-	-	-	-	1.+.1	+.+	-	-	-	-	-	1	-	+.1	-	-	+.+	2.+.1	-	3	-	2		1	Pm
Tsuga mertensiana	-	-	-	-	1.+.+	1.+.1	2.+.1	1.+.2	-	-	-	-	-	2	-	-	+.1	1.+.1	-	+.+	-	3	-	2		1	Pm
Bryum sandbergii	-	-	-	1.1.1	-	-	2.5.2	-	-	1.2.2	1.2.2	1.2.2	1.1.1	3	-	-	-	-	-	-	-	0	-	2	2	-	Te
Plagiochila asplenioides	-	-	-	1.1.2	-	-	-	-	-	-	-	-	-	1	-	1.1.2	-	1.3.2	-	1.1.2	1.1.2	4	-	2	2	-	Te
Bazzania tricrenata	-	-	1.1.2	-	-	1.2.2	-	-	1.1.2	-	-	-	-	2	-	-	1.2.2	-	-	1.2.2	1.1.2	3	-	2	2	-	M
Scapania bolanderi	-	-	-	1.1.2	-	-	-	-	-	1.1.+	1.1.1	-	1.1.+	2	-	1.1.2	-	-	-	-	1.1.2	2	-	2	2	-	M

Sporadic species, Streptopus assoc.

A layer:
Pm Thuja plicata 66(5.6.2)

B layer:
Pm Sambucus pubens 102(1.6.1)

C layer:
H Arnica latifolia 10(+.1)
G Corallorhiza mertensiana 02(+.1)
G Dicentra formosa 107(+.+); 102(1.4.2); 02(+.+)
H Dryopteris austriaca 13(3.+.2); 14(2.6.2)
H Epilobium angustifolium 10(+.+); 44(+.+); 107(+.+)
Ch Gaultheria humifusa 07(1.2.2)
H Goodyera oblongifolia 07(+.1); 125(+.1)
G Habenaria saccata 17(1.+.2)
G Listera cordata 13(+.3); 37(+.1)
Ch Luetkea pectinata 85(+.2)
H Luzula parviflora 107(+.+); 102(1.+.1); 103(+.+)
Ch Lycopodium clavatum 66(2.+.3)
Ch Lycopodium selago 02(+.+); 85(+.+)
Pnd Oplopanax horridus 103(+.+)
Pne Phyllodoce empetriformis 10(+.+); 11(+.+)
H Polystichum munitum 17(+.+); 06(+.+)
Ch Pyrola secunda 107(+.1); 125(+.2); 66(1.+.+)
Pnd Rhododendron albiflorum 125(+.+)
H Senecio triangularis 37(+.1)
Pm Thuja plicata 66(1.+.2)
H Tiarella laciniata 13(+.2)
H Trientalis arctica 17(1.+.2)
Pnd Vaccinium ovalifolium 13(+.2); 51(1.+.+)
H Valeriana sitchensis 37(3.6.3)
H Viola glabella 07(1.+.2); 66(+.+)

D layer (humicolous):
M Brachythecium asperrimum 37(1.2.2); 10(1.2.2)
Mt Cephalozia lammersiana 17(2.2.2)
Mt Cephalozia leucantha 51(1.1.2)
L Cladonia coniocraea 17(+.2); 16(+.1)
t Dicranella heteromalla 13(1.1.2); 102(1.2.2)
t Diplophyllum albicans 51(1.1.2)
t Diplophyllum plicatum 85(+.2)
t Ditrichum montanum 66(1.1.1)
Mt Eurhynchium stokesii 103(2.2.2); 06(1.3.2)
Mt Heterocladium procurrens 17(+.2); 34(1.1.2); 06(1.1.2)
M Hookeria lucens 51(1.+.2)
M Hypnum dieckii 51(1.2.2); 06(1.2.2)
Mt Lescuraea baileyi 37(+.2)
Mt Lophozia porphyroleuca 02(1.2.2); 11(1.2.2)
Th Moerckia blyttii 17(1.1.2); 51(6.6.3); 11(1.2.2)
Mt Nardia scalaris 51(1.1.2)
Te Oligotrichum parallelum 85(1.1.2)
Mt Orthocaulis floerkii 85(3.2.2); 07(+.2); 02(1.1.2)
Mt Orthocaulis kunzeanus 51(+.2)
Th Pellia epiphylla 13(1.2.2); 85(1.+.2)
Te Pogonatum alpinum 85(1.2.2)
t Pohlia nutans 85(2.2.2)
Te Polytrichum commune 44(1.+.2)
W Pleurozium schreberi 34(+.+); 11(+.2)
Mt Ptilidium californicum 85(1.1.2); 36(3.1.2); 02(+.2)
M Scapania undulata 51(+.2)
Td Sphagnum girgensohnii 13(+.1); 51(4.6.2); 11(+.2)
Td Sphagnum squarrosum 17(1.5.2)
Pm Thuja plicata 66(1.+.1)
Pm Tsuga heterophylla 13(3.+.1); 14(1.+.1); 51(1.+.1)
Pnd Vaccinium spp. 61(1.+.1); 10(1.+.1)

SYNTHESIS TABLE IV *Leptarrhena* - *Caltha leptosepala* association (*Leptarrheneto* - *Calthetum leptosepalae*)

Plot number	87	52	70	73	79	95	88	Pres.	Fid.	Tot. c.d.	Life-form
Plot size (acre)	1/60	3/80	1/90	1/40	1/20	1/40	1/60				
Date	31/8 1960	6/9 1960	24/8 1960	30/8 1960	11/8 1960	21/9 1960	31/8 1960				
Locality (see legend)	RM	RM	RM	RM	RM	G	RM				
Latitude	49 46	49 48	49 46	49 46	49 46	49 24	49 46				
Longitude	123 03	123 02	123 02	123 02	123 02	123 05	123 03				
Landform (see legend)	2	1	1	1	1	1 (2)	2				
Slope above (est. ft.)	300	along stream	along stream	along stream	150	along stream	300				
Area of assoc. (acre)	1/25	1/10	1/60	1/25	1/20	1/30	1/40				
Altitude (ft.)	4060	4735	4800	4680	4550	4200	4060				
Aspect	W	N80W	N40W	S40W	S60W	S40E	S30E				
Slope (degrees)	9	6	4	9	10	14	2				
Wind exposure (A-B-C)	0-0-6	0-0-6	0-0-5	0-0-5	0-0-7	0-0-5	0-0-6				
Snow cover (months)	8	9	9	9	8½	8½	8				
% coverage:											
By vegetation layer B_1	-	-	-	-	8	-	-				
B_2	-	1	-	-	10	1	-				
B	-	1	-	-	15	1	-				
C	95	60	85	85	98	95	90				
D_H	80	95	90	90	70	85	85				
By decayed wood	-	-	-	3	-	-	-				
By rock	-	-	-	-	-	-	-				
By open water	-	5	-	-	-	-	-				
Regeneration (no./sq. meter)		------------	------------	none	------------	------------					
Total soil depth (cm.)	67	?	74	36	40	55	80				
Depth to bottom of A_h (cm.)	66	?	18	25	40	28	64				
Depth to seepage, if present	20	?	32	2	?	22	68				
B layer:											
Salix commutata	-	+.+	-	-	1.5.2	-	-	2	4	-	Pnd
C layer:											
Leptarrhena pyrolifolia	2.+.3	7.6.2	6.5.3	6.4.2	5.+.3	7.6.3	6.4.3	5	4	225	H
Erigeron peregrinus	2.+.2	4.3.2	7.4.2	4.2.2	6.6.2	5.4.3	3.3.2	5	4	134	H
Caltha leptosepala	6.4.2	3.2.2	5.3.3	6.4.2	4.4.2	5.3.3	6.5.2	5	5	164	H
Parnassia fimbriata	5.3.3	5.4.2	-	5.3.2	3.4.2	3.3.2	5.4.2	5	4	110	H
Carex spectabilis	3.3.2	1.1.2	-	+.+	4.4.2	3.2.2	4.3.2	5	3	30	H
Carex nigricans	-	-	5.5.2	5.6.2	2.3.2	7.7.3	2.3.2	4	2	102	H
Epilobium alpinum	-	3.2.1	1.+.1	2.2.2	1.+.1	3.2.2	-	4	4	11	G
Deschampsia atropurpurea	-	2.+.1	1.+.2	+.2	1.+.1	2.+.2	-	4	2	2	H
Phyllodoce empetriformis	-	1.+.1	1.2.2	1.4.2	1.3.2	+.+	-	4	1	-	Pne
Mitella pentandra	-	1.+.2	1.+.2	1.+.1	1.+.2	1.+.2	-	4	3	-	H
Equisetum palustre	4.4.2	4.3.2	-	3.+.2	7.7.3	-	5.4.2	4	4	100	G
Agrostis aequivalvis	-	2.1.2	-	1.+.2	-	5.4.3	1.+.2	3	2	26	H
Veratrum eschscholtzii	-	-	+.+	+.+	5.5.2	+.+	-	3	2	25	G
Luetkea pectinata	-	1.2.2	3.2.2	1.+.2	-	+.2	-	3	2	5	Ch
Juncus mertensianus	-	1.1.2	-	2.2.2	-	1.+.2	2.2.2	3	3	2	H
Valeriana sitchensis	-	-	-	2.3.2	2.+.2	+.2	1.2.2	3	2	2	H
Vaccinium deliciosum	-	-	+.+	+.+	1.5.2	+.+	-	3	1	-	Pnd
Petasites frigidus	-	5.6.2	+.+	3.2.2	-	-	-	3	4	30	H
Arnica latifolia	-	4.3.2	1.3.2	-	1.+.2	-	-	3	3	10	H
Hippuris montana	-	3.3.2	2.2.2	-	-	1.1.2	-	3	2	6	H

• • • • • • • • • continued

Eriophorum - *Sphagnum* association (*Eriophoreto* - *Sphagnetum*)

Plot number	81	78	84	86	105	Pres.	Fid.	Tot. c.d.	Life-form
Plot size (acre)	1/40	1/20	1/20	1/20	1/40				
Date	23/8 1960	25/8 1960	29/8 1960	29/8 1960	21/7 1961				
Locality (see legend)	RM	RM	RM	RM	H				
Latitude	49 46	49 46	49 46	49 46	49 24				
Longitude	123 02	123 02	123 03	123 03	123 11				
Landform (see legend)	1	1	1	2	2				
Slope above (est. ft.)	-	-	-	180	300				
Area of assoc. (acre)	1/7	1/10	1/4	1/3	1/20				
Altitude (ft.)	4600	4600	4350	4310	3450				
Aspect	flat	flat	flat	N	W				
Slope (degrees)	0	0	0	4	10				
Wind exposure (A-B-C)	0-0-5	0-0-5	0-0-6	0-0-6	0-0-6				
Snow cover (months)	8	8½	8	8	7½				
% coverage:									
By vegetation layer B_1	-	-	-	-	-				
B_2	-	-	-	-	-				
B	-	-	-	-	-				
C	75	90	90	90	98				
D_H	50	95	80	20	90				
By decayed wood	3	-	3	-	-				
By rock	1	-	-	-	-				
By open water	25	5	-	-	-				
Regeneration (no./sq. meter)	-----------	-----------	none	---------	---------				
Total soil depth (cm.)	?	85	?	84	?				
Depth to bottom of A_h (cm.)	?	85	?	83	?				
Depth to seepage, if present	?	36	?	83	?				
C layer:									
Carex aquatilis	8.7.3	-	2.3.2	7.6.2	8.7.3	4	5	201	H
Eriophorum angustifolium	-	4.3.2	8.6.2	7.7.1	2.2.1	4	5	136	H
Deschampsia atropurpurea	-	1.+.1	3.3.2	2.3.2	-	3	2	6	H
Veratrum eschscholtzii	-	+.+	1.+.1	-	+.+	3	1	-	G
Carex nigricans	-	8.5.2	-	1.5.2	-	2	2	75	H
Carex spectabilis	-	5.3.2	5.5.2	-	-	2	2	50	H
Equisetum palustre	-	1.+.1	-	3.+.1	-	2	2	5	G
Tofieldia glutinosa	-	-	1.+.2	3.+.2	-	2	2	5	G
Calamagrostis canadensis	-	-	1.+.2	-	2.2.2	2	2	1	H
Agrostis aequivalvis	-	-	-	1.+.2	2.2.2	2	2	1	H
Luetkea pectinata	-	2.+.2	-	-	+.1	2	2	1	Ch
Hippuris montana	-	1.+.1	-	-	1.2.2	2	1	-	H
Scirpus caespitosus	1.+.2	-	1.+.2	-	-	2	3	-	H
D layer (humicolous):									
Drepanocladus aduncus	7.6.2	3.3.2	-	4.2.2	2.3.2	4	2	66	Te
Sphagnum plumulosum	2.6.2	6.6.3	6.6.2	-	-	3	3	67	Td
Scapania uliginosa	-	4.3.2	3.2.2	4.2.2	-	3	3	25	M
Polytrichum commune	-	4.5.3	2.2.2	-	3.4.2	3	3	16	Te
Mnium nudum	-	2.3.2	2.2.2	2.2.2	-	3	2	3	Te
Calliergonella cuspidata	2.2.2	-	2.2.2	-	1.3.2	3	3	2	W
Sphagnum mendocinum	-	-	7.6.2	-	8.7.3	2	3	125	Td
Sphagnum squarrosum	-	6.6.3	-	5.3.2	-	2	2	58	Td

• • • • • • • • continued

SYNTHESIS TABLE IV, continued — Leptarrhena - Caltha leptosepala association

Plot number	87	52	70	73	79	95	88	Pres.	Fid.	Tot. c.d.	Life-form
C layer, continued:											
Juncus drummondii	-	2.1.2	1.1.2	1.3.2	-	-	-	3	2	1	H
Habenaria saccata	+.2	+.+	-	1.2.2	-	-	1.+.3	3	2	-	G
Viola palustris	-	-	-	-	2.2.2	-	5.3.2	2	2	26	H
Senecio triangularis	-	-	-	3.4.2	4.3.3	-	-	2	2	15	H
Tofieldia glutinosa	2.+.2	-	-	-	1.+.2	-	3.+.2	3	3	6	G
Carex illota	-	-	-	+.1	2.+.1	-	-	2	2	1	H
Agrostis thurberiana	-	-	+.+	-	1.+.2	-	-	2	2	-	H
Veronica serpyllifolia	-	-	1.+.1	-	-	1.+.2	-	2	3	-	H
Cassiope mertensiana	-	-	+.+	+.+	-	-	-	2	1	-	Pne
Chamaecyparis nootkatensis	+.+	-	-	+.+	1.+.+	-	-	3	1	-	Pm
Carex ablata	1.+.2	-	-	-	+.1	-	-	2	2	-	H
D layer (humicolous):											
Rhytidiadelphus squarrosus	7.5.3	5.3.2	6.4.3	4.6.2	6.3.2	5.3.2	8.7.2	5	4	251	W
Drepanocladus aduncus	6.5.3	6.3.2	7.4.3	6.6.2	1.2.2	7.6.2	4.4.2	5	4	209	Te
Philonotis fontana	4.3.2	6.6.2	4.3.2	6.6.2	6.4.2	1.2.2	-	5	4	119	Td
Mnium nudum	2.2.2	4.3.2	1.2.2	-	5.2.2	-	-	3	2	36	Te
Sphagnum plumulosum	-	-	-	1.1.2	1.4.2	4.4.2	-	3	2	10	Td
Moerckia blyttii	-	2.1.2	-	2.+.2	3.+.2	-	-	3	2	7	Th
Bryum sp.	2.2.2	5.4.2	-	-	2.2.2	-	-	3	2	27	Te
Bryum sandbergii	2.2.2	2.2.2	-	-	-	-	5.7.2	3	2	27	Te
Cratoneuron commutatum	1.2.2	3.2.2	-	2.2.2	-	-	-	3	3	6	M
Dicranum fuscescens	-	2.3.2	2.2.2	-	-	-	-	2	2	2	Te
Campylium stellatum	2.2.2	-	-	2.2.2	-	2.2.2	-	3	3	3	Td
Scapania uliginosa	-	2.2.2	2.2.2	-	-	-	-	2	2	2	M
Marsupella sparsifolia	-	1.3.2	2.2.2	-	-	-	-	2	2	2	t
Abies amabilis	+.+	-	-	-	-	-	+.+	2	1	-	Pm

Sporadic species:

B layer:

Pm Chamaecyparis nootkatensis 79(4.6.1)
Pnd Rhododendron albiflorum 79(1.6.2)
Pm Tsuga mertensiana 95(+.+)
Pnd Vaccinium deliciosum 79(1.+.2)

C layer:

H Agrostis idahoensis 87(1.+.2)
H Calamagrostis canadensis 88(5.6.3)
H Eriophorum angustifolium 87(1.2.2)
Ch Gaultheria humifusa 88(+.1)
G Habenaria dilatata 88(1.+.3); 87(+.2)
H Hordeum brachyantherum 95(3.3.2)
Ch Lycopodium selago 52(+.1)
G Lysichitum americanum 87(+.+)
H Mimulus lewisii 52(3.4.2)
Ch Rubus pedatus 79(+.+)
Pnd Salix commutata 79(4.5.2)
H Saxifraga arguta 52(3.3.2)
H Scirpus caespitosus 87(8.7.3)
Pnd Sorbus occidentalis 95(+.+)
Pnd Vaccinium membranaceum 95(1.3.+)

D layer (humicolous):

Pm Abies amabilis 88(+.+)
Mt Anastrepta orcadensis 70(2.2.2)
t Aulacomnium palustre 73(5.6.2)
W Calliergonella cuspidata 70(1.2.2)
Mt Cephalozia leucantha 52(2.1.2)
Pm Chamaecyparis nootkatensis 87(+.+)
Th Conocephalum conicum 73(2.2.2)
t Dicranella squarrosa 95(1.2.2)
Te Drepanocladus exannulatus 73(1.2.2)
t Kiaeria falcata 70(1.1.1)
Mt Lophozia porphyroleuca 52(2.1.2)
t Pohlia sp. 52(5.4.3)
Te Polytrichum commune 95(2.3.2)
Te Rhacomitrium canescens 95(6.4.2)
Te Rhacomitrium heterostichum 52(1.2.2)
Td Sphagnum squarrosum 73(1.2.2)

Eriophorum - Sphagnum association

Sporadic species:

C layer:

H Agrostis thurberiana 78(1.+.1)
H Agrostis idahoensis 84(1.+.2)
H Caltha leptosepala 86(5.+.2)
Ch Gaultheria humifusa 105(1.4.2)
G Streptopus roseus 105(1.+.2)
H Trientalis arctica 105(5.4.2)
H Viola glabella 84(2.+.2)
H Viola palustris 105(5.5.2)

D layer (humicolous):

Mt Anastrepta orcadensis 84(1.1.2)
Mt Calypogeia trichomanis 86(1.1.2)
M Cratoneuron commutatum 86(1.1.2)
M Hypnum circinale 86(1.1.2)
Mt Leiocolea obtusa 81(1.1.2)
Mt Orthocaulis floerkii 78(2.2.2)
t Pohlia sp. 105(2.3.2)
t Polytrichum juniperinum 84(1.1.2)
W Rhytidiopsis robusta 78(3.3.2)
Td Sphagnum megallanicum 84(4.4.2)

SYNTHESIS TABLE V — Subalpine Lysichitum association (Chamaecypareto - Lysichitetum) | Subalpine Oplopanax association (Thujeto - Oplopanacetum abietetosum amabilis)

Plot number	18	126	127	49	128	41	89	92	91	35	38
Plot size (acre)	1/5	1/5	1/5	1/5	1/5	1/5	3/40	1/5	1/5	1/5	1/5
Date	27/7 1959	12/9 1961	13/9 1961	25/7 1960	13/9 1961	29/7 1960	31/8 1960	8/8 1960	12/8 1960	28/8 1960	12/8 1960
Locality (see legend)	SM	H	H	SM	H	SM	RM	RM	RM	RM	RM
Latitude	49 22	49 23	49 23	49 22	49 23	49 22	49 46	49 46	49 46	49 46	49 45
Longitude	122 57	123 11	123 11	122 57	123 11	122 57	123 03	123 03	123 03	123 03	123 03
Landform (see legend)	1(2)	2	2	2	2	1-(2)	2	1-(2)	1-(20	1-(2)	1-(2)
Slope above (est. ft.)	1500	1000	500	500	1000	1000	350	500	600	1500	400
Area of assoc. (acre)	1/4	1/5	1/4	1/3	1/2	1/5	1/20	1/3	1/5	1/2	5
Altitude (ft.)	3000	2900	2930	2900	2970	3050	4060	3770	3865	4030	3575
Aspect	N70W	S60W	S40W	S40E	W	S80W	N30W	N80W	N60W	N50W	S10E
Slope (degrees)	27	8	7	15	20	25	10	17	19	20	18
Wind exposure (A-B-C)	6-4-1	5-2-1	5-2-2	7-5-3	6-2-1	7-5-2	8-6-4	8-6-2	7-6-3	7-5-3	7-2-1
Snow cover (months)	7	6	6	6½	6	6½	8	6	6½	7	6
% coverage:											
By vegetation layer A_1	10	65	40	5	40	)35	)20	)35	20	)35	30
A_2	8	)40	30	45	40	)	)	)	15	)	60
A_3	35	)	20	45	30	30	15	10	10	8	3
A	45	75	60	80	80	55	30	45	40	40	80
B_1	10	25	20	28	35	18	25	20	2	10	2
B_2	65	40	20	30	30	25	30	75	70	70	40
B	65	65	35	50	55	45	40	85	72	80	42
C	65	65	65	60	65	75	70	60	40	50	60
DH	65	80	80	75	70	60	85	60	80	70	50
D_L	20	8	15	20	3	4	3	10	3	10	6
D_R	1	2	-	-	-	1	-	-	-	-	-
D	85	90	95	95	73	65	88	70	83	80	56
By decayed wood	35	10	20	25	6	5	6	20	15	20	25
By rock	1	2	-	-	-	1	-	-	-	-	-
Tallest tree on plot (ft.):											
Western hemlock	128	111	94	-	113	-	-	135	102	112	160
Mountain hemlock	124	97	89	100	108	97	91	-	143	136	-
Amabilis fir	104	107	48	75	74	92	23	154	142	121	136
Yellow cedar	107	111	86	87	-	92	59	-	-	-	-
Western red cedar	-	-	-	-	99	-	-	54	-	-	128
Douglas fir	-	-	-	-	-	-	-	-	-	-	170
Sitka spruce	-	-	-	-	-	-	-	158	-	-	-
Regeneration (no./sq. meter):											
West. or mtn. hemlock	?	66	101	672	64	56	-	31	11	8	1
Amabilis fir	?	30	107	10	2	10	-	72	18	37	12
Yellow cedar	?	9	55	1	2	5	-	-	-	-	-
Total soil depth (cm.)	100	?	?	72	?	94	100	67	55	72	102
Depth to bottom of A_h (cm.)	28	?	?	45	?	64	65	10	15	27	9
Depth to seepage, if present	50	?	?	50	?	66	10	-	25	56	-

Sporadic spp., Lysichitum assoc.

A layer:
- Pm Pinus monticola 49(+.3)
- Pm Thuja plicata 128(5.7.+)

B layer:
- Pnd Rhododendron albiflorum 89(+.+)
- Pm Taxus brevifolia 128(2.6.+)
- Pm Thuja plicata 128(+.+)

C layer:
- H Agrostis alba 128(+.1)
- H Arnica latifolia 41(1.4.2)
- H Boykinia elata 128(+.2)
- H Caltha leptosepala 89(5.6.3)
- H Carex physocarpa 128(+.2)
- Pnd Cladoth. pyrolaeflorus 41(+.1)
- G Equisetum palustre 89(5.4.3)
- H Galium triflorum 128(1.1.2)
- G Habenaria dilatata 89(+.3)
- H Hippuris montana 89(1.+.1)
- H Juncus mertensianus 89(5.7.3)
- H Polystichum munitum 127(+.+)
- Pnd Sorbus occidentalis 128(+.2)
- H Tiarella laciniata 128(+.1)
- H Trientalis arctica 128(1.+.2)

D layer (humicolous):
- Mt Cephalozia leucantha 126(1.1.2)
- t Diplophyllum taxifolium 18(1.1.2)
- Mt Lophozia porphyroleuca 41(1.1.2)
- Mt Ptilidium californicum 49(1.2.2)
- L Cladonia coniocraea 18(1.1.2)
- M Cratoneuron commutatum 89(2.2.2)
- Mt Blephar. trichophyllum 49(1.1.2)
- Pm Thuja plicata 128(1.+.2)
- L Cladonia bellidiflora 89(1.+.2)
- Pm Tsuga mertensiana 41(1.+.1)
- Mt Orthocaulis floerkii 89(2.+.2)
- M Scapania uliginosa 89(4.5.2)
- W Rhytidiad. squarrosus 89(5.4.2)
- Td Philonotis fontana 89(4.6.2)
- Mt Heterocladium procurrens 128(1.2.2)
- Te Drepanocladus aduncus 89(3.4.2)
- t Dicranella squarrosa 89(1.2.2)
- W Hylocomium splendens 49 (+.+)
- Te Hygrohypnum ochraceum 89(3.2.2)
- M Hookeria lucens 126(1.1.1)

A layer:	Sub-layer	18	126	127	49	128	41	89	Pres.	Fid.	Tot. c.d.	Life-form
Chamaecyparis nootkatensis	1	-	6.+.2	5.7.2	-	-	)4.7.3	)5.+.2	5	2	161	Pm
	2	1.6.2	-	5.7.2	4.6.2	-	)	)				
	3	+.2	-	-	5.7.2	-	3.7.2	5.6.2				
No. trees over 3 in./acre		25	25	50	120	-	65	213				
Basal area, sq. ft./acre		54	56	110	136	-	113	139				
Gross volume, cu. ft./acre		1531	3160	2620	2879	-	2842	2388				
Tsuga heterophylla	1	+.2	6.+.1	5.7.+	-	4.+.+	-	-	5	2	124	Pm
	2	-	)2.+.1	+.+	5.7.2	+.+	1.+.+	-				
	3	1.+.2	)	+.+	3.6.2	5.+.+	-	-				

	Sub-layer	92	91	35	38	Pres.	Fid.	Tot. c.d.	Life-form
Tsuga heterophylla	1	)4.+.2	-	)5.7.2	5.7.2	5	2	161	Pm
	2	)	4.7.1	)	8.8.2				
	3	2.+.2	4.7.1	3.+.2	-				
No. trees over 3 in./acre		30	40	40	110				
Basal area, sq. ft./acre		64	68	131	358				
Gross volume, cu. ft./acre		2448	1934	4428	19154				
Abies amabilis	1	)5.7.2	5.7.2	)5.7.2	-	5	2	81	Pm
	2	)	1.+.2	)	+.1				
	3	2.+.2	-	3.+.2	-				

.... continued

.... continued

SYNTHESIS TABLE V, continued — Subalpine *Lysichitum* association

Plot number		18	126	127	49	128	41	89	Pres.	Fid.	Tot. c.d.	Life-form
Tsuga heterophylla, continued												
No. trees over 3 in./acre		35	65	35	80	95	20	-				
Basal area, sq. ft./ acre		77	84	97	94	100	23	-				
Gross volume, cu. ft./acre		2876	2948	2640	2794	2223	156	-				
Abies amabilis	1	-	+.1	-	-	-	}4.7.1	-	5	2	113	Pm
	2	+.2	}6.7.1	-	+.1	5.7.1		-				
	3	-		5.+.+	3.+.1	4.7.2	3.7.1	-				
No. trees over 3 in./acre		55	125	90	40	90	100	-				
Basal area, sq. ft./acre		21	52	14	42	36	60	-				
Gross volume, cu. ft./acre		482	1526	154	872	770	1535	-				
Tsuga mertensiana	1	4.+.2	+.1	+.2	2.+.3	+.2	}4.7.2	}2.+.1	5	2	45	Pm
	2	+.2	}2.7.1	+.+	2.+.2							
	3	4.6.1		-	2.+.2	-	4.7.1	+.+				
No. trees over 3 in./acre		85	25	5	60	35	115	40				
Basal area, sq. ft./acre		172	25	26	52	25	68	126				
Gross volume, cu. ft./acre		5854	770	692	1325	850	1430	3121				
Totals, including sporadics:												
No. trees over 3 in./acre		200	230	200	305	275	300	295				
Basal area, sq. ft./acre		324	217	248	381	409	264	270				
Gross volume, cu. ft./acre		10743	8408	6106	9869	9296	5963	5530				
B layer:												
Vaccinium alaskaense	1	-	-	-	-	1.6.3	-	-	5	2	130	Pnd
	2	7.8.2	5.6.1	5.6.2	4.7.2	4.7.3	4.6.2	1.3.2				
Abies amabilis	1	3.6.2	4.6.2	5.6.1	2.+.1	4.+.1	4.7.2	3.+.1	5		93	Pm
	2	3.6.2	3.+.+	3.6.1	4.6.2	2.+.+	2.+.1	1.+.+				
Cham. nootkatensis	1	1.+.1	1.+.+	1.+.+	4.6.2	1.+.+	1.+.2	5.6.2	5		61	Pm
	2	+.1	-	1.+.+	1.+.1	1.+.1	1.+.1	5.6.2				
Tsuga mertensiana	1	2.+.2	1.+.2	2.+.+	4.6.2	4.6.2	4.7.2	-	5		36	Pm
	2	2.6.2	+.+	-	2.+.2	+.1	2.+.2	2.+.1				
Menziesia ferruginea	1	-	-	-	-	3.6.3	-	-	5	2	33	Pnd
	2	1.5.2	4.4.2	2.6.2	2.5.1	4.7.3	3.6.2	2.4.1				
Tsuga heterophylla	1	2.+.2	2.+.2	1.+.+	4.6.2	3.+.+	1.+.1	-	5		22	Pm
	2	1.6.2	1.+.1	1.+.+	3.6.2	1.+.+	1.+.1	-				
Vaccinium ovalifolium	2	1.5.1	-	-	-	1.5.2	2.5.1	3.4.1	3	2	6	Pnd
Cladothamnus pyrolaeflorus	1	-	-	-	-	+.3	+.3	-	3	2	5	Pnd
	2	+.+.1	-	-	-	1.+.2	3.6.2	*				
Vaccinium membranaceum	2	1.5.1	-	+.+	-	-	2.5.2	2.4.2	3	2	2	Pnd
Rubus spectabilis	2	+.1	-	-	1.5.1	2.6.2	1.6.2	-	3	2	1	Pnd
Sorbus occidentalis	1	-	-	-	-	+.3	+.3	-	3	2	1	Pnd
	2	-	+.+	-	-	1.+.2	2.+.3	-				
C layer:												
Lysichitum americanum		6.8.2	5.6.2	7.8.2	6.6.2	7.8.2	7.7.2	5.6.2	5	4	266	G
Rubus pedatus		4.3.2	4.3.3	4.6.2	4.3.3	2.2.2	3.4.2	1.+.2	5	2	46	Ch
Clintonia uniflora		3.5.3	4.4.3	3.5.3	4.3.2	2.3.2	3.4.2	-	5	2	36	G
Carex laeviculmis		+.1	-	+.1	1.2.1	+.+	+.+	6.7.2	5	3	33	H
Veratrum eschscholtzii		3.3.2	1.+.+	1.+.1	2.+.1	1.+.2	4.5.2	3.4.2	5	3	21	G
Blechnum spicant		4.6.2	3.5.2	2.4.1	2.5.1	2.4.2	1.4.2	-	5	2	18	H
Athyrium filix-femina		+.1	+.+	2.+.2	-	2.5.1	4.6.2	3.6.2	5	2	17	H
Streptopus roseus		3.3.3	1.+.2	2.+.2	-	2.2.2	3.3.2	2.3.2	5	2	13	G
Streptopus amplexifolius		3.2.1	+.+	+.+	1.+.1	1.+.2	1.+.1	2.+.2	5	2	6	G
Vaccinium alaskaense		1.2.2	1.+.2	1.+.1	3.4.2	1.+.+	2.+.2	1.+.2	5		6	Pnd
Abies amabilis		1.3.2	2.+.+	2.+.1	2.+.1	1.+.2	1.+.1	2.+.1	5		4	Pm
Cornus canadensis		1.2.2	1.+.2	1.+.2	2.+.2	1.+.2	2.+.2	-	5	2	2	Ch
Tsuga heterophylla		1.4.3	2.+.+	2.+.1	+.+	1.+.2	1.+.1	-	5		2	Pm
Menziesia ferruginea		+.1	1.+.2	-	+.+	+.+	2.+.2	+.+	5		1	Pnd
Listera cordata		+.2	+.+	+.1	+.1	+.2	+.2	-	5	3	-	G
Coptis asplenifolia		2.5.2	4.5.3	4.6.3	-	3.+.2	2.3.2	-	4	5	27	H

. . . . . . continued

Subalpine *Oplopanax* association

		92	91	35	38	Pres.	Fid.	Tot. c.d.	Life-form
Abies amabilis, continued		50	35	45	5				
		129	134	65	11				
		6398	6816	2467	540				
Thuja plicata	2	-	-	-	3.+.1	3	3	5	Pm
	3	+.1	-	-	1.+.1				
		5	-	-	20				
		5	-	-	36				
		104	-	-	1190				
Tsuga mertensiana	1	-	1.+.3	}+.2	-	3	2	5	Pm
	2	-	3.+.2		-				
		-	15	5	-				
		-	61	131	-				
		-	2809	4590	-				
Picea sitchensis	1	}2.+.2	-	-	2.+.0	3	4	1	Pm
	2		-	-	-				
		5	-	-	-				
		53	-	-	-				
		2500	-	-	-				
Totals, including sporadics:									
No. trees over 3 in./acre		90	90	90	155				
Basal area, sq. ft./acre		251	263	327	579				
Gross volume, cu. ft./ac.		11450	11559	11458	28259				
B layer:									
Oplopanax horridus	1	2.6.3	+.3	-	-	5	5	135	Pnd
	2	6.7.2	7.9.1	7.7.2	2.5.2				
Vaccinium alaskaense	2	4.6.2	5.6.2	5.6.2	4.6.2	5	2	70	Pnd
Abies amabilis	1	3.6.1	+.+	4.7.2	3.6.1	5		60	Pm
	2	3.6.1	3.+.1	3.+.1	5.7.1				
Vaccinium ovalifolium	2	2.4.2	3.5.2	1.+.1	2.+.+	5	3	7	Pnd
Vaccinium membranaceum	2	1.4.1	1.+.2	1.4.2	+.+	5	2	-	Pnd
Lonicera utahensis	2	(+.2)	1.+.2	+.1	1.+.2	5	5	-	Pnd
Ribes bracteosum	2	3.6.2	-	2.5.1	1.+.1	4	5	6	Pnd
Sorbus occidentalis	1	1.+.3	-	-	-	4	2	1	Pnd
	2	2.5.3	1.+.1	-	+.+				
Menziesia ferruginea	1	2.+.3	-	-	-	4	2	3	Pnd
	2	2.6.3	2.+.2	-	1.+.+				
Tsuga mertensiana	1	2.+.1	-	-	-	3		3	Pm
	2	2.+.1	-	2.+.1	-				
Rubus spectabilis	2	4.6.2	-	2.+.1	-	3	3	11	Pnd
C layer:									
Athyrium filix-femina		5.7.3	4.6.2	5.7.2	1.5.2	5	3	60	H
Gymnocarpium dryopteris		4.5.2	5.6.2	4.4.2	3.4.2	5	3	50	G
Streptopus roseus		5.4.1	3.4.2	4.5.2	3.6.3	5	2	45	G
Tiarella unifoliata		3.3.2	4.4.2	3.3.2	3.2.2	5	3	25	H
Clintonia uniflora		4.5.2	1.+.2	1.+.2	4.4.2	5	2	20	G
Viola glabella		3.3.2	3.5.3	3.3.3	+.2	5	3	15	H
Abies amabilis		2.+.1	1.+.1	3.+.1	3.+.1	5		11	Pm
Oplopanax horridus		3.5.2	2.+.1	1.+.1	1.+.2	5		6	Pnd
Streptopus amplexifolius		3.4.3	2.+.3	1.+.2	1.+.2	5	3	6	G
Rubus pedatus		3.3.2	1.5.2	1.2.2	2.+.2	5	2	6	Ch
Veratrum eschscholtzii		3.+.2	1.+.1	2.+.1	+.1	5	2	5	G
Pyrola secunda		2.3.2	1.+.2	1.3.2	2.2.2	5	2	2	Ch
Osmorhiza purpurea		2.+.1	1.+.2	2.3.2	+.2	5	3	2	H
Tiarella trifoliata		1.+.2	2.+.2	2.1.2	1.+.2	5	2	2	H

. . . . continued

SYNTHESIS TABLE V, continued   Subalpine *Lysichitum* association

Plot number	18	126	127	49	128	41	89	Pres.	Fid.	Tot. c.d.	Life-form
C layer, continued:											
Gymnocarpium dryopteris	2.5.2	2.5.2	-	-	3.4.2	4.5.2	1.2.2	4	2	17	G
Tiarella unifoliata	+.2	-	1.+.2	+.2	3.5.2	2.2.2	-	4	2	6	H
Tiarella trifoliata	1.5.2	-	1.+.2	1.3.2	3.5.2	+.2	-	4	2	5	H
Streptopus streptopoides	1.+.2	-	1.+.1	2.+.2	2.+.2	2.3.2	-	4	2	3	H
Habenaria saccata	+.1	-	+.1	-	+.2	1.+.3	2.+.2	4	3	1	G
Cham. nootkatensis	-	-	1.+.2	+.1	1.+.+	1.+.1	2.+.2	4		1	Pm
Valeriana sitchensis	-	-	-	-	4.5.2	4.5.2	2.3.2	3	2	21	H
Viola glabella	-	-	-	-	4.6.3	2.5.2	3.4.2	3	2	16	H
Parnassia fimbriata	-	-	-	-	1.2.2	1.2.3	4.4.2	3	2	10	H
Senecio triangularis	-	-	-	-	1.+.1	1.+.2	3.3.2	3	2	5	H
Rubus spectabilis	-	+.+	-	-	+.+	+.2	-	3		-	Pnd
Maianthemum dilatatum	-	+.1	1.+.1	-	1.+.2	-	-	3	2	-	G
Mitella pentandra	-	-	-	-	1.+.2	+.1	1.+.1	3	2	-	H
Leptarrhena pyrolifolia	-	-	-	-	-	1.+.2	5.3.3	2	1	25	H
Epilobium alpinum	-	-	-	-	-	+.1	3.2.2	2	2	5	G
Linnaea borealis	-	-	-	3.4.2	-	+.2	-	2	2	5	Ch
Erigeron peregrinus	-	-	-	-	-	1.+.1	3.3.2	2	1	5	H
Nephrophyllidium crista-galli	-	-	2.5.2	-	2.3.2	-	-	2	3	2	H
Agrostis aequivalvis	-	-	-	-	-	+.+	2.+.2	2	2	1	H
Goodyera oblongifolia	-	-	-	+.1	+.1	-	-	2	2	-	H
Osmorhiza purpurea	-	-	-	-	+.+	1.+.1	-	2	2	-	H
Saxifraga arguta	-	-	-	-	1.+.2	-	1.+.1	2	2	-	H
Lycopodium clavatum	-	-	-	+.+	+.2	-	-	2	2	-	Ch
Carex spectabilis	-	-	-	-	-	+.+	1.+.2	2	2	-	H
Gaultheria ovalifolia	-	-	-	-	-	+.2	1.2.2	2	2	-	Ch
Pyrola secunda	-	-	-	1.+.1	+.1	-	-	2	2	-	Ch
Melica smithii	-	-	-	-	-	+.+	1.+.2	2	2	-	H
D layer (humicolous):											
Mnium nudum	5.6.3	5.5.3	6.7.3	5.5.3	7.7.3	6.6.3	-	5	3	191	Te
Rhytidiadelphus loreus	3.2.2	5.6.3	4.6.3	5.3.2	5.6.3	3.4.2	2.3.2	5	3	96	W
Rhytidiopsis robusta	2.3.2	4.5.2	2.3.1	6.6.2	4.5.2	3.4.2	-	5	2	60	W
Plagiothecium undulatum	2.3.2	4.4.2	5.6.2	2.2.+	4.3.2	+.+	-	5	3	47	M
Sphagnum squarrosum	-	5.6.2	3.6.3	2.5.3	3.6.3	3.5.2	1.2.2	5	4	41	Td
Dicranum fuscescens	3.3.2	3.3.2	2.3.1	4.4.2	3.3.2	3.3.2	3.3.2	5	2	36	Te
Pellia epiphylla	3.2.2	1.2.2	1.2.2	2.5.2	2.2.2	4.5.2	2.+.2	5	3	18	Th
Abies amabilis	2.+.1	2.+.1	2.+.1	2.+.1	1.+.1	1.+.1	-	5		4	Pm
Plagiothecium elegans	3.3.2	1.3.2	2.2.2	-	2.2.2	+.+	-	4	2	7	M
Mnium spinulosum	-	3.3.2	2.2.2	1.2.2	1.3.2	-	1.2.2	4	3	6	Te
Tsuga heterophylla	-	1.+.+	1.+.1	3.1.+	+.1	-	-	3		5	Pm
Brachythecium asperrimum	-	-	2.2.2	2.2.2	2.2.2	-	-	3	2	3	M
Lophocolea heterophylla	+.2	-	-	2.1.2	-	1.1.2	-	3	2	1	Mt
Cephalozia media	1.1.2	2.1.2	-	1.1.2	-	1.1.2	-	3	2	1	Mt
Chamaecyparis nootkatensis	-	+.+	+.+	+.+	+.+	-	-	3		-	Pm
Plagiochila asplenioides	-	1.1.2	-	1.1.2	-	1.1.2	-	3	2	-	Te
Lepidozia reptans	1.2.2	1.2.1	-	-	-	1.2.2	-	3	2	-	Mt
Scapania bolanderi	-	1.1.1	-	1.1.2	-	+.+	-	3	2	-	M
Calypogeia trichomanis	-	1.1.2	1.1.2	-	-	1.1.2	1.2.2	3	2	-	Mt
Mnium punctatum	-	-	-	-	-	1.+.1	7.6.3	2	2	50	Te
Drepanocladus fluitans	-	-	-	-	-	1.1.2	4.3.2	2	2	10	Te
Eurhynchium stokesii	-	-	-	3.5.2	3.3.2	-	-	2	2	10	Mt
Campyllium stellatum	-	-	-	-	-	2.2.2	2.2.2	2	2	2	Td
Conocephalum conicum	-	-	-	-	2.3.2	-	2.2.2	2	3	2	Th
Hypnum circinale	-	-	-	-	-	2.2.2	2.2.2	2	2	2	M
Dicranum scoparium	-	-	2.2.2	1.3.2	-	-	-	2	2	1	Te
Pleurozium schreberi	-	-	-	+.+	-	2.2.2	-	2	2	1	W
Bazzania ambigua	-	2.2.3	-	1.1.2	-	-	-	2	2	1	M
Sphagnum girgensohnii	2.6.2	-	-	1.2.2	-	-	-	2	3	1	Td
Cephalozia lammersiana	1.2.2	-	-	-	-	1.2.2	-	2	2	-	Mt
Plagiothecium denticulatum	-	+.2	-	1.1.2	-	-	-	2	2	-	M
Hypnum dieckii	1.2.2	-	1.2.2	-	-	-	-	2	3	-	M
Bryum sandbergii	-	-	-	-	-	1.3.2	1.1.2	2	2	-	Te
Calypogeia neesiana	1.1.2	-	-	-	-	1.1.2	-	2	2	-	Mt

Subalpine *Oplopanax* association

	92	91	35	38	Pres.	Fid.	Tot. c.d.	Life-form
C layer, continued:								
Vaccinium alaskaense	2.+.1	1.+.1	1.+.2	2.+.2	5		2	Pnd
Streptopus streptopoides	2.+.2	1.+.1	1.+.+	1.+.3	5	2	1	G
Vaccinium membranaceum	1.+.1	1.+.2	1.+.1	1.+.1	5		-	Pnd
Listera caurina	+.1	+.1	+.+	+.1	5	2	-	G
Cornus canadensis	2.+.2	2.2.2	-	5.4.3	4	2	27	Ch
Valeriana sitchensis	2.4.1	3.3.2	4.5.3	-	4	2	16	H
Habenaria saccata	3.+.3	-	+.3	+.2	4	2	5	G
Sorbus occidentalis	2.+.2	+.1	-	1.+.1	4		1	Pnd
Lycopodium clavatum	+.+	1.+.2	-	1.+.2	4	3	-	Ch
Ribes lacustre	3.+.2	-	-	+.+	3	3	5	Pnd
Linnaea borealis	2.3.3	-	-	2.3.3	3	2	2	Ch
Tsuga heterophylla	-	-	1.+.1	1.+.1	3		-	Pm
Claytonia sibirica	1.+.3	-	2.+.1	-	3	2	1	H
Rubus spectabilis	-	1.+.2	+.2	-	3		-	Pnd
Ribes bracteosum	-	-	+.2	1.+.2	3		-	Pnd
D layer (humicolous):								
Rhytidiopsis robusta	4.6.2	4.5.2	4.4.2	6.6.2	5	2	66	W
Dicranum fuscescens	3.5.2	3.5.2	3.4.2	4.3.2	5	2	25	Te
Abies amabilis	2.+.1	1.+.1	3.+.1	3.+.1	5		11	Pm
Hypnum circinale	2.3.2	2.4.2	2.3.2	3.2.2	5	2	8	M
Scapania bolanderi	2.1.2	2.1.2	1.1.2	2.1.1	5	3	3	M
Tsuga heterophylla	+.1	1.+.1	1.+.1	1.+.1	5		-	Pm
Mnium nudum	-	7.6.2	7.7.3	2.3.2	4	2	101	Te
Bryum sandbergii	4.5.2	1.1.2	1.3.2	-	4	3	10	Te
Eurhynchium stokesii	2.2.2	2.2.2	1.1.2	-	4	2	2	Mt
Mnium punctatum	6.6.3	-	1.1.2	-	3	2	33	Te
Rhytidiadelphus loreus	4.3.2	2.3.2	-	-	3	2	11	W
Cephalozia media	-	-	1.1.2	2.2.2	3	2	1	Mt
Calypogeia neesiana	-	1.1.2	1.1.2	-	3	2	-	Mt
Moerckia blyttii	-	2.2.2	1.2.2	-	3	2	1	Th
Cladonia coniocraea	-	1.+.+	-	1.+.+	3	2	-	L
Thuja plicata	+.1	-	-	+.+	3		-	Pm
Ptilidium californicum	1.1.2	-	1.1.2	-	3	2	-	Mt
Diplophyllum taxifolium	1.1.2	-	+.2	-	3	2	-	t
Plagiothecium undulatum	1.2.2	-	+.2	-	3	2	-	M

Sporadic species:

A layer:
Pm Pseudotsuga menziesii 38(4.+.1)

B layer:
Pnd Ribes lacustre 92(3.6.2)

C layer:
H Adenocaulon bicolor 38(+.1)
H Agrostis alba 92(1.+.1)
H Carex laeviculmis 92(1.+.1)
G Corallorhiza mertensiana 38(+.+)
H Luzula parviflora 91(+.1)
G Lysichitum americanum 92(1.+.+)
H Mitella pentandra 92(1.+.1)
Ch Moneses uniflora 38(1.+.2)
H Polystichum munitum 38(+.+)
Pm Pseudotsuga menziesii 38(+.+)
Pm Sambucus pubens 92(+.1)
H Senecio triangularis 35(2.4.2)

C layer, continued:
H Stellaria crispa 92(+.1)
Pm Thuja plicata 38(+.1)
Pnd Vaccinium ovalifolium 91(+.2)

D layer (humicolous):
Mt Lophocolea heterophylla 92(1.1.2)
M Plagiothecium elegans 91(2.2.2)
L Cladonia bellidiflora 92(+.+)
M Plagiothecium denticulatum 35(+.2)
M Brachythecium asperrimum 35(1.1.2)
W Rhytidiadelphus squarrosus 35(+.2)
Mt Lophozia porphyroleuca 35(1.1.2)
Mt Heterocladium procurrens 91(2.2.2)
t Dicranella heteromalla 91(2.2.2)
M Bazzania ambigua 35(1.1.2)
t Pohlia nutans 35(+.2)
t Polytrichum juniperinum 91(1.1.2)
Te Pogonatum urnigerum 35(1.3.2)
M Hookeria lucens 91(2.1.2)
Te Pogonatum contortum 91(1.2.2)
Te Pogonatum alpinum 92 (+.2)

SYNTHESIS TABLE VI   Vaccinium membranaceum - Rhododendron association (Tsugeto - Vaccinietum membranacei)

Plot number	Sub-layer	39	80	110	120	67	57	60	64	119	Pres.	Fid.	Tot. c.d.	Life-form
Plot size (acre)		1/5	1/5	1/5	1/5	1/5	1/20	1/10	1/10	1/10				
Date		23/8 1960	25/8 1960	5/8 1961	22/8 1961	24/8 1960	12/8 1961	12/8 1961	11/8 1961	21/8 1961				
Locality (see legend)		RM	RM	Lions	Dia. H	RM	RM	RM	RM	Dia. H				
Latitude		49 46	49 46	49 27	49 48	49 46	49 48	48 47	49 47	49 49				
Longitude		123 02	123 02	123 12	122 59	123 02	122 59	123 00	123 00	122 59				
Landform (see legend)		2	2	3	2	3	2	3	3	3				
Slope above (est. ft.)		75	75	-	75	-	100	-	-	-				
Area of assoc. (acre)		1	1	1	2	1/5	1/20	1/2	1/5	1				
Altitude (ft.)		4600	4600	3880	4700	4840	4850	5000	5060	5600				
Aspect		W	W	flat	S60E	flat	W	flat	S	S40E				
Slope (degrees)		27	25	-	44	-	25	-	6	10				
Wind exposure (A-B-C)		8-5-3	8-6-4	8-5-2	8-6-3	8-3-1	9-8-7	9-7-3	9-7-3	9-8-7				
Snow cover (months)		8	8½	7½	8½	8	8	8	8½	9				
% coverage:														
By vegetation layer A_1		)30	15	)75	)35	25	40	50	45	)				
A_2		)	20	)	)	25	)60	)60	)60	)10				
A_3		35	22	20	40	30	)	)	)	)				
A		45	50	80	50	65	70	80	80	10				
B_1		5	20	7	25	30	3	8	25	55				
B_2		90	85	80	80	80	75	70	80	25				
B		92	90	85	95	90	75	70	90	70				
C		8	8	4	3	2	20	4	6	60				
D_H		40	25	70	8	40	65	8	5	20				
D_L		4	3	1	1	4	1	2	2	1				
D_R		1	1	2	1	1	-	-	-	-				
D		44	29	72	10	44	66	10	7	21				
By decayed wood		8	6	3	3	10	10	20	10	10				
By rock		1	2	4	12	1	-	-	-	--				
Tallest tree on plot (ft.)														
Western hemlock		-	-	57	-	-	-	-	-	-				
Mountain hemlock		82	88	75	103	81	82	72	63	34				
Amabilis fir		57	70	60	101	67	80	62	60	22*				
Yellow cedar		62	?	58	-	-	-	-	-	-				
Regeneration (no./sq. meter):														
Mountain hemlock		-	-	28	-	-	-	-	-	-				
Amabilis fir		1	-	19	-	-	5	-	-	-				
Yellow cedar		2	2	9	-	-	-	-	-	-				
Total soil depth (cm.)		76	38	?	75	40	61	44	57	50				
Depth to bottom of A_h (cm.)		15	21	?	10	14	6	35	30	10				
Depth to seepage, if present		-	-	?	-	-	-	-	-	-				
Remarks										* Alpine fir				
A layer:														
Tsuga mertensiana	1	)6.7.2	5.7.3	)8.8.2	)4.+.2	5.7.2	7.8.1	7.8.1	6.8.1	)	5	2	601	Pm
	2	)	5.7.2	)	)	5.7.2	)7.8.1	)7.8.1	)7.8.1	)4.7.1				
	3	5.7.2	4.7.2	3.+.1	5.7.2	5.7.2	)	)	)	)				
No. trees over 3 in./acre		155	120	180	105	255	55	120	105	170				
Basal area, sq. ft./acre		188	224	264	142	234	?	?	?	?				
Gross volume, cu. ft./acre		3153	5023	5192	3003	5060	?	?	?	?				
Abies amabilis	1	)+.+	+.1	)+.1	)5.+.2	3.+.1	+.1	+.1	3.+.1	-	5	2	240	Pm
	2	)	3.+.1	)	)	5.7.2	)7.8.1	)5.+.1	)5.+.1	-				
	3	4.+.1	4.7.1	3.+.1	5.7.1	5.7.2	)	)	)	-				
No. trees over 3 in./acre		85	100	70	105	180	35	35	70	-				
Basal area, sq. ft./acre		43	53	26	181	104	?	?	?	-				
Gross volume, cu. ft./acre		547	997	360	4451	1741	?	?	?	-				
Chamaecyparis nootkatensis	1	)4.+.+	-	)+.+	-	-	-	-	-	-	2	1	31	Pm
	2	)	-	)	-	-	-	-	-	-				
	3	4.+.+	2.+.+	4.+.1	-	-	-	-	-	-				
No. trees over 3 in./acre		40	30	45	-	-	-	-	-	-				
Basal area, sq. ft./acre		38	58	20	-	-	-	-	-	-				
Gross volume, cu. ft./acre		709	988	331	-	-	-	-	-	-				
Totals, including sporadics:														
No. trees over 3 in./acre		280	250	310	210	435	90	155	175	230				
Basal area, sq. ft./acre		269	335	347	323	338	-	-	-	-				
Gross volume, cu. ft./acre		4409	7008	6581	7454	6901	-	-	-	-				
B layer:														
Vaccinium membranaceum	2	5.6.1	5.6.3	1.+.+	7.7.3	7.7.3	8.8.2	5.7.3	8.7.3	4.6.1	5	3	335	Pnd
Tsuga mertensiana	1	2.6.2	4.+.1	2.+.+	4.6.1	5.7.2	+.+	4.7.1	4.6.1	7.6.+	5		144	Pm
	2	-	2.6.1	-	4.+.1	3.+.1	1.+.1	2.+.1	1.+.1	4.6.+				
Abies amabilis	1	3.6.1	4.6.1	4.+.+	4.6.1	4.7.2	+.+	+.+	4.6.1	-	5		68	Pm
	2	+.+	1.+.1	2.+.1	4.+.1	1.+.+	2.+.1	1.+.+	2.+.1	-				
Rhododendron albiflorum	1	-	2.6.3	-	2.6.3	-	-	-	-	-	4	4	298	Pnd
	2	7.8.3	6.7.3	8.7.2	6.7.3	7.7.3	-	7.8.3	-	3.6.2				
Vaccinium deliciosum	2	5.6.3	2.6.3	-	-	2.6.2	5.5.2	2.5.2	4.6.3	1.3.3	4	2	63	Pnd
Vaccinium ovalifolium	2	4.5.1	3.+.1	+.1	-	+.+	-	-	-	-	3	2	15	Pnd
Sorbus occidentalis	1	-	-	1.5.2	-	-	-	-	-	-	3	2	1	Pnd
	2	+.+	+.+	1.+.2	-	2.+.1	-	-	-	+.+				

. . . . continued

SYNTHESIS TABLE VI, continued Vaccinium membranaceum - Rhododendron association

Plot number	Sub-layer	39	80	110	120	67	57	60	64	119	Pres.	Fid.	Tot. c.d.	Life-form
B layer, continued:														
Vaccinium alaskaense	2	-	5.6.2	5.7.2	-	-	-	-	-	-	2	1	50	Pnd
Chamaecyparis nootkatensis	1	1.+.+	3.+.1	+.+	-	-	-	-	-	-	2		20	Pm
	2	4.+.2	3.6.1	1.+.+	-	-	-	-	-	-				
Menziesia ferruginea	2	-	-	+.+	1.5.2	-	-	-	-	-	2	1	-	Pnd
C layer:														
Phyllodoce empetriformis		1.2.1	1.+.+	1.2.1	+.+	1.3.2	4.5.2	1.3.2	3.5.2	6.6.2	5	2	48	Pne
Vaccinium deliciosum		4.+.1	4.5.2	-	1.+.+	1.+.2	4.6.2	2.2.2	2.6.2	3.3.2	5		37	Pnd
Vaccinium membranaceum		3.2.2	3.3.2	2.+.+	2.+.2	2.+.2	3.+.2	3.+.2	2.3.2	4.4.1	5		34	Pnd
Cassiope mertensiana		1.+.+	+.+	-	-	1.+.+	1.+.+	1.3.1	+.+	5.5.2	4	2	25	Pne
Luetkea pectinata		2.+.1	-	-	-	1.+.1	1.+.1	1.3.2	1.+.1	3.2.3	4	2	11	Ch
Abies amabilis		1.+.+	2.+.1	2.+.1	1.+.+	-	1.+.+	+.+	2.+.+	-	4		3	Pm
Rubus pedatus		2.+.1	3.2.2	+.+	-	-	1.+.1	-	-	2.+.1	3	2	7	Ch
Tsuga mertensiana		+.+	-	-	+.+	-	-	+.+	+.+	-	3		-	Pm
Rhododendron albiflorum		-	2.+.1	1.+.+	-	-	-	-	-	-	2		1	Pnd
Chamaecyparis nootkatensis		1.+.1	1.+.1	+.1	-	-	-	-	-	-	2		-	Pm
Sorbus occidentalis		+.+	1.+.+	-	-	-	-	-	-	-	2		-	Pnd
D layer (humicolous):														
Rhytidiopsis robusta		4.3.2	3.4.2	6.6.3	2.2.+	2.2.2	1.2.1	2.4.1	1.3.+	-	5	2	51	W
Orthocaulis floerkii		4.3.2	3.4.2	2.1.2	1.1.+	4.3.2	2.+.1	1.2.2	2.1.1	3.2.2	5	2	33	Mt
Dicranum fuscescens		-	-	6.6.3	4.3.2	-	7.6.2	4.5.2	3.5.2	4.4.1	4	2	118	Te
Cladonia bellidiflora		-	-	2.1.2	1.+.+	2.2.2	-	-	1.1.2	2.1.2	3	2	3	L
Crocynia membranacea		1.+.1	1.+.1	-	-	+.2	-	+.2	-	2.2.2	3	2	1	L
Cladonia carneola		1.+.1	-	-	-	1.+.1	-	+.2	2.2.2	-	3	2	1	L
Cladonia pleurota		1.+.1	1.+.1	-	-	1.+.1	-	+.2	2.1.2	-	3	2	1	L
Dicranum scoparium		5.5.3	5.5.3	-	-	5.6.2	-	-	-	-	2	2	75	Te
Abies amabilis		+.+	-	2.+.1	-	-	1.+.+	-	-	-	2		-	Pm
Chamaecyparis nootkatensis		1.+.1	-	1.+.1	-	-	-	-	-	-	2		-	Pm
Ptilidium pulcherrimum		1.1.2	1.1.2	+.+	-	-	-	-	-	-	2	1	-	Mt
Mnium spinulosum		+.+	+.2	-	-	-	-	-	-	-	2	1	-	Te
Plagiothecium elegans		-	-	-	2.1.1	-	1.2.2	-	-	-	2	2	-	M
Hypnum circinale		1.1.2	1.1.2	-	-	-	-	-	-	-	2	1	-	M
Plagiothecium denticulatum		-	+.2	-	-	1.1.2	-	-	-	-	2	1	-	M
Lescuraea baileyi		-	1.1.2	-	-	1.3.2	-	-	-	-	2	2	-	Mt
Rhacomitrium heterostichum		-	-	1.3.2	1.1.1	-	-	-	-	-	2	2	-	Te
Cetraria islandica		-	1.2.2	-	-	3.2.2	3.1.2	-	-	-	2	2	-	L
Brachythecium sp.		-	+.2	-	-	+.2	-	-	+.2	-	2	2	-	M
Bryum sp.		-	-	-	-	-	1.1.1	1.4.2	-	-	2	2	-	Te
Pohlia nutans		-	1.1.2	-	-	-	-	1.1.2	-	-	2	2	-	t
Barbilophozia lycopodioides		1.2.2	1.2.2	-	-	-	-	-	-	-	2	2	-	Mt
Cladonia squamosa		1.1.1	1.+.2	-	-	-	-	-	1.2.2	-	2	2	-	L

Sporadic species:

A layer:
- Pm Abies lasiocarpa 119(4.6.+)
- Pm Pinus monticola 110(+.+)
- Pm Tsuga heterophylla 110(+.+)

B layer:
- Pm Abies lasiocarpa 119(4.6.+)

C layer:
- G Clintonia uniflora 39(1.+.1)
- G Corallorhiza mertensiana 110(+.1)
- Ch Gaultheria humifusa 110(1.3.2)
- Ch Lycopodium sitchense 119(1.2.2)
- H Streptopus roseus 120(1.+.1)
- Pnd Vaccinium alaskaense 110(2.+.+)
- G Veratrum eschscholtzii 39(+.+)

D layer, humicolous:
- Mt Blepharostoma trichophyllum 67(1.+.+)
- L Cladonia rangiferina 39(+.+)
- t Diplophyllum plicatum 80(1.1.2)
- Mt Lophozia porphyroleuca 80(1.1.2)
- Te Plagiochila asplenioides 39(+.+)
- W Pleurozium schreberi 110(1.1.2)
- Te Pogonatum alpinum 80(1.2.2)
- t Polytrichum piliferum 119(1.1.2)
- L Stereocaulon tomentosum 67 (1.1.2)
- Pm Tsuga mertensiana 110(+.+)

SYNTHESIS TABLE VII Dwarf *Tsuga* association (*Nano-Tsugetum mertensianae*)

	typical subassociation (subassoc. *nano-tsugetosum mertensianae*)					*Luetkea* subassociation (subassoc. *luetkeetosum pectinatae*)				
Plot number	30	113	121	97	116	40	61	69	74	100
Plot size (acre)	1/5	1/20	1/40	1/40	1/20	1/40	1/20	1/40	1/40	1/40
Date	24/8 1959	16/8 1961	22/8 1961	20/9 1960	17/8 1961	8/9 1960	7/9 1960	24/8 1960	30/8 1960	20/9 1960
Locality (see legend)	SM	Gar.	Gar.	G	RM	SM	RM	RM	RM	G
Latitude	49 23	49 48	49 49	49 24	49 47	49 22	49 47	49 46	49 46	49 24
Longitude	122 57	123 00	122 56	123 05	122 59	122 57	123 00	123 02	123 02	123 05
Landform (see legend)	4	2	2	2	2	2	2	2	2	2
Slope above (est. ft.)	-	500	300	-	500	90	70	200	200	250
Area of assoc. (acre)	3/4	1/20	1/10	1/30	1/10	1/5	1	1	1/8	1/5
Altitude (ft.)	4015	5000	5100	4400	4750	3310	5050	4820	4725	4230
Aspect	S80E	E	S20W	N60W	S15W	N30E	W	N	N50W	N50E
Slope (degrees)	10	15	23	16	7	13	26	7	22	30
Wind exposure (A-B-C)	0-8-6	0-8-5	0-8-2	0-8-5	0-8-6	0-6-4	0-6-5	0-6-5	0-7-5	0-6-4
Snow cover (months)	7	8½	8	8	8½	7	8½	8½	8½	8½
% coverage:										
By vegetation layer B_1	25	15	20	5	1	1	-	-	-	2
B_2	65	60	70	85	60	55	50	40	20	8
B	80	70	80	85	60	55	50	40	20	10
C	35	85	45	80	85	90	90	95	70	95
D_H	50	70	15	70	70	60	50	60	70	1
D_L	1	-	-	-	-	-	-	-	-	-
D_R	10	1	2	10	-	1	-	-	5	1
D	60	70	17	80	70	60	50	60	75	?
By decayed wood	1	-	-	-	-	-	-	-	-	-
By rock	20	1	8	30	-	2	-	-	30	1
Regeneration (no./sq. meter):	none					none				
Total soil depth (cm.)	48	24	?	51	40	60	55	36	60	82
Depth to bottom of A_h (cm.)	6	3	?	5	5	10	5	12	2	8
Depth to seepage, if present	-	-	?	-	-	46	-	-	5	?

Sporadic species

B layer:

- Pnd Cladoth. pyrolaeflorus 30(3.6.1)
- Pnd Vaccinium ovalifolium 30(+.1)

C layer:

- H Blechnum spicant 40(+.+)
- H Carex pyrenaica 30(+.1)
- Pnd Cladoth. pyrolaeflorus 30(1.+.1)
- H Juncus drummondii 30(+.1)
- Pnd Menziesia ferruginea 30(+.+)
- H Pedic. ornithorhyncha 121(+.1)
- H Saxifraga ferruginea 30(+.1)
- Ch Rubus pedatus 30(1.+.1)

D layer (humicolous):

- Pm Abies amabilis 97(+.+)
- Mt Calypogeia sp. 69(2.1.2); 100(+.2
- Mt Cephalozia leucantha 69(1.+.+)
- L Cladonia coniocraea 69(3.+.2)
- L Cladonia rangiferina 40(2.3.1)
- L Cetraria islandica 69(3.+.1)
- t Dichodontium olympicum 61(3.4.2)
- Te Dicranum scoparium 30(2.3.?)
- L Lecidia granulosa 61(1.1.?)
- Mt Lophozia incisa 74(4.?.2)
- Mt Gymnomitrium varians 116(1.?.?)
- Te Mnium nudum 100(1.1.?)
- Mt Nardia scalaris 61(1.1.2)
- Te Oligotrichum parallelum 100(1.1.?
- W Pleurozium schreberi 40(1.1.?)
- Te Pogonatum alpinum 40(1.?.?)
- t Polytrichum juniperinum 30(+.2)
- t Polytrichum norvegicum 69(1.?.?)

	Sub-layer	30	113	121	97	116	Subassociation Pres.	Subassociation Char. c.d.	40	61	69	74	100	Subassociation Pres.	Subassociation Char. c.d.	Entire association Pres.	Fid.	Tot. c.d.	Life-form
B layer:																			
Tsuga mertensiana	1	5.6.1	5.6.1	5.6.1	4.+.+	+.+	5	91	+.+	-	-	-	1.5.+	5	37	5	2	640	Pm
	2	7.7.1	8.8.1	8.7.1	9.8.+	8.7.+			7.6.+	7.7.+	7.6.1	5.5.1	4.4.+						
Vaccinium deliciosum	2	2.6.2	2.4.2	4.5.3	-	-	3	4	-	-	-	2.+.1	+.1	2	-	2		15	Pnd
Vaccinium membranaceum	2	3.5.2	-	-	-	-	1	5	-	-	1.+.+	-	+.+	2	-	2		5	Pnd
Sorbus occidentalis	2	2.+.2	-	1.+.1	-	-	2	1	-	-	-	-	2.+.+	1	1	2	2	2	Pnd
Chamaecyparis nootkatensis	1	2.+.1	-	-	-	-	2	1	-	-	-	-	-	1	1	2	1	2	Pm
	2	1.5.1	+.+	-	-	-			2.+.+	-	-	-	-	-					
Abies amabilis	1	1.+.+	-	-	-	-	1	-	-	-	-	-	-	2	-	2	1	-	Pm
	2	+.+	-	-	-	-			+.+	-	-	-	+.+						
Pinus monticola	2	+.0	-	-	-	-	1	-	+.+	-	-	-	-	1	-	2	1	-	Pm
C layer:																			
Phyllodoce empetriformis		5.6.2	5.7.3	5.5.?	6.6.3	6.5.2	5	28	8.7.3	7.7.3	7.6.3	1.2.1	-	4	43	5	2	316	Pne
Cassiope mertensiana		2.4.2	6.7.3	4.4.2	7.6.3	7.7.3	5	29	7.6.3	7.7.3	7.6.3	3.4.3	-	4	39	5	2	299	Pne
Luetkea pectinata		3.5.2	3.4.2	2.+.2	4.+.2	2.2.3	5	4	4.3.2	3.3.2	3.2.2	7.7.3	8.8.3	5	29	5	3	168	Ch
Tsuga mertensiana		2.5.1	5.4.2	2.+.1	4.+.+	5.5.+	5	12	3.+.+	5.3.+	4.4.2	6.3.1	1.+.+	5	15	5		125	Pm
Vaccinium deliciosum		5.6.2	3.4.2	4.4.2	1.+.+	1.3.1	5	8	4.3.2	2.+.1	4.3.1	1.+.1	3.6.1	5	5	5	2	66	Pnd
Deschampsia atropurpurea		+.1	1.+.2	+.2	1.+.1	+.1	5	-	1.+.1	2.+.2	1.+.1	2.+.2	6.6.2	5	7	5	4	35	H
Lycopodium sitchense		3.3.2	4.5.3	3.3.2	2.3.2	2.3.2	5	4	3.3.2	3.4.2	-	-	-	2	5	4	2	32	Ch
Vaccinium membranaceum		2.5.1	1.+.1	-	2.+.+	-	3	-	-	1.+.+	+.+	1.+.+	-	3	-	4	2	2	Pnd
Hippuris montana		-	-	-	-	-	0	1	1.2.2	1.3.2	2.+.1	6.7.3	6.6.3	5	13	3	3	67	H
Chamaecyparis nootkatensis		1.+.+	-	-	-	-	1	-	1.+.+	-	1.+.+	2.+.+	-	3	-	3		1	Pm
Sorbus occidentalis		1.+.1	-	-	+.+	-	2	-	-	-	-	+.+	1.+.+	2	-	3		-	Pnd
Hieracium gracile		1.4.1	-	+.1	-	+.+	3	-	-	1.+.2	-	-	-	1	-	3	2	-	H
Carex nigricans		-	-	-	-	-	0	-	1.+.+	-	-	4.3.?	-	2	5	2	1	10	H
Veratrum eschscholtzii		+.+	-	1.+.+	-	-	2	-	-	-	-	-	2.+.2	1	1	2	1	1	G
Abies amabilis		-	-	-	+.+	-	1	-	-	-	-	1.+.+	1.+.+	2	-	2		-	Pm
Gaultheria humifusa		1.4.2	-	-	1.3.2	-	2	-	1.+.2	-	-	-	-	1	-	?	2	-	Ch
Erigeron peregrinus		-	+.+	+.+	-	-	2	-	-	-	-	-	-	0	-	2	1	-	H
D layer (humicolous):																			
Orthocaulis floerkii		2.3.2	2.2.2	3.2.2	5.3.2	6.3.2	5	13	5.2.2	4.3.2	4.3.2	6.5.2	-	4	19	5	2	143	Mt
Dicranum fuscescens		1.2.2	1.2.1	4.4.2	6.5.2	4.4.2	5	11	3.2.2	3.2.2	5.3.2	4.4.2	-	4	11	5	2	88	Te
Rhacomitrium heterostichum		6.5.2	-	-	4.4.2	6.6.3	3	25	5.2.2	3.2.2	-	-	3.2.2	3	12	4	2	111	Te
Cladonia bellidiflora		1.1.2	-	-	1.1.+	3.2.2	3	2	2.2.2	1.1.1	2.+.1	-	-	3	1	4	2	7	L
Kiaeria falcata		-	3.2.2	-	4.3.2	-	2	7	6.4.2	3.2.2	2.2.2	-	-	3	13	3	2	53	t
Kiaeria blyttii		-	2.2.2	2.1.2	-	2.3.2	3	1	-	-	-	-	4.1.2	1	10	3	2	13	t
Rhytidiopsis robusta		2.3.1	-	-	2.3.1	-	2	1	2.2.2	-	2.2.2	3.2.2	-	3	2	3	2	9	W
Crocynia membranacea		2.2.2	1.3.2	1.1.2	-	3.4.2	4	1	-	-	2.2.2	-	-	1	1	3	2	7	L
Cladonia pleurota		-	1.1.2	2.2.2	-	-	2	1	-	1.+.+	1.1.2	-	-	2	-	3	2	1	L
Cladonia squamosa		1.1.2	1.1.2	1.1.+	-	1.2.2	4	-	-	-	-	-	-	0	-	3	2	-	L
Rhacomitrium varium		-	7.5.3	-	3.3.2	-	2	27	-	-	-	-	-	0	-	2	2	55	Te
Lophozia porphyroleuca		-	-	-	1.2.2	-	1	-	-	-	4.2.2	5.+.2	-	2	17	2	2	35	Mt
Rhacomitrium canescens		4.4.2	-	-	-	-	1	10	-	5.4.2	-	-	-	1	25	2	2	35	Te
Pellia neesiana		-	-	-	-	-	0	-	-	-	1.+.1	4.+.2	-	2	5	2	2	10	Th
Pohlia drummondii		-	1.1.2	-	-	3.3.2	2	2	-	-	-	-	1.1.2	1	-	2	2	5	t
Stereocaulon tomentosum		1.1.2	2.+.2	-	-	-	2	-	3.1.2	-	-	-	-	1	5	2	2	6	L
Marsupella sparsifolia		2.2.2	2.2.2	-	-	-	2	1	-	2.3.2	-	-	-	1	-	2	2	3	t
Harpanthus scutatus		-	2.2.2	-	-	-	1	1	-	2.3.2	-	-	-	1	1	2	2	2	Mt
Plagiothecium denticulatum		1.1.1	-	-	-	-	1	-	-	1.1.1	-	-	1.2.2	2	-	2	1	-	M
Diplophyllum taxifolium		-	-	-	1.1.2	-	1	-	1.2.2	-	-	-	-	1	-	2	2	-	t
Diplophyllum plicatum		-	-	-	1.1.2	-	1	-	-	-	-	-	1.1.2	1	-	2	2	-	t
Anastrepta orcadensis		-	-	-	-	-	0	-	-	1.1.2	-	1.1.2	1.1.2	3	-	2	2	-	Mt
Cladonia chlorophaea		1.1.2	1.1.2	-	-	-	2	-	-	-	-	-	-	0	-	2	2	-	L

SYNTHESIS TABLE VIII

Vaccinium deliciosum association (Vaccinietum deliciosi) (plots 32, 77, 71, 56, 115) · Carex nigricans association (Caricetum nigricantis) (plots 54, 68, 65, 59, 76) · Polytrichetum norvegici (plots 114, 58) · Saxifragetum tolmiei (plots 63, 72, 111)

Plot number	32	77	71	56	115	54	68	65	59	76	114	58	63	72	111
Plot size (acre)	1/40	1/20	1/60	1/20	1/40	3/80	1/20	1/40	1/40	1/40	1/40	1/40	1/40	1/20	1/40
Date	10/9 1959	30/8 1960	30/8 1960	6/9 1960	17/8 1961	6/9 1960	7/9 1960	7/9 1960	6/9 1960	30/8 1960	16/8 1961	6/9 1960	7/9 1960	7/9 1960	4/8 1961
Locality (see legend)	SM	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM	Lions
Latitude	49 23	49 46	49 46	49 48	49 47	49 48	49 46	49 47	49 48	49 46	49 48	49 48	49 47	49 47	49 27
Longitude	122 56	123 02	123 02	122 59	122 59	123 00	123 01	123 00	122 59	123 02	122 59	122 59	123 00	123 00	123 12
Landform (see legend)	4	2	2	2	2	2	flat	2	flat	flat	flat	flat	2	2	2
Slope above (est. ft.)	200	500	100	30	300	200	50	100	60	200	300	60	100	120	140
Area of assoc. (acre)	1/20	1/2	1/40	1/10	1/20	1/10	1/10	1/20	1/25	1/6	1/2	1/40	1/20	1/10	1/10
Altitude (ft.)	4490	4650	4750	4850	4700	4750	5000	5000	4900	4675	4750	4900	5100	5100	4630
Aspect	S40W	N80W	N70W	W	E	W	-	S70E	-	-	-	-	N60W	N20W	N70E
Wind exposure (A-B-C)	0-8-7	7-7-4	0-7-6	0-9-7	0-8-6	0-0-6	0-0-5	0-0-4	0-0-5	0-0-5	0-0-5	0-0-5	0-0-7	0-0-7	0-0-4
Snow cover (months)	7½	8½	8½	8	8½	9	9	9½	9½	9	9	9	9	9	9½
% coverage: By vegetation layer B_1	5	10	-	-	-	-	-	-	-	-	-	-	-	-	-
B_2	40	15	20	10	50	-	-	-	-	-	-	-	-	-	-
B	45	20	20	10	50	-	-	1	-	-	-	-	-	-	-
C	40	80	90	95	95	95	95	90	90	50	70	40	8	15	15
D_H	25	70	70	60	70	75	30	75	65	85	85	90	20	9	6
D_R	25	-	-	-	1	-	-	-	-	-	-	-	1	5	3
By decayed wood	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
By rock	50	-	-	-	1	-	5	-	-	-	-	-	35	70	75
By open water	-	-	-	-	-	-	-	-	-	15	-	-	-	-	-
Regeneration (no./sq. meter)	none					none					none		none		
Total soil depth (cm.)	21	50	53	55	48	55	55	50	75	72	53	65	55	28	?
Depth to bottom of A_h (cm.)	?	14	14	19	6	15	5	6	3	?	8	6	5	?	?
Depth to seepage, if present	-	-	10	-	-	-	-	-	-	46	-	-	-	-	?

Sporadic species, Vacc. deliciosum assoc

A layer:
Pm Tsuga mertensiana 77(+.+)
B layer:
Pm Abies amabilis 77(+.+)
C layer:
Pm Abies amabilis 56(+.+)
H Carex nigricans 77(1.4.2)
H Carex spectabilis 32 (+.+)
H Carex pyrenaica 32 (+.+)
Pm Cham. nootkatensis 71(+.+)
H Saxifraga ferruginea 32(1.+.1)
Pnd Sorbus occidentalis 32(+.+)
G Veratrum eschscholtzii 71(+.+)
D layer (humicolous):
Mt Anastrepta orcadensis 71(1.+.2)
Mt Blephar. trichophyllum 115(+.2)
Mt Calypogeia trichomanis 115(1.+.2)
Mt Cephalozia leucantha 115(1.1.2)
Te Dicranum scoparium 32(5.5.2)
t Diplophyllum taxifolium 115(1.1.2)
t Kiaeria falcata 32(1.2.2)
t Marsupella ustullata 32(3.4.2)
Te Mnium nudum 71(1.2.2)
M Plagiothecium elegans 115(1.1.2)
Te Rhacomitrium canescens 32(1.2.2)
L Stereocaulon tomentosum 32(1.+.1)

Vaccinium deliciosum association	Sub-layer	32	77	71	56	115	Pres.	Fid.	Tot. c.d.	Life-form
B layer:										
Vaccinium deliciosum	2	2.4.2	3.4.2	5.5.3	4.+.3	7.5.3	5		91	Pnd
Tsuga mertensiana	1	4.5.1	-	-	-	-	5	1	49	Pm
	2	6.6.1	1.+.+	2.+.+	3.+.1	+.+				
Vaccinium membranaceum	2	2.3.1	4.6.2	2.+.1	4.+.1	1.5.1	5	2	22	Pnd
Cham. nootkatensis	1	-	4.6.1	-	-	-	3	1	15	Pm
	2	3.+.+	1.4.2	+.+	-	-				
Sorbus occidentalis	2	2.5.1	+.+							
C layer:										
Vaccinium deliciosum		6.6.2	8.7.2	8.7.3	6.7.2	6.4.3	5	3	249	Pnd
Phyllodoce empetriformis		4.5.2	5.6.2	5.6.2	7.6.3	8.6.2	5	2	185	Pne
Cassiope mertensiana		5.5.2	4.3.2	4.3.2	6.5.3	2.3.1	5	2	79	Pne
Luetkea pectinata		3.3.2	2.3.2	1.+.1	1.+.2	4.2.3	5	2	16	Ch
Deschampsia atropurpurea		+.+	-	+.2	+.1	+.2	4	2	-	H
Vaccinium membranaceum		3.5.1	-	+.1	1.+.1	-	3	2	5	Pnd
Rubus pedatus		-	2.3.2	-	-	3.+.1	2	1	6	Ch
Tsuga mertensiana		-	2.+.+	-	2.+.1	-	2		2	Pm
D layer (humicolous):										
Dicranum fuscescens		2.2.2	7.5.2	6.4.2	7.6.2	7.6.2	5	2	184	Te
Orthocaulis floerkii		3.2.2	5.3.2	6.3.2	4.3.2	2.2.2	5	2	74	Mt
Rhytidiopsis robusta		2.1.2	6.5.2	4.2.2	4.3.1	3.2.2	5	2	59	W
Cetraria islandica		2.+.1	1.2.2	1.2.3	3.2.2	3.2.2	5	4	11	L
Cladonia bellidiflora		2.2.2	1.2.2	-	3.2.2	+.+	4	2	6	L
Rhacomitrium heterostich.		3.2.2	-	-	4.5.2	-	2	2	15	Te
Crocynia membranacea		1.+.1	-	-	3.4.2	-	2	2	5	L
Cladonia carneola		-	1.1.2	-	1.1.2	-	2	2	-	L
Cladonia gracilis		2.2.2	-	-	2.2.2	-	2	2	2	L
Cladonia squamosa		1.2.2	1.2.2	-	-	-	2	2	-	L

Carex nigricans association	54	68	65	59	76	Pres.	Fid.	Tot. c.d.	Life-form	114	58	63	72	111
C layer:														
Carex nigricans	9.7.2	9.9.3	8.7.2	9.8.2	7.3.2	5	4	410	H	8.6.3	7.4.2	-	+.1	-
Deschampsia atropurpurea	5.3.2	+.1	5.+.2	3.+.1	2.+.1	5	2	56	H	2.4.2	+.+	-	+.+	-
Juncus drummondii	3.1.2	3.1.2	1.+.2	+.1	-	4	3	10	H	1.+.2	2.1.2	-	-	4.3.3
Carex spectabilis	2.1.2	-	5.3.2	-	2.4.2	3	2	27	H	2.1.2	-	-	-	3.2.2
Luetkea pectinata	-	1.3.2	3.6.3	1.+.2	3.5.2	4	2	10	Ch	2.3.2	-	-	-	1.2.2
Phyllodoce empetriformis	2.3.+	1.+.+	1.+.+	1.+.+	-	4	1	1	Pne	+.+	+.+	1.3.+	+.+	+.1
Hieracium gracile	1.+.2	+.+	2.3.1	1.+.+	-	4	2	1	H	-	-	-	-	-
Saxifraga tolmiei	-	1.1.2	-	2.2.2	-	2	3	1	Ch	+.2	2.2.2	4.4.3	5.4.3	4.2.3
Vaccinium deliciosum	1.2.+	-	+.+	1.+.+	-	3	1	-	Pnd	+.+	-	-	+.+	-
Cassiope mertensiana	1.+.+	-	-	1.+.+	-	2	1	-	Pne	+.+	+.+	-	+.+	+.1
Tsuga mertensiana	-	-	-	-	-				Pm	-	-	+.+	2.+.+	+.+
Cryptogramma crispa	-	-	-	-	-				H	-	-	-	-	1.+.2
Athyrium alpestre	-	-	-	-	-				H	-	-	-	-	2.+.3
Luzula wahlenbergii	-	-	-	-	-				H	-	+.2	+.3	3.+.2	3.3.3
Epilobium alpinum	-	-	-	-	-				G	-	-	+.+	-	-
Vaccinium membranaceum	-	-	-	-	-				Pnd	-	-	-	-	+.+
Saxifraga ferruginea	-	-	-	-	-				H	-	-	-	-	+.1
D layer (humicolous):														
Polytrichum norvegicum	4.2.2	5.6.3	7.6.3	7.7.3	7.7.2	5	5	135	t	8.6.3	9.8.3	2.2.2	1.2.2	-
Kiaeria blyttii	4.2.2	4.3.2	6.3.2	3.2.2	-	4	4	58	t	4.5.2	2.2.2	-	3.3.1	2.1.2
Pohlia drummondii	6.3.2	-	4.2.1	-	-	2	2	43	t	-	-	-	2.2.2	1.1.1
Crocynia membranacea	-	-	1.1.2	1.1.2	-	2	2	-	L	-	3.1.2	-	-	-
Rhacomitrium heterostichum	5.2.2	-	-	-	-	1	2	25	Te	1.1.2	-	-	1.3.2	-
Stereocaulon tomentosum	-	-	-	-	-				L	+.1	1.1.2	-	-	-
Oligotrichum hercynicum	-	-	-	-	-				t	-	-	2.2.2	2.2.2	2.2.2
Gymnomitrium varians	-	-	-	-	-				Mt	-	-	5.4.3	4.4.3	3.3.2
Bryum sp.	-	-	-	-	-				Te	-	-	-	-	3.3.2
Calypogeia trichomanis	-	-	-	-	-				Mt	2.3.2	-	1.1.1	3.1.2	-
Lophozia porphyoleuca	-	-	-	-	-				Mt	-	-	-	-	1.1.2

Sporadic species, Carex nigricans assoc.

C layer:
Ch Gaultheria humifusa 54(+.1)
H Hippuris montana 54(1.3.2)
Ch Lycopodium sitchense 54(+.+)
Pm Tsuga mertensiana 65(+.+)

D layer (humicolous):
Mt Anastrepta orcadensis 54(1.2.2)
Mt Gymnomitrium varians 68(1.2.2)
Mt Pleuroclada albescens 54(3.2.2)
Mt Orthocaulis floerkii 54(4.3.2)
Td Sphagnum plumulosum 76(7.7.1)
Mt Cephalozia sp. 54(1.1.2)
t Pohlia nutans 54(1.2.2)
Te Polytrichum commune 76(2.2.2)

SYNTHESIS TABLE IX *Phyllodoce* - *Cassiope* association (*Phyllodoceto* - *Cassiopetum mertensianae*)

Plot number	Sub-layer	33	62	53	96	98	99	75	112	129	130	23	48	31	45	46	Pres.	Fid.	Tot. c.d.	Life-form
Plot size (acre)		1/40	1/20	1/10	1/40	1/40	1/40	1/40	1/40	1/40	1/40	1/5	1/40	1/40	1/40	1/40				
Date		11/9 1959	7/9 1960	6/9 1960	20/9 1960	20/9 1960	20/9 1960	25/8 1961	13/8 1961	3/10 1961	3/10 1961	29/7 1959	22/7 1960	10/9 1959	21/7 1960	21/7 1960				
Locality (see legend)		SM	RM	RM	G	G	G	RM	Gar.	SM	SM	SM	SM	SM	SM	SM				
Latitude		49 23	49 47	49 48	49 24	49 24	49 24	49 46	49 48	49 23	49 23	49 22	49 23	49 23	49 24	49 24				
Longitude		122 57	123 00	123 00	123 05	123 05	123 05	123 02	123 00	122 57	122 57	122 57	122 58	122 56	122 57	122 57				
Landform (see legend)		2	2	2	2	4	2	2	2	2	2	4	1	4	4	4				
Slope above (est. ft.)		120	60	200	300	40	120	300	500	150	70	none	30	none	none	none				
Area of assoc. (acre)		1/2	2	15	1/5	1/5	1/2	1/40	10	1/40	1/20	1/3	1/20	1/2	1/10	1/5				
Altitude (ft.)		3825	5100	4750	4370	4400	4250	4600	5075	4000	3950	3630	3760	4410	4600	4600				
Aspect		S25W	W	N50W	N40E	flat	N	N50W	S80E	S40W	S60W	flat	N40E	N60W	S70E	flat				
Slope (degrees)		10	12	9	14	-	26	9	14	11	18	-	6	10	20	-				
Wind exposure (A-B-C)		0-7-5	0-0-6	0-0-7	0-6-5	0-9-8	0-5-5	0-7-5	0-0-6	0-5-3	0-7-5	6-5-2	0-0-8	0-8-7	0-9-8	0-9-8				
Snow cover (months)		7½	8½	9	8½	8½	9	8	9	8	8	7½	7½	8	8½	8½				
% coverage:																				
By vegetation layer A		-	-	-	-	-	-	-	-	-	-	5	-	-	-	-				
B_1		-	-	-	-	-	-	-	-	1	-	1	-	-	8	3				
B_2		9	1	-	7	4	2	5	-	20	18	25	5	1	20	20				
B		9	1	-	7	4	2	5	-	21	18	25	5	1	25	20				
C		90	90	90	90	95	95	98	96	90	90	60	90	65	50	80				
D_H		35	45	70	70	50	80	65	60	85	50	50	75	40	30	30				
D_R		4	-	-	5	-	-	-	-	-	4	30	5	15	20	3				
D		39	45	70	75	50	80	65	60	85	54	80	80	55	50	33				
By decayed wood		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
By rock		5	1	-	8	-	1	-	-	-	10	40	10	35	30	20				
Regeneration (no./sq. meter)				-------	-------	-------	-------	-------	-------	none	-------	-------	-------	-------	-------					
Total soil depth (cm.)		55	32	38	61	47	85	51	40	?	?	53	21	22	27	28				
Depth to bottom of A_h (cm.)		35	5	8	5	5	3	28	3	?	?	13	6	?	8	16				
Depth to seepage, if present		35	-	-	40	-	-	37	-	?	?	-	-	-	-	-				
B layer:																				
Tsuga mertensiana	1	-	-	-	-	-	-	-	-	+.+	-	+.1	-	-	4.6.+	+.+	4	2	68	Pm
	2	2.+.1	1.+.+	-	4.+.+	2.5.+	2.+.+	+.+	-	4.5.+	4.6.+	4.6.1	4.5.+	-	-	3.5.+				
Cham. nootkatensis	1	-	-	-	-	-	-	-	-	-	-	1.6.1	-	-	-	-	3	2	52	Pm
	2	-	-	-	-	-	-	4.5.1	-	2.+.+	2.+.+	4.6.1	-	+.+	5.6.+	3.5.+				
Vaccinium membranaceum	2	3.5.1	-	-	2.3.+	1.3.+	1.+.+	-	-	+.+	-	1.4.1	-	1.+.1	-	-	3		6	Pnd
Vaccinium deliciosum	2	4.5.3	-	-	1.+.2	-	-	-	-	4.6.3	4.6.3	1.3.2	1.3.3	-	-	-	2		30	Pnd
Sorbus occidentalis	2	-	-	-	+.+	+.+	-	-	-	-	-	+.1	-	-	+.+	+.+	2	2	-	Pnd
C layer:																				
Phyllodoce empetriformis		8.7.3	8.9.3	7.6.2	9.9.3	9.7.3	9.9.3	7.6.3	6.5.3	7.6.2	6.6.3	6.6.3	8.7.3	5.6.2	4.6.2	7.7.3	5	3	849	Pne
Cassiope mertensiana		4.5.3	4.5.2	8.7.3	6.5.2	7.6.2	7.5.2	6.6.3	8.9.3	4.5.1	4.3.2	7.6.2	9.8.3	8.6.3	5.6.3	7.7.3	5	3	651	Pne
Vaccinium deliciosum		7.7.2	+.+	+.1	3.+.+	3.3.+	2.+.+	4.4.1	2.3.1	7.6.3	6.6.3	4.3.2	3.4.3	2.5.2	3.6.3	6.7.3	5	2	209	Pnd
Luetkea pectinata		2.3.2	4.3.2	4.3.2	5.4.3	4.2.2	4.+.2	3.+.2	4.2.2	4.+.2	5.+.2	2.3.2	2.4.2	3.3.2	+.1	3.4.1	5	2	128	Ch
Lycopodium sitchense		4.3.2	5.5.3	5.4.3	1.+.+	1.3.2	+.+	-	5.5.3	-	1.+.+	1.2.1	2.4.3	+.2	-	+.+	4	3	86	Ch
Vaccinium membranaceum		2.3.2	-	+.+	2.+.+	1.+.+	2.+.+	-	-	2.+.1	-	+.+	1.2.2	3.5.2	2.+.+	4.6.1	4	2	20	Pnd
Tsuga mertensiana		3.+.1	2.+.+	-	2.+.+	3.3.+	2.+.+	1.+.+	-	-	3.+.+	+.1	-	+.+	-	-	3		18	Pm
Deschampsia atropurpurea		1.+.1	-	+.1	2.+.2	1.+.1	+.1	1.+.1	+.+	-	-	-	-	2.+.1	-	-	3	2	1	H
Chamaecyparis nootkatensis		-	-	-	-	+.+	-	2.+.+	-	-	3.+.+	+.+	-	+.+	+.+	-	2		6	Pm
Carex nigricans		-	3.2.2	-	-	1.4.+	-	1.5.1	-	2.4.2	-	1.1.2	1.2.1	-	-	-	2	1	6	H
Rubus pedatus		1.+.2	-	-	-	-	-	-	-	3.+.2	1.+.1	+.1	-	-	+.1	-	2	1	5	Ch
Hippuris montana		-	-	-	2.2.2	1.+.1	2.+.2	+.2	-	-	-	-	-	-	-	-	2	1	2	H
Gaultheria humifusa		-	1.+.2	1.4.2	-	+.2	-	-	1.+.2	-	-	-	-	-	-	-	2	2	-	Ch
Carex spectabilis		1.+.+	-	-	-	-	-	+.+	-	-	-	-	-	1.+.1	+.1	-	2	1	-	H
Sorbus occidentalis		+.+	-	-	+.+	+.+	-	-	-	+.+	-	-	-	-	-	+.+	2		-	Pnd
D layer (humicolous):																				
Dicranum fuscescens		3.3.2	-	6.4.2	3.4.2	5.5.3	7.5.3	6.5.2	-	7.6.3	5.6.2	4.3.2	8.7.2	5.4.2	3.6.2	1.2.2	5	2	341	Te
Orthocaulis floerkii		3.2.2	-	7.5.1	4.3.2	4.3.3	6.4.3	4.1.2	3.1.1	5.5.3	4.3.2	3.2.2	4.3.1	3.2.2	3.6.2	3.3.2	5	2	188	Mt
Rhacomitrium heterostichum		3.2.2	1.1.+	6.5.2	4.3.2	4.3.2	2.1.2	-	-	-	3.3.2	5.3.2	1.+.2	3.2.2	2.4.1	3.3.2	4	2	100	Te
Crocynia membranacea		1.1.2	4.3.2	4.4.2	-	1.2.2	-	1.1.2	4.3.3	-	1.1.2	1.1.2	-	1.3.2	-	2.1.2	4	3	31	L
Kiaeria falcata		-	5.3.2	3.2.2	6.5.3	3.3.2	3.1.2	-	6.4.2	-	-	-	-	-	2.6.2	5.4.2	3	3	132	t
Rhytidiopsis robusta		2.3.2	-	-	-	-	3.2.2	5.2.2	-	2.1.2	2.2.2	+.1	1.1.2	-	3.6.2	-	3	1	38	W
Bryum sp.		3.4.2	-	-	4.2.2	1.2.2	3.3.2	-	-	-	2.2.2	-	-	1.1.2	3.5.2	1.3.1	3	2	21	t
Cladonia bellidiflora		2.1.2	+.+	3.4.2	-	1.1.1	-	-	-	3.+.2	2.+.2	-	1.+.1	3.2.2	-	-	3	2	17	L
Gymnomitrium varians		-	4.4.2	2.3.2	3.4.2	-	-	-	5.3.2	-	-	-	2.2.2	2.2.2	-	-	2	2	43	t
Marsupella sparsifolia		-	-	-	-	-	-	-	-	-	-	3.3.2	2.5.1	1.2.2	-	2.5.2	2	2	12	t
Rhacomitrium canescens		-	-	-	-	-	-	-	-	-	-	1.2.2	3.2.2	1.1.2	-	1.2.2	2	2	5	Te

Sporadic species:

A layer:
Pm Tsuga mertensiana 23(+.2)

B layer:
Pm Abies amabilis 31(+.+); 129(+.+)
Pnd Clado. pyrolaeflorus 45(+.+); 96(1.3.+)
Pnd Menziesia ferruginea 23(+.1)
Pm Pinus monticola 23(+.+)
Pnd Vaccinium ovalifolium 99(+.+)

C layer:
Pm Abies amabilis 96(1.+.+)
H Caltha leptosepala 75(1.+.1)
Pnd Clado. pyrolaeflorus 48(+.+); 96(1.+.+)
H Hieracium gracile 31(2.+.1); 53(+.1); 122(+.1)
H Juncus drummondii 31(+.+); 46(+.+); 45(+.+)
H Leptarrhena pyrolifolia 75(+.+)

C layer, continued:
Pne Phyllodoce glanduliflora 112(1.4.3)
Pm Pinus monticola 31(+.+)
Pnd Rhododendron albiflorum 62(+.+)
H Saxifraga ferruginea 31(+.+); 23(+.2); 48(+.+)
Pnd Vaccinium ovalifolium 48(+.+); 99(+.+)
G Veratrum eschscholtzii 23(+.1)

D layer, humicolous:
Pm Abies amabilis 46(+.+); 48(+.+); 96(+.+); 130(+.+)
Mt Calypogeia neesiana 96(1.1.2); 99(1.1.2)
L Cetraria islandica 129(2.+.2)
L Cladonia gracilis 23(1.1.2)
L Cladonia pleurota 23(1.1.2); 53(2.3.2) 112(1.1.2)
L Cladonia rangiferina 23(1.3.2); 46(3.3.2)
L Cladonia squamosa 23(1.+.3)
t Dichodontium olympicum 53(1.1.2)
Pnd Vaccinium deliciosum 75(1.+.1); 129(1.+.+)

D layer (humicolous), continued:
Te Dicranum scoparium 33(5.4.3); 48(2.4.2)
t Diplophyllum taxif. 96(1.1.2); 130(1.2.2)
Mt Gymnomit. concinnatum 23(1.1.2); 96(1.1.2)
Mt Harpanthus scutatus 96(1.1.2)
M Hypnum circinale 75(2.2.2)
Mt Lescuraea baileyi 33(1.1.2); 129(2.1.2); 130(1.1.1)
Mt Lophozia alpestris 45(1.1.2)
Mt L. porphyroleuca 96(2.1.2); 99(2.1.2)
M Plagiothecium elegans 33(1.1.2)
Mt Plectocolea obovata 31(2.2.2)
W Pleurozium schreberi 45(2.1.2); 48(2.1.2)
Te Pogonatum alpinum 23(1.2.2)
t Polytrichum norvegicum 62(1.+.+)
t Polytrichum piliferum 23(+.2)
Te Rhacomitrium varium 23(1.2.2)
L Stereocaulon tomentosum 31(+.1); 62(1.1.2); 112(3.1.3)

APPENDIX IV

PLATE I

PLATE II

PLATE III

PLATE I

A. Excellent growth of amabilis fir on a *Streptopus* association at 4000 feet, Paul Ridge, Garibaldi Park.

B. Dense cover of *Oplopanax horridus* along a temporary mountain stream near 3600 feet, Paul Ridge, Garibaldi Park.

C. Sparse distribution of mountain hemlock in the upper subzone, 4000 feet, Mount Seymour. The ridge in the upper right-hand corner is in the lower subzone at 3300 feet.

D. Typical isolated clump of mountain hemlock in the upper subzone, 4600 feet, Paul Ridge, Garibaldi Park. The snow-free ring around the clump (June 17) is occupied by small mountain hemlock, yellow cedar, *Rhododendron albiflorum*, and *Vaccinium membranaceum*.

E. Near its upper limit the *Vaccinium membranaceum* - *Rhododendron* association occurs only on exposed ridges where snow accumulation is least. 5100 feet, Paul Ridge, Garibaldi Park.

F. Succession from (1) *Phyllodoce* - *Cassiope* to (2) dwarf *Tsuga* near the crest of a ridge where snow duration is reduced. 5000 feet, near Mamquam Lake, Garibaldi Park.

PLATE I

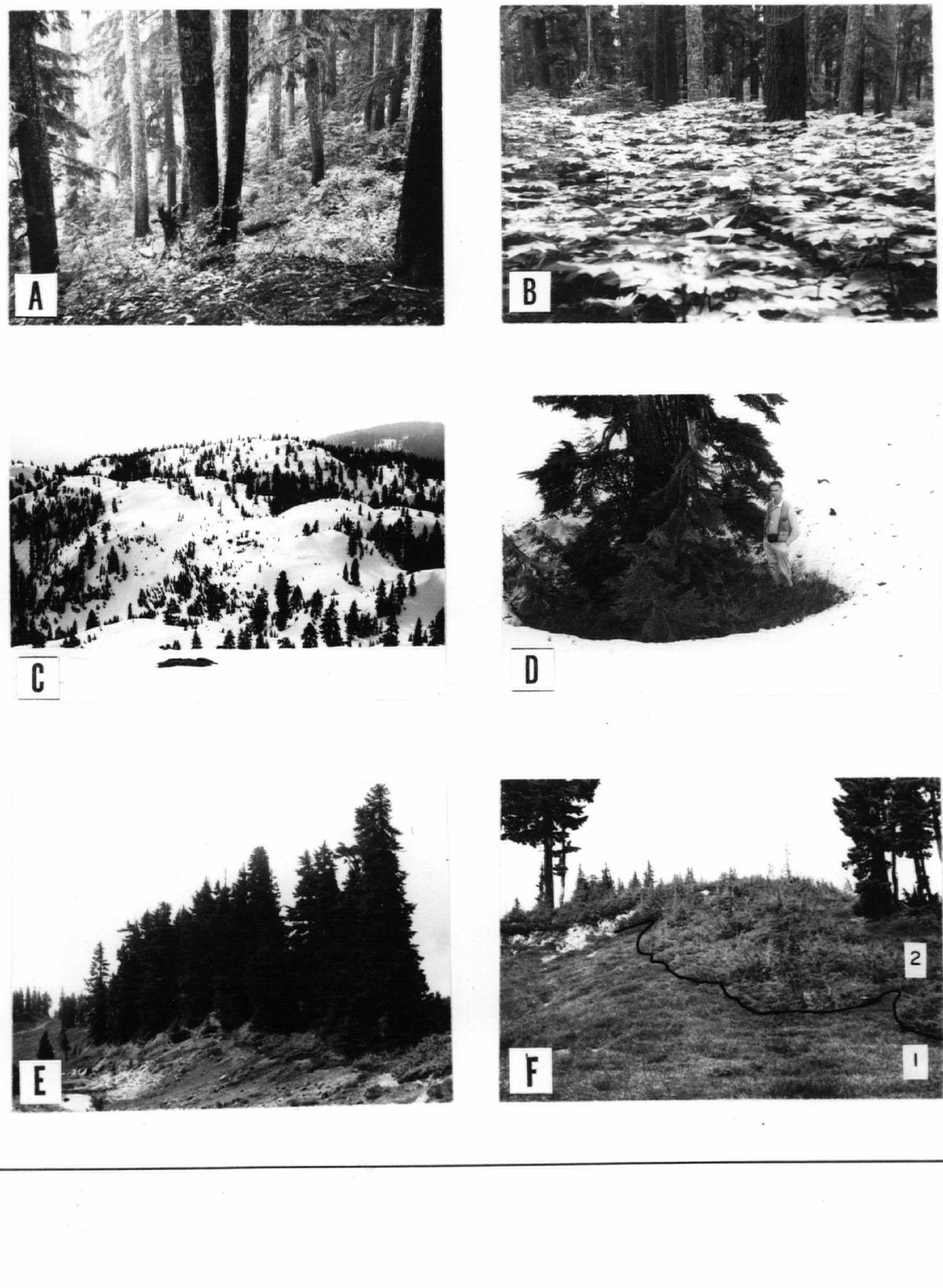

PLATE II

A. Wet edaphic Leptarrhena - Caltha leptosepala association in the upper subzone, surrounded by stunted yellow cedar. 4500 feet, Paul Ridge, Garibaldi Park.

B. Early stage of succession from open water towards Eriophorum - Sphagnum. Drepanocladus exannulatus and Carex aquatilis are main species. 4600 feet, Paul Ridge, Garibaldi Park.

C. Invasion of (2) dwarf mountain hemlock onto a (1) Phyllodoce - Cassiope area. 5100 feet, Garibaldi Park.

D. Well developed Phyllodoce empetriformis - Cassiope mertensiana association. 5100 feet, Garibaldi Park.

E. Primary succession of a Carex nigricans association towards Phyllodoce - Cassiope. 4800 feet, Paul Ridge, Garibaldi Park.

F. High sociability of Gymnomitrium varians on an unstable colluvial slope. 4800 feet, near Mamquam Lake, Garibaldi Park.

PLATE II

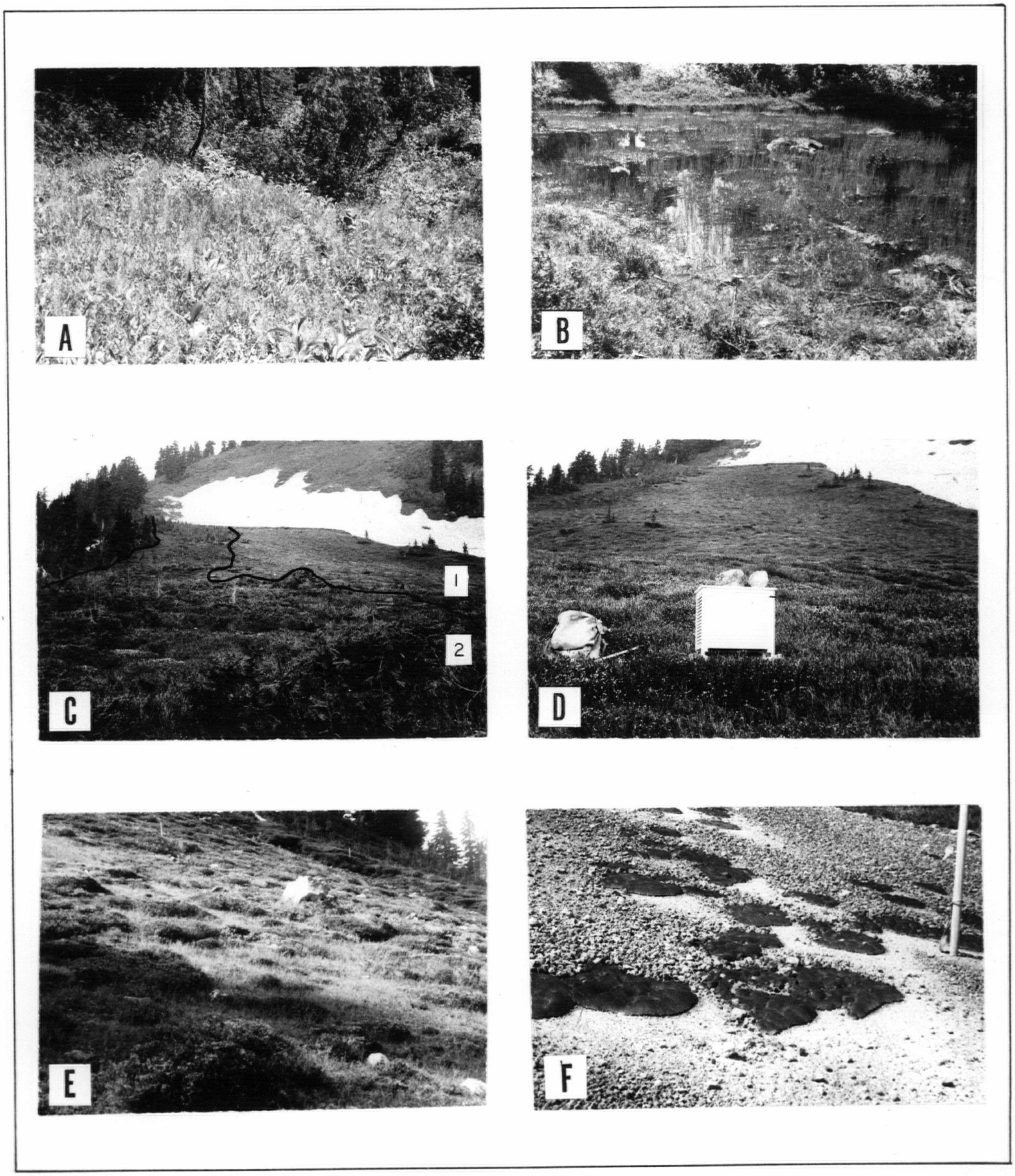

PLATE III

A. Mesic habitats at 5000 feet and higher occupied by *Phyllodoce* - *Cassiope* with sporadic clumps of mountain hemlock. On the warmer westerly slope in the centre of the photograph, trees are favoured. Otherwise they are restricted to prominences or ridges. Upper subzone, Garibaldi Park.

B. Deformation of mountain hemlock by snow-creep. July 7, 1962. 3800 feet, Mount Seymour.

C. Mesic *Vaccinium membranaceum* - *Rhododendron* association of the upper subzone. 3900 feet, near The Lions.

D. Small stream in the upper subzone occupied by *Drepanocladus exannulatus* and *Scapania uliginosa*, and flanked by *Philonotis fontana* and *Petasites frigidus*. With increased organic accumulations, these stages will develop towards a *Leptarrhena* - *Caltha leptosepala* association.

E. *Saxifraga tolmiei* established below a rock where there is greater soil stability on a colluvial slope. 5000 feet, Paul Ridge, Garibaldi Park.

F. Secondary succession towards *Gymnomitrium varians* and *Saxifraga tolmiei*, 16 years after the removal of the sod covering in a *Carex nigricans* association. 4900 feet, Garibaldi Park.

PLATE III